Oakland-San Francisco Bay Bridge
San Francisco
San Francisco County
California

HAER No. CA-32

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141-

PHOTOGRAPHS

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, D. C. 20013-7127

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SAN FRANCISCO OAKLAND BAY BRIDGE
(Oakland-San Francisco Bay Bridge)
Spanning the San Francisco Bay
San Francisco
San Francisco County
California

HAER No. CA-32

ADDENDUM TO:
OAKLAND-SAN FRANCISCO BAY BRIDGE
San Francisco
San Francisco County
California

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

Historic American Engineering Record
National Park Service
Western Region
Department of the Interior
San Francisco, California

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HISTORIC AMERICAN ENGINEERING RECORD
SAN FRANCISCO-OAKLAND BAY BRIDGE
(Oakland-San Francisco Bay Bridge)

HAER NO. CA-32

Addendum to: Oakland-San Francisco Bay Bridge

Location: San Francisco Bay spanning from San Francisco to Oakland crossing Yerba Buena Island in San Francisco Bay, San Francisco and Alameda counties, California

USGS San Francisco North Quadrangle, 7.5' UTM Coordinates;

West Bay Span

I. San Francisco Approach 10/0552872/4181230
II. West Anchorage 10/0553777/4182104
III. Center Anchorage 10/0554874/4183403

USGS Oakland West Quadrangle, 7.5' UTM Coordinates;

IV. East Anchorage at Yerba Buena Island 10/0555802/4184503

Yerba Buena Island
Tunnel 10/0555946/4184684

East Bay Span

I. West Viaduct at Yerba Buena Island 10/0556048/4184807
II. East Approach 10/0559248/4186043

Date of Construction: 1933 - 1936: Bridge and approaches modified eliminating the Electric Key System Trains and putting Auto and Truck traffic on both decks -1959 to 1963; Reconstruction of the Decks at Pier E-9 due to failure during the 1989 Loma Prieta Earthquake; Seismic retro-fitting several sections of the bridge: 1960 to present.

Engineer: C. H. Purcell, Chief Engineer for the Bay Bridge
California Toll Bridge Authority

Builder:

Contract #2.	West Bay Substructure	Transbay Construction Co.
Contract #3	SF Anchorage, Approaches	Healy-Tibbets
Contract #4	East Bay Substructure	Bridge Builders, Inc.
Contract #5	Yerba Buena Island Tunnel Anchorage	Clinton Construction
Contract #6	West Bay Superstructure	Columbia Steel Co.
	Steel work	US Steel Corp/American Bridge Co.
Contract #7	East Bay Super Structure	Columbia Steel Co.
	Steel work	US Steel Corp/American Bridge Co.
Contract #8	Oakland Approaches	Clinton Construction

Present Owner: California Department of Transportation
P.O. Box 23660
Oakland, CA 94623

Present Occupant: California Department of Transportation and the public

Present Use: Designed use as a bridge for Automobile, Buses and Truck traffic between Oakland and San Francisco.

Significance: The San Francisco-Oakland Bay Bridge is one of the most impressive engineering structures in the United States. It is also one of the most important transportation links in the United States, serving as the terminus of an interstate highway and as the linchpin for the transportation network of the San Francisco Bay Area, one of the nation's largest metropolitan regions. The bridge has been recognized by the American Society of Civil Engineers as a nationally significant structure from the standpoint of engineering as well as its importance in the transportation history of California and the nation. The Bay Bridge was also a milestone in the political history of the Bay Area. The history of the Bay Area is filled with controversies over transportation projects, from the 19th century debates over subsidies to the railroads, continuing through the freeway revolt of the 1950s and seemingly endless debates between supporters of transit and highway development in more recent decades. The long debate over construction of the Bay Bridge is remarkable for the fact that the people of the Bay Area and their political leaders united behind it with almost unanimous support. People may disagree as to whether the Bay Bridge is more important for its engineering, its role in transportation history or for its importance in the politics of the area. The structure is highly significant in all of these different ways.

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Date: May 1, 1999

ARCHITECTURAL AND ENGINEERING INFORMATION

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INTRODUCTION

The San Francisco-Oakland Bay Bridge, or simply the Bay Bridge, is one of the most impressive engineering structures in the United States. It is also one of the most important transportation links in the United States, serving as the terminus of an interstate highway and as the linchpin for the transportation network of the San Francisco Bay Area, one of the nation's largest metropolitan regions. The bridge has been recognized by the American Society of Civil Engineers as a nationally significant structure from the standpoint of engineering as well as its importance in the transportation history of California and the nation. The Bay Bridge was also a milestone in the political history of the Bay Area. The history of the Bay Area is filled with controversies over transportation projects, from the 19th century debates over subsidies to the railroads, continuing through the freeway revolt of the 1950s and seemingly endless debates between supporters of transit and highway development in more recent decades. The long debate over construction of the Bay Bridge is remarkable for the fact that the people of the Bay Area and their political leaders united behind it with almost unanimous support. Some people may disagree as to whether the Bay Bridge is more important for its engineering, its role in transportation history or for its importance in the politics of the area. That debate may never be satisfactorily resolved, nor is it necessary to do so. The structure is highly significant in many different ways.

This study analyzes the history of the Bay Bridge from these three vantage points, paying approximately equal attention to each. The three are closely linked. The structure is so important to the transportation of the area because it literally bridged the two major population centers of the Bay Area, crossing the great 4 1/2-mile expanse of water that separated them. The task of building that bridge was formidable; no one had ever before contemplated a bridge that was so long, so expensive, or with such deep piers. It was also an enormously expensive undertaking, costing more than twice what it cost, for example, to build the Golden Gate Bridge. In the absence of a great need for the bridge, it is likely that the residents of the San Francisco Bay Area in the 1920s and 1930s would have simply abandoned the idea as infeasible, as had all previous generations of Californians. The need for the bridge was so great, however, that political and civic leaders persevered, overcoming a long series of political, legal, financial, and regulatory obstacles. The tenacity with which the bridge was pursued is an excellent indicator of how important it was, at least in the view of the Bay Area leadership at the time.

The imperative demand for the bridge also helps explain the broad support for its construction. The transportation network of the Bay Area was at a turning point during the 1920s. From the late 1890s through the early 1920s, private interests had pieced together a reasonably efficient network for moving people and goods from the East Bay to San Francisco. That network was built around electric interurban trains and ferryboats, as well as larger navigational craft, and main line freight and passenger rails. Two things happened during the 1920s to upset this system: the population of the area grew and the number of automobiles grew at an even faster rate. The growth in automobile use taxed all aspects of travel in the area, choking traffic in the cities, overloading the inter-city roads, and crowding the waters of the Bay with vehicular ferries, dedicated to carrying automobiles across the Bay. Bay Area cities, working closely with the

State of California, responded to this congestion by building hundreds of miles of new roads in the area, roads that were far more sophisticated than is generally thought to be the case with highway development from the 1920s. These new roads facilitated relatively high-speed automobile travel from the East Bay cities to Oakland and from Peninsula cities to San Francisco. They could do everything but connect the East Bay and Peninsula cities with each other. That, more than anything else, was the transportation problem that was solved by construction of the Bay Bridge.

As prodigious as highway development may have been, automobile traffic did not during the 1920s displace the longstanding commitment of the area to mass transit. Interurban electric trains and ferries carried far more people across the Bay than did automobiles and the vehicular ferries. Granted, the trend was decidedly in favor of automobile use, but transit users still outnumbered automobile commuters by more than three-to-one at the time the bridge was built.

Recognizing this reality, the planners of the Bay Bridge designed it to be a multi-modal structure, carrying interurban trains as well as various types of rubber-tired vehicles, including automobiles, trucks, and buses. The decision for multi-modal use was made with the understanding that it would be very expensive. The heavier loading and appurtenant facilities (rails, railroad approaches, train terminals, and so forth) associated with rail service increased the cost of the bridge by an estimated 25 percent. Unfortunately, the train service on the bridge was a disaster, failing altogether less than twenty years after the bridge was built. In light of that failure, it is easy to see the trains as an afterthought or empty gesture on the part of the bridge designers, most of whom came from the state Division of Highways and were highway builders at heart. That facile conclusion does not, however, square with the facts. Train service on the Bay Bridge was achieved at great cost, in dollars, in engineering complexity, and in political frustrations. That service failed for many reasons but not for lack of effort by the bridge designers.

The political and financial hurdles for the Bay Bridge were matched, if not exceeded, by the technical problems it posed. Indeed, those technical problems bled into its political and financial problems to the extent that many were reluctant to approve and pay for the bridge because they felt it could not be built. Once the decision was made to go ahead with the bridge, the engineering staff proceeded with amazing speed to design and build it; the bridge was designed in two years and built in a little more than three years, for a total of about five and one-half years from start to finish. This great haste, which is ultimately one of the most impressive aspects of the bridge's construction, can be attributed to many factors – the need to make good on so many political commitments, the need to minimize the crushing interest payments on a loan from the federal government, and the desire to put thousands to work in the depth of the Great Depression. For all of these reasons, this huge project was likely a world record in another category in civil engineering, measured by the ratio of design and construction time against cost. (Military construction often exceeds this pace, particularly during wartime.)

The State of California achieved this feat, led by Chief Engineer, C. H. Purcell, by relying on the best technical advice available. Purcell and his staff had essentially no experience in the design of any of the bridge types that would be built on the Bay Bridge, other than the smaller truss

spans on the East Bay side. To design the suspension spans, the cantilever spans, and the world record-setting deep underwater piers, Purcell turned to some of the best-known and most experienced bridge engineers in the country, including Ralph Modjeski, Leon Moisseiff, and Daniel Moran. By design or good luck, the low bidders for construction of the job included some of the titans of large construction contracting, including the American Bridge Company and McClintic-Marshall for the steel work and all of the "Six Companies" contractors for the foundation work. Things did not always go smoothly in either the design or construction, but they did proceed at a pace that is almost unthinkable today.

The Bay Bridge was opened slightly ahead of schedule and under budget and almost immediately served double and then triple the anticipated traffic. Indeed, if there was one major mistake made by Purcell and his staff, it was their fundamental error in traffic projections. The state's loan from the federal government was constrained by these projections; the federal government would lend only as much as could be supported by tolls based upon traffic projections. The many economies that went into the bridge design were unnecessary; the bridge revenues would have supported a loan perhaps twice its actual size. In their defense, however, Purcell and his staff in 1930 could not have anticipated the factors that went into that increase in traffic after 1936 -- a hugely popular World's Fair on Treasure Island, mid-span on the bridge in 1939 and 1940; America's entry into World War II in 1941 and the transformation of the Bay Area into a key element of the war effort; and the unprecedented population growth of the Bay Area in the post-war era. The bridge was built at an opportune time; it is difficult to imagine how the Bay Area could have accommodated wartime and post-war growth without it. It was an opportune time for Bay Bridge tolls as well; the bridge was running a huge surplus some twenty years after it was built, a surplus that was used not only to remove mass transit from the bridge, but also to subsidize mass transit development elsewhere.

The Bay Bridge represents a milestone in bridge engineering on a national scale and a milestone in the political and economic history of the Bay Area and California. To establish a context for interpreting that significance, this document will explore the various elements that led to construction of the bridge: the transportation system of the Bay Area before the bridge was built; the long political struggle by Bay Area leaders to get the bridge approved; as well as the complex process through which the bridge was designed and built. It will close with a brief discussion of what has happened to the bridge since it was built, and closing comments on the place of the bridge in engineering and transportation history.

A fourth issue is discussed at appropriate locations throughout this study: the relationship between the Bay Bridge and its famous neighbor, the Golden Gate Bridge. Bridge historians and historians of the Bay Area have been drawn to this comparison because of unavoidable circumstances: the bridges were built at the same time and only about three miles apart. Invariably, the Bay Bridge, the great workhorse of Bay Area bridges, has been compared (usually unfavorably) with the grace and beauty of the Golden Gate. The historiography of American bridges makes it impossible to discuss the Bay Bridge without discussing the Golden Gate Bridge, particularly with respect to the aesthetics of the design of each.

This study takes the approach that there is no objective way of comparing the aesthetic appeal of these two bridges. The Bay Bridge may be homely or beautiful, depending upon the tastes of the observer. This study will argue, however, that it is patently false to argue that aesthetics was not a consideration in the design of the Bay Bridge. The designers of the bridge had at all times to balance three major considerations: cost, structural integrity, and aesthetics. Cost and structural integrity were unavoidable considerations. Cost was especially important because the funds for construction were borrowed from the federal government and there was no chance that the government would lend any more than the $70 million it had committed. The structural integrity of the bridge was an especially important consideration in light of the daring nature of the design and the number of untested technologies that were involved. Of the three considerations, aesthetics was most easily compromised; the cost could not be exceeded and the bridge could not be made unsafe, but the quality of its appearance could theoretically be sacrificed.

What is remarkable about the history of the bridge, however, is the degree to which aesthetics affected all aspects of its design. Concern over appearance dominated discussions among the engineers and between the engineers and consulting architects. Many of the most important design decisions were made for the purpose of achieving the best-looking bridge possible. This is not to say that aesthetics was ever the dominant consideration; the engineers and architects of the bridge made all major decisions by balancing aesthetics, cost, and safety. The point is that aesthetics were indeed taken into consideration, along with the other fundamental criteria. The beauty, or lack of it, of the Bay Bridge is ultimately a personal and subjective judgement, one that may be colored by many factors. The heavy traffic on the bridge – it carries 274,000 cars a day, by far the most of any bridge in the state and probably in the country as well – may contribute to its utilitarian impression. If it lacks the consistent aesthetic vision of the Golden Gate Bridge, that fact too may be attributed to its multiplicity of bridge forms, which in turn comprises one of the principal reasons it is so important from the standpoint of its engineering. In the final analysis, the Golden Gate and Bay Bridge are simply very different types of structures, each being important in its own realm, and neither being ultimately comparable to the other.

Brief comments are in order regarding the use of certain place names in the Bay Area. First, the bridge in question will hereafter be called the Bay Bridge, even though its official name is the San Francisco-Oakland Bay Bridge, or SFOBB. The island midway between Oakland and San Francisco will be called Yerba Buena Island, even though it was commonly called Goat Island during the 1920s and 1930s. A point at the south of San Francisco will be called Hunters Point, even though it is sometimes called Hunter's Point in historical literature.

Another brief comment is in order regarding the equivalency of money between the 1920s, 1930s, and today. As a general rule, a dollar during the 1920s and 1930s was the equivalent of ten dollars today. The factor changed a little from year to year. Money actually became dearer during the deflationary 1930s. By 1936, when the Bay Bridge was completed, one dollar was the equivalent of nearly dollars today. Thus, the original 65-cent toll for the Bay Bridge in 1936 was the equivalent of almost $8.00 in today's dollars!

Organization of this Report

- Chapter 1 offers a physical description of the bridge and its components.
- Chapter 2 offers an overview of the status of various transportation systems in the Bay Area in 1930, at the time the Bay Bridge was approved for construction. In brief, this chapter attempts to lay out the transportation problem that the Bay Bridge was designed to solve.
- Chapter 3 offers an overview of events in the Bay Area from the 1920s, which lead to the decision to build the Bay Bridge. It focuses particularly on the important but often overlooked role of the City and County of San Francisco as an advocate for the bridge.
- Chapter 4 focuses on the critical role of the Hoover-Young Commission, which met in 1929 and 1930 in cementing a consensus that the bridge could and should be built.
- Chapter 5 will present an overview of the legislative and regulatory hurdles that had to be overcome before the bridge could be built, including the creation of the California Toll Bridge Authority, permits from the War Department, applications to the Reconstruction Finance Corporation, and congressional hearings regarding the project.
- Chapter 6 will present a brief overview of the design and construction of very large bridges in the United States in the decade prior to the building of the Bay Bridge, to establish a context for the significance of the Bay Bridge on a national basis.
- Chapter 7 will present a detailed history of the design of the Bay Bridge in the years 1931-33.
- Chapter 8 will focus on the role of the Board of Consulting Architects in designing the Bay Bridge.
- Chapter 9 will present a detailed history of the construction of the Bay Bridge.
- Chapter 10 will focus on the history of the Bay Bridge from the standpoint of the workmen.
- Chapter 11 will present a history of the use of the Bay Bridge by the interurban lines, chronicling the detailed negotiations with the railroads, the causes of delays in building the railroad connections on the bridge, and the causes for declining usage of the bridge by the railroads.
- Chapter 12 will survey the coverage of the construction of the Bay Bridge in popular media and will chronicle the celebrations upon its completion, including the use of the Bay Bridge as a theme for the Golden Gate International Exposition.
- Chapter 13 will survey the history of bridge after its completion in 1936. This chapter will focus on the plans for a second bridge during the 1950s (the so-called Second Crossing), the reconstruction of the bridge in 1958-62, and the major repair work to the bridge following the Loma Prieta earthquake in 1989.
- Chapter 14 will present concluding comments regarding the national significance of the Bay Bridge in the areas of transportation, engineering, and the political history of the Bay Area.

Two appendices have been included to assist the reader in what is sometimes a complex narrative. Appendix 1 includes a timeline of events leading to the building of the Bay Bridge. There were multiple currents – political, technical, financial – all of which affected the Bay Bridge design and construction schedule. Appendix 1 exists to help the reader keep these straight. Appendix 2 offers an organizational chart of the people involved in the design of the Bay Bridge.

1. DESCRIPTION OF THE BAY BRIDGE

1.1. Bridge Setting

The Bay Bridge was the longest bridge in the world at the time it was built. It is also among the world's most complex bridges in that it incorporates a variety of different bridge types connected to form a single structure carrying two levels of traffic between San Francisco and Oakland, California. The Yerba Buena Island tunnel links the west spans and the east spans. The upper deck originally carried six lanes of two-way auto traffic; the lower deck originally carried three lanes of two-way truck traffic and two sets of rails for inter-urban rail vehicles (streetcars). Drawing 1, "Title Sheet," of this HAER documentation, shows the location of the bridge in relation to San Francisco, Oakland, and Yerba Buena Island.

The Bay Bridge is formally called the San Francisco-Oakland Bay Bridge (SFOBB). As the name clearly indicates, it extends across San Francisco Bay between Oakland and San Francisco. The physical and cultural setting for the bridge is that of the most intensively urbanized parts of the San Francisco Bay Area. When it was built, the bridge began and ended in major harbor areas – the bustling San Francisco harbor and the Port of Oakland, which was then just emerging as a major harbor facility.

In San Francisco, the bridge begins on what historically was called "Rincon Hill": that hill was partially destroyed during construction of the anchorage and viaducts for the bridge. Rincon Hill is south of the Ferry Building and southwest of Union Square. The waterfront near the anchorage for the bridge was a busy harbor facility at the time the bridge was built. Since 1936, however, commercial tonnage in the port area of San Francisco has declined dramatically and the waterfront has been reused for a variety of commercial and residential purposes.

The East Bay setting for the bridge has changed dramatically since completion of the bridge in 1936. The Port of Oakland has grown into one of the third largest port facility on the West Coast, specializing in handling containerized cargo. The waterfront south of the bridge is lined with massive cranes and other harbor structures as well as major rail and highway connections. In addition to the port, the East Bay setting for the Bay Bridge is dominated by freeway connections that have been built and rebuilt since the 1950s. None of the original Bay Bridge approaches remain on the Oakland side. The Bay Bridge today may be accessed in the East Bay from three interstate highways: Interstate 80 from the north, Interstate 580 from the east, and Interstate 880 from the south. The interchange for these three freeways, which is being rebuilt at the time of this writing, exists just east of the tollbooth for the bridge. It includes a complex series of elevated ramps, which allow the traffic to proceed from one freeway to another or to the tollbooth for the bridge. The tollbooth is located on a spit of man-made land, which extends into the Bay and is within the city limits of Oakland. Downtown Oakland is southeast of the tollbooth.

The San Francisco Bay and Yerba Buena Island define the setting for the Bay Bridge. Yerba Buena is a natural island situated about midway between San Francisco and Oakland. Beginning

in 1900, the island was used as a station for the U.S. Navy. [It was an Army post before 1900.] While the Bay Bridge was under construction, the Army Corps of Engineers was creating a new island, called Treasure Island, on shoals north of Yerba Buena Island to serve as a site for the 1939 World's Fair. In 1940, Treasure Island was also taken over by the Navy. Treasure Island and Yerba Buena Island were used together as the Treasure Island Naval Station between 1940 and the closure of the station in 1998. The Bay Bridge passes over and through Yerba Buena Island on steel and concrete viaducts and in a tunnel. Today, Yerba Buena Island includes relatively few buildings and has a park-like feel, particularly since the Navy vacated the island.

1.2. General Description of the Bridge

The original planning and construction documents for the San Francisco – Oakland Bay Bridge describe the project as consisting of the following five distinct segments connected end-to-end across San Francisco Bay: the San Francisco Approach, the West Bay Crossing, the Island Crossing, the East Bay Crossing, and the Oakland Approach. The bridge connected to the existing roadway system at each end. In Oakland, this required construction of a "distribution structure", overpasses, and underpasses east of the Toll Plaza.

The bridges, viaducts, and tunnel total about 5 miles of which approximately 4 miles are over water. In 1936, the State of California claimed the bridge was 8 ¼ miles long, a figure that included a mass transit elevated loop in San Francisco and long approaches on the East Bay, many of which no longer exist. The San Francisco Viaduct to the anchorage is 3,707 feet. The distance from the San Francisco anchorage to the Yerba Buena Island anchorage is 9,528 feet (1.8 miles). The distance on the island is 1,663 feet, which includes a tunnel and viaducts. The distance from the island to the Oakland Toll Plaza is 20,942 feet, about 4 miles, some of which is on fill.

As originally designed, the double-decked bridge carried two-way automobile traffic on the top deck and truck and interurban trolleys on the lower level. There were six lanes on the top deck, three in each direction. The lower deck carried two trolley tracks in addition to truck lanes. The complex mix of truck, trolley, and automobile traffic required a large number of different on- and off-ramps on both approaches. The on- and off-ramp structure was particularly complex in San Francisco, where the bridge approaches were made to conform to the existing street grid. On the Oakland approach, the transitions were easier because the bridge approaches were built on a broad expanse of land, made by filling in the shore of San Francisco Bay.

In the late 1950s and early 1960s, the bridge and approaches were modified to carry mixed car/truck traffic on each deck and remove the electric railway system. The upper deck was designed to carry westbound traffic and the lower deck east bound traffic. This required strengthening the upper deck to accommodate the additional weight of trucks. The upper deck through the tunnel was lowered to accommodate the height of trucks. The lower deck required new concrete slabs where the rails were removed and the removal of a series of center columns at Yerba Buena Island. A lower roadway deck was added to the San Francisco viaducts to connect

to the freeway system.

1.3. Structural Materials and Loads

All permanent structures of the bridge were built of steel and/or reinforced concrete. Reinforced concrete was used for foundations, short-span structures in the San Francisco Approach and the Island Crossing, and for roadway slabs of the long-span steel structures. Steel was used for all main superstructure components of the West Bay Crossing and East Bay Crossing. Five types of steel were used: carbon steel, silicon steel, and nickel steel for major structural components, as well as special heat-treated eyebars for special application in the East Bay Crossing trusses, and cold-drawn wire for the cables of the West Bay Crossing. All connections of structural plate steel were made with rivets or bolts. Rivets were the norm – bolts were used only at special locations where riveting was not feasible.

The upper deck was designed for automobile traffic, with six ton vehicles in six lanes (9'-8" wide each), plus a ten ton truck in any one lane. The lower deck was designed for three lanes (10'-4" wide each) of 30 ton trucks, and two lines (27' wide space) for 70-ton Interurban electric rail cars. Wind loads were taken at 30 pound per square foot, typical for bridges of that era. Earthquakes were considered by designing for a load of 10 per cent of the weight of the bridge, acting laterally.

1.4. The San Francisco Approach

The San Francisco approach to the upper deck included a long concrete viaduct structure that began at Fifth Street (between Harrison and Bryant) and extended to the anchorage along the centerline of the main bridge. From the anchorage to the first pier, W-1 of the west bay span (suspension bridge) is a steel deck truss that is supported by two intermediate piers. (A discussed throughout this description, the Bay Bridge was built through a series of contract – the San Francisco approach, the West Bay Crossing, East Bay Crossing, and so forth. The bridge from the anchorage to Pier W-1 was actually built as part of the West Bay Crossing contract, not as part of the approaches. This description is designed to present the elements of a bridge in the most logical manner and does not in all cases match the divisions of bridge elements that were used in awarding construction contracts.)

The San Francisco approach, as it existed in 1936, is shown in Drawing 2, "Key Plans," of this HAER documentation. The approach is illustrated in Detail 1, "San Francisco Approach." The drawing includes arrows labeled R, T, and A, for rail, truck, and automobile traffic flows.

There was one on-ramp that provided access from First Street, between Howard and Folsom Streets, to the upper deck just west of the anchorage. There was an off-ramp just west of the anchorage that looped around and connected to Fremont Street at Harrison Street. The two-way truck traffic access and egress from the lower deck was from Harrison Street between First and Second Streets. The trains came off of the lower deck between First and Second Streets and looped through the Transbay Transit Terminal at Mission Street, located between Fremont and

First Street, and then back onto the bridge.

The original structures are mostly of reinforced concrete construction, with haunched concrete girders, carrying reinforced concrete slabs, supported on reinforced concrete multi-column bents, with foundations consisting of spread footings on rock or timber piles to rock. Steel girders were used at certain locations, mainly in the Terminal ramps, where the elevated roadway crosses city streets. These steel spans shared concrete bents with adjacent concrete spans, and are supported at intermediate locations by steel bents. The high curved ramp that currently serves the upper deck as an off-ramp on the south side of the highway is a notable, relatively unmodified example of the original construction.

The west approach truss spans are continuous spans of 380 feet each that bridge the distance from the San Francisco Anchorage to the transition Pier W1 that begins the suspension system. Intermediate supports are provided at bents A & B, which are closely spaced to meet existing street geometry. These truss spans have a structural framing system similar to the suspension spans, but with allowance made for the suspension bridge cables passing through the trusses as they drop beneath deck level just west of W1. The allowance consists of special plate girders, parallel to the trusses, that carry the floor beam loads past the cables to common panel points.

1.5. The West Span

The West Span beginning at pier W-1 is comprised of two back-to-back suspension spans, one anchored at Yerba Buena Island, one in San Francisco, and each is anchored to a massive center anchor pier. Each suspension bridge is about 4700 feet long. The tandem suspension bridges extend from Transition Pier W-1 to Yerba Buena Island, with a westward extension of the cables underneath the west approach truss spans to their anchorage in San Francisco. Each of the main spans are 2,310 feet and side spans are 1,160 feet. The overall structural system consists of two parallel wire cables, 26 inches in diameter, supported on X-braced steel towers, and supporting a truss stiffened double deck roadway.

The truss system is 66 feet wide and 35 feet deep, with wind bracing in the lower plane but not in the upper plane, and with no sway bracing. The truss chords and diagonals are box-shaped, with both solid plate sides and laced sides. The vertical members are H-shaped. The floor system consists of reinforced concrete slabs, supported on steel longitudinal I-beam stringers, supported on transverse steel plate girder floor beams.

The West Span, or West Bay Crossing, is shown in general view in Drawing 4 of this HAER documentation. The key structural elements of the suspension bridges are illustrated in Drawing 7.

Significant Structural Components of the West Bay Crossing:

Caissons – these large cellular reinforced concrete caissons were amongst the largest in the world at the time of their construction, and were floated into place. They represented an incremental

improvement in the open-dredging process, by maintaining domes over the cell tops to permit floatation control by compressed air during sinking.

Towers – these towers represent the first use of batter-leg towers on a major suspension bridge. The slight incline to the tower legs allows the cables to be centered over the trusses, while at truss elevation the tower legs are slightly outboard of the truss centerlines. This allows better utilization of all the space on the decks.

Tower Bases – the connections of the steel tower shafts to the caisson caps is by bearing plates on milled concrete surfaces for compression, and by long embedded anchor bolts for tension. This detail provides the normal bearing capacity required of all suspension bridge towers, plus an additional ductile reserve in tension and bending that is required for seismic resistance.

Tower / Truss Articulation – the trusses are supported over most of their lengths by the cable system, but at the towers they are supported by a system of vertical links and lateral bearings. The vertical links, under each truss and connected to the inside legs of the cruciform-section towers, act like large rocker bearings. They provide the vertical/torsional rigidity along with large longitudinal movement capacity required for operation of trains. The lateral bearings at these locations consist of girder members with slots that engage pins in the tower system. This allows transfer of lateral wind load from the trusses to the towers in the presence of the large longitudinal movements of the trusses. These articulations resist load in three directions – vertical, transverse, and torsion – and allow movement in the other three directions – longitudinal, transverse rotation, and vertical rotation.

Rigid Suspenders – the majority of suspenders consist of pairs of wire ropes looped over cable strands and connected with sockets to the trusswork. In each of the four shorter (~1100 ft) side spans of the West Bay Crossing, the shortest suspenders that hang the truss from the cables are of different. Rather than consisting of wire rope looped over the cables like all the other suspenders of the bridge, these suspenders consist of short fabricated steel shapes that can resist compression as well as tension. The compression resistance is required due to the long side spans of the bridge, which cause a stress reversal in these suspenders under unbalanced live load.

Center Anchorage – this anchorage is unique among U.S. suspension bridges, and even among world suspension bridges until construction of the back-to-back Minami Bisan-Seto and Kita Bisan-Seto bridges on the Honshu-Shikoku corridor in Japan in the 1980s. The center anchorage serves to connect the ends of the bridge cable together and to anchor both bridges. Many aspects of the unit are unusual, it is the A-frame system at its top that is unique. This fabricated and riveted steel assembly transfers balanced cable forces directly from one cable to the other, and transfers unbalanced cable forces into the concrete box pier beneath. The A-frame is post-tensioned to the pier with eyebars, providing a sturdy and constructable system.

Piers

The West Bay Crossing piers are identified as W-1 through W-6, numbered from west to east. Piers W-2, W-3, W-5 and W-6 support the suspension towers. Pier W-1 is a land pier. Pier W-4, the most unusual of the West Bay Crossing piers, supports the center anchorage. During the 1930s, it was sometimes called "Moran's Island," after the underwater construction expert, Daniel Moran, who helped conceive of how to build it and the other deepwater piers of the Bay Bridge. The structural system for the West Span foundations are illustrated in plan and section in Drawing 10 of this HAER documentation.

Pier W-1 was built on reclaimed tidelands. This pier was sunk to bedrock by means of an open cofferdam of sheet pilings. Pier W-1 is a tall concrete structure and functions as a connector or transition pier between the suspension bridge and the cable anchorage. The cables pass over saddles atop this pier before descending to their anchors at the bottom of the San Francisco anchorage. This pier also serves as the eastern end of the continuous truss spans and western end of the deck for the suspension bridge. Like all of the concrete elements in San Francisco and on Yerba Buena Island, Pier W-1 is defined architecturally by stepped forms, which create deep reveals and shadow lines. (There are also two smaller, intermediate steel piers between the anchorage and Pier W-1. These, called Piers A and B, are original to the bridge. The steel forms of these piers mimic those of the suspension towers.)

Pier W-2 was located at the outer edge (eastern end) of an historic steamship dock, leading east from the Embarcadero. Construction of this pier was carried out from the steamship dock. The pier site was excavated by open trenching. A timber frame was towed to the pier site and sunk by weighting it down. Sheet piling was driven into the sides of this frame to bedrock, 80 feet below the surface. The sheet pilings then formed a steel box, or cofferdam, to the desired shape of the pier. This "box" was excavated to bedrock. Concrete was poured in the cofferdam by buckets. As the poured concrete reached to nine feet from the surface, the cofferdam was de-watered and the concrete poured in the dry. The concrete pour continued to a height of 40 feet above water level, forming the base for the suspension tower. Pier W-2 supports the westernmost suspension tower.

Piers W-3, W-4, W-5, and W-6 were the most difficult piers to construct, owing to the great depth to of overburden and water bedrock in the shipping channel. The piers are cellular in plan, i.e. are not solid concrete structures. The "cells" of these piers correspond with cells in the caissons, specially designed structures used in construction of these piers. Each cell is a 15-foot diameter cylinder, which served as a dredging well while the pier was being excavated and also served as a form for the concrete pour. The depth of these piers reflects the distance to bedrock, not necessarily the depth of water at the location. Pier W-3, for example, was built in a water depth of 50' but is the deepest of the piers, reaching bedrock at -220'. Pier W-4 reaches bedrock at about -180'. Pier W-5 reaches bedrock at only -105', and Pier W-6 at about the same depth. The water depth is greatest at W-6, near Yerba Buena Island. Of these four, Piers W-3, W-5, and W-6 are nearly identical, differing chiefly in height (or depth to bedrock). Pier W-4 is the central anchorage and is nearly twice as wide and long as the others and is discussed separately.

The method of construction for the four cellular piers helped define their form. The construction caisson for Piers W-3 and W-6 comprised 28 steel cylinders, 15 feet in diameter, held in place in rectangular steel and wooden frames. Thus, the caisson included the cylinders (set in four rows of seven), with a series of spandrel shapes, created by the voids between the rectangular grid and the cylinders. During construction, the cylinders were used as wells for excavation by clamshell buckets. The spandrel areas were used to pour concrete and ultimately form the structural basis for the piers. Pier 5, the smallest of the four, is built around 21 cylinders, with three rows of 15 foot diameter cylinders set in groups of seven. Pier 4, the double anchorage, is simply a much larger version of the same cellular design; it comprises 55 cylinders, 15 feet in diameter, set in five rows of eleven.

These caissons were ferried into place and sunk, using a complicated method described in greater detail under "Historical Context." Briefly, the caissons were sunk below the water level when the voids outside the cells were partially filled with concrete. The caissons were held in place using a block and tackle device while more concrete was poured, until the caisson reached the mud level. As the caisson was lowered, new cylinders and metal frames were welded to the top to raise the height. The mud was excavated by clamshell buckets on derricks. As the mud was removed, the caisson was forced further into the bed of the bay by the weight of new concrete. This process was continued until the steel frame, with sharp cutting edges on the outside, rested on bedrock.

When the pier reached its final elevation, the crew began construction of the base for the steel towers, which rise above the water on Piers W-2, W-3, W-5, and W-6; the central anchorage, Pier W-4, was built of concrete above the water level and supports no tower. Immediately above the water level, each pier includes a fender. The fender is a concrete arm, cantilevered from the bulk of the pier, finished in timber. The base for the steel tower is only about one-half the area of the base of the pier. Pier W-4, the center anchorage is a concrete structure, rising nearly 300' above the water level. As noted, Drawing 10 of this HAER documentation illustrates both the structural system and the construction methods for the West Span foundation.

Towers

The towers are of two different heights: Towers W-2 and W-6 are 458 feet tall, Towers W-3 and W-5 are 502 feet tall to accommodate the vertical curve profile of the roadway. The main tower shafts are a multi-cellular cruciform cross section, made up of riveted steel plates and bulkheads. The shafts are battered (slightly angled) to meet lateral stability and geometrical clearance requirements without wasting space on the deck of the bridge. Each steel X-brace and horizontal strut consists of multiple riveted girders, laced together to form an architectural and structural unit. The widths of the bracing members were increased beyond those required for strength, for appearance purposes. At the top of each main tower is an open gallery, also provided for aesthetic purposes. The tower foundations consist of dredged and sunken, reinforced concrete caissons at W-3 through W-6. W-1 and W-2 foundations are of reinforced concrete, cast in place in cofferdams.

The suspension bridge towers on the West Bay Crossing are built on Piers W-2, W-3, W-5, and W-6. Although there are minor variations (minor in terms of the grand scale of these structures), the four suspension towers are nearly identical. The steel bottom, or base plate, for each tower begins 40 feet above low water level for the bay. The outside towers (on Piers W-2 and W-6) are 414 feet high above their base plates. Towers on 3 and 4 (closest to the center anchorage) are 458 feet high above their base plates; the increased height relates to the fact that the center anchorage is higher than the deck level anywhere else on the bridge. The towers are distinctive in that the legs are slightly battered, representing the first use of this technology in a major suspension bridge. The slight incline of the tower legs allows the cables to be centered over the trusses, while at truss elevation the tower legs are slightly outboard of the truss centerlines. This allows for better use of the space on the decks.

The towers comprise two thick vertical members, or columns, with horizontal and diagonal bracing, tying the two together. Each column supports the vertical reactions from a cable, while the bracing resists lateral loads. The central horizontal struts also support the decks. The columns are hollow, a fact that is attributable to the unusual manner in which the towers were erected. Each column is in the form of a cross with a hollow center. The columns were built of a series of steel cells, or rectangles that vary in size; the largest are 3 feet 6 inches by 4 feet. There are six cells at the top and bottom and four cells on each side, surrounding a hollow core of 7 feet x 8 feet. At the bottom, or base plate level, each column is about 30 feet by 20 feet, with the larger measurement being east-west oriented, in the direction of the cable. The two columns are about 83 feet apart. The steel that encloses these cells varies in thickness from nearly three inches to less than one inch.

The hollow core of the column was served as a base for an unusual crane, called a hammerhead derrick, which was built inside the lowest parts of the tower and used to hoist additional tower parts into place. As the tower rose, the derrick was raised and new parts of the tower were hoisted into place until the tower columns had been completed. As the columns were being raised and erected, the diagonal and horizontal bracing was installed as well.

At the base of the steel tower (the concrete top of the pier), the steel columns are bolted into place on plates set into the concrete. The base connection is by bearing plates on milled concrete surfaces for compression, and by long embedded anchor bolts for tension. This detail provides the normal bearing capacity required of all suspension bridges, plus an additional ductile reserve in tension and bending, required for seismic resistance.

The lowest strut is located a very short distance above the base plate, and the diagonal braces begin immediately above the horizontal member. All members other than the tower columns are latticed, i.e. comprising numerous crossing steel members, which appear to be solid because of solid steel plates placed on the outside. As noted, there are two sets of crossing steel members between the bottom horizontal member and the deck supports. The horizontal deck struts are located a little less than half-height in the towers. Three sets of crossing members exist above the deck levels; these too are latticed members. The towers terminate in a horizontal member, with

minor members above each column to accept the cable saddles. Drawing 9 of this HAER documentation illustrates the tower design. The cellular form of the tower is shown in the detail to the right.

Anchorages

There are three anchorage structures for the West Bay Crossing suspension spans, but these operate as if there were four because Pier W-4 is a double anchorage. The three anchorage structures are: the San Francisco anchorage; Pier W-4; and the Yerba Buena anchorage. The western suspension span extends from the San Francisco anchorage to Pier W-4, while the eastern suspension bridge extends from Pier W-4 to Yerba Buena Island. The San Francisco anchorage is part of a tall reinforced concrete structure, which at its top also serves as a pier for the viaduct approaches to the bridge. The double anchorages at Pier W-4 are integrated into the tall reinforced concrete structure that is the visible part of "Moran's Island." The Yerba Buena Island anchorage is partly in tunnels.

The means of anchoring the suspension cables is much the same at each of the four anchorage points. The cables are held in place by a series of eyebars, which are embedded in the concrete at each of the four anchorage points. Each anchorage is built around three elements: inclined steel girders which hold the backs of the eyebars; the eyebars themselves; and masses of reinforced concrete, which hold the eyebars in place and serve to anchor the cables. This arrangement is most easily seen at the San Francisco anchorage, although the systems are quite similar at the other anchorages as well. The steel girders were built in an inclined position and would ultimately be encased in concrete. Each girder accepted seven eyebars. There were five sets of these girders for each cable, accommodating 35 eyebars. The opposite end of each eyebar (away from the girders and toward the bridge) was fitted with a steel spool, or strand shoe. The wire for the cables was spun around a shoe, then strung over the tops of the towers and around a shoe at the opposing anchorage. For the San Francisco anchorage, for example, the cable was also spun around shoes at the western side of Pier W-4.

The wire used in the bridge was round steel wire that measures about .19 inches in diameter (five such wires laid side by side would measure about an inch). As the wire was spun, it wrapped around the shoe, leaving one wire on either side. Ultimately, 472 wires were wrapped around each shoe, with 236 on either side of it. These 472 wires would be crimped and bound to form a strand of wire. As noted, there were 35 eyebars and shoes for each cable, meaning that there were ultimately 35 strands of wire, each with 472 wires each. As a final measure, these 35 strands were wrapped with additional wire to form a cable that is more than two feet in diameter.

As noted, the San Francisco anchorage is a gravity structure, resisting the pull of the cables by virtue of the mass of concrete. The actual anchorage occurs near the bottom of this concrete mass. The inclined steel girders are not seen; these girders were buried in the concrete. The eyebars are embedded in the concrete, with only a short length protruding. Unbound wires exist at either side of each shoe, which is attached to the eyebar. At some distance from the eyebars, the wires have been bound to form strands. At a point still further from the eyebars, the strands have been

wrapped into a single cable. This final wrap occurs just before the cable leaves the anchorage building. The huge cables leave the anchorage in this form, and this is the character of the cables at every place in which they are visible to the public.

The tall concrete building called the San Francisco anchorage is actually both a pier and an anchorage. At the top, the building supports the elevated roadway as it climbs over the remnants of Rincon Hill. In its exterior, the building is a battered and heavily inflected concrete mass, with huge buttresses at its base, from which the cables emerge. Architecturally, the San Francisco anchorage is the largest and most successful expression of the stepped forms used in all major concrete elements on the bridge.

Pier W-4, or "Moran's Island," is a double anchorage and is arguably the most inventive single element of the Bay Bridge. The means of attaching the cables at this point are equally ingenious, although little may now be seen; most of this system is embedded in the concrete. Like the San Francisco anchorage, the W-4 system is built around five rows of inclined steel girders to hold the eyebars. The girders, in turn, are attached to one another by heavy metal beams to form a steel box, called an A-frame by its fabricator. The columns of the girders extend below the eyebars and are attached to vertical steel bars, which are embedded deep into the concrete. Thus, the two anchorages pull against each other, held in place by the steel box and the concrete around it. Before the A-frame was concreted into place, the bottom of it was connected to an eye-bar chain (connected to the base of the anchorage), and the eye-bar chain was stretched to a tension of 7.4 million pounds, essentially a post-tension procedure, effected long before post-tensioning was an acknowledged procedure in bridge construction. The chains and the rear of the A-frame were then encased in concrete and covered by a steel hood, called a shroud. Architecturally, Pier W-4 was treated in the same manner as the San Francisco anchorage; heavily inflected, stepped concrete forms which are battered, or tapered toward the top. The steelwork for the shrouds is inflected in the manner of the concrete work below.

At the Yerba Buena Island anchorage, the cables pass over an inclined bent (leaning east, toward the anchors) before reaching the anchorage structure. The cables are anchored at Yerba Buena Island in two tunnels, excavated 170 feet into the solid rock of the island, at an angle of 37 degrees from horizontal. The tunnels were tapered, their larger diameter at the rear. The steel girders to hold the eyebars were embedded at the rear of the tunnels. The cables pass over the bent and into tunnels, which were mined to reach the bedrock of Yerba Buena Island. The cable bent is carried on a concrete pier that also serves as part of the bridge abutment.

Drawing 11 of this HAER documentation illustrates the structural system for the three anchorage structures. The three sectional views, A-A, B-B, and C-c, illustrate the different means by which the cables were anchored in these three structures: the gravity anchorage in San Francisco, the post-tensioned eye-bar chains in the center anchorage, and the tunnel anchorage on Yerba Buena Island.

Suspension System

The cables are anchored in a gravity anchorage at the San Francisco end, in a tunnel anchorage at the Yerba Buena Island end, and in a unique cantilever box anchorage at the common center anchorage. The cables were spun in place from 0.192 in. diameter galvanized steel cold drawn wire. These wires were placed using a spinning wheel to carry wire from reels stored on the anchorage, to the final location in the saddles on the towers. The wires were bound in to 37 strands consisting of 472 wires each. They were then compacted into their final round shape, coated with red lead paste, and wrapped with additional wire. A 10-ft length model cable was built to determine the final dimensions of the compacted and wrapped cable.

The course of each cable, once it leaves the San Francisco anchorage, is strung over the top of Pier W-1, a concrete pier that reaches only to the height of the deck and serves to bring the cable to deck height (as well as supporting the viaduct); rises to the top of the tower at Pier W-2; suspends in a catenary between Piers W-2 and W-3 before its rises to the top of the tower at Pier W-3; and descends to an anchorage at Pier W-4. That is effectively the end of the western suspension bridge. The cable for the eastern bridge follows that pattern in reverse; starting at the W-4 anchorage; rising to the top of the tower at Pier W-5; suspended in a catenary between the towers of Piers W-5 and W-6 before rising to the top of the tower at W-6; and descending to the anchorage at Yerba Buena Island. Drawing 8 of this HAER documentation illustrates both the structural system and the construction method for the suspension spans. That drawing also illustrates the sequence through which elements of the stiffening truss were attached to the cable, to avoid creating an imbalance.

The principal structural elements to hold the cables in place, other than the anchorages, are steel "saddles," atop the towers at Piers W-1, W-2, W-3, W-5, and W-6, as well as at the cable bent at the Yerba Buena Island anchorage. The saddles are heavy, three-sided cast steel pieces that hold the cable in place and transfer loads to the supporting structure. Each saddle weighs 46 tons. These were said to be the largest single-piece casts ever used in bridge construction at the time the Bay Bridge was built. The cables were spun in this saddle. A typical saddle is shown in section and elevation in Drawing 12 of this HAER documentation.

The deck is suspended from the cables by a series of suspender "ropes." These ropes are wire cables, each 2.25 inches in diameter. A rope was attached to the cables by a cable band, a metal clamp in two semi-circular parts, which was bolted together at prescribed locations. There are 612 cable bands altogether, with four ropes from each. Collectively, the ropes measure 43 miles in length. The lengths of rope differ, depending upon the location within the catenary of the suspended span. The panels of the deck stiffening truss were suspended from the suspender ropes, with the tops of the stiffening truss panels hung from the rope lengths. The exceptions to this rule are the shorter side spans of the West Bay Crossing. On these spans, the shortest suspenders in each span consist of short fabricated steel shapes that can resist compression as well as tension. The compression resistance is required due to the long side spans of the bridge, which causes a stress reversal in these suspenders under unbalanced live loads. There are eight such suspenders on the bridge. Drawing 9 of this HAER documentation illustrates the manner in

which the stiffening truss was attached to the cables by suspender ropes.

1.6. Yerba Buena Island

Yerba Buena Island is located about halfway across the Bay Bridge and more or less in line with the points of origin in San Francisco and Oakland. A bend in the viaduct on the east side of Yerba Buena Island exists because the three points are not exactly on line. The bridge crosses 2950 feet over Yerba Buena Island, or a little more than half a mile. The roadway is in a cut between the Yerba Buena Island anchorage and the Yerba Buena Island Tunnel and is in tunnel for 540 feet. There is also a short cut section at the east portal of the tunnel. The remainder of the course over Yerba Buena Island is on a steel truss viaduct, high over the east side of the island, which connects to the east span.

Yerba Buena Island Tunnel

The Yerba Buena Island tunnel, one of the superlatives of the Bay Bridge, represented the largest diameter tunnel in the world at the time it was built. It still remains the largest diameter tunnel in the world. Its construction introduced several new and innovative technologies, including the practice of placing the sidewalls before excavating for the arched roof.

The tunnel is in the shape of what is often called a "horseshoe" tunnel, although it is more accurately described as a segmental arch, with vertical sidewalls and an arched roof. The tunnel portals, particularly the west portal, are among the most interesting elements of the entire bridge structure from the standpoint of architectural design. The San Francisco portals include stepped concrete elements that appear as large blocks at either side of the tunnel and as three segmental arched forms at the tunnel itself. These interesting forms are now difficult to see, however, owing to the fact that traffic is unidirectional heading west on the top deck, making these elements visible only through the rear view mirror of the driver.

The original tunnel construction consisted of a 79 foot wide, 540 foot long tunnel to carry the twin decks through the rock of the island outcropping. The tunnel form itself consists of an arch founded on two retaining walls; the arch forms the ceiling of the tunnel, spans 79 feet with a rise of 21 feet, with a three to six foot thick slab rib to resist the earth pressure from above. The retaining walls, upon which the arch is supported, form the walls of the tunnel, and are 35 feet tall, supported on spread footings. The inside of the arch and walls are finished with tile. Inside this structural unit, a structural frame is supported to carry upper deck traffic. A slab on grade carries lower deck traffic. The original upper deck framing consisted of reinforced concrete beams and slabs, supported on corbels and pilasters built into the retaining walls, and by a row of columns between truck lanes and trackways at about the center of the tunnel. The tunnel was modified extensively in the late 1950s, as described in Section 1.1.7 below.

Drawing 13 of this HAER documentation illustrates the structural system as well as the method

of construction for the Yerba Buena Island tunnel. As discussed later in this report, the walls and arch of the tunnel were built before the tunnel was fully excavated. Drawing 13 also shows the original assignment of traffic lanes on the bridge: six automobile lanes on the top deck and two truck lanes and two trolley tracks on the bottom.

Yerba Buena Island Viaducts

The original viaducts consisted of reinforced concrete slab, beam, and bent structures similar to those built for the San Francisco Approach. The upper deck was framed with reinforced concrete columns, and girders, supported on three column bents, with columns in the middle of the lower deck.

The original steel truss spans that provide a transition between the concrete viaduct and the East Bay Crossing consist of through steel truss spans, each straight but on an overall curved alignment. The basic structural system of these spans is similar to that of the through trusses of the East Bay Crossing, that are described subsequently. Structurally speaking, it may be argued that these spans are really part of the East Bay Crossing, even though contractually they evidently were not. The Yerba Buena Viaduct is shown in elevation and section in Drawing 6 of this HAER documentation.

1.7. The East Span

The east span is comprised of the series of trusses and girder spans. Four deck trusses of about 290 feet each connect the east span to the tunnel through Yerba Buena Island. The largest section of the eastern span is the massive cantilever bridge, 1400 feet long in the cantilevered and suspended segment, with flanking anchor spans of about 510 feet each. The balance of the span includes five through trusses of about 570 feet each, and fourteen deck trusses about 290 feet each. The final segment toward the Oakland toll plaza includes ten 82-foot steel girder spans and six 41-foot concrete girder spans. The curved geometry of the bridge alignment is accommodated with the 288 feet spans across the island, plus an additional curve at about E-9 that was necessary to clear the ferry terminal that was on a spit of fill in the bay at that location when the bridge was built.

The general characteristics of the East Span, or East Bay Crossing, are shown in Drawing 4 of this HAER documentation. That drawing depicts the lengths and forms of the three major structural elements: the cantilever, through truss spans, and deck truss spans. The drawing shows the unique design of Pier E-9, at the juncture of the through truss and deck truss elements. It is the only four-column pier on the bridge and is spanned by two 50' metal plates. Those plates failed during the 1989 Loma Prieta earthquake.

Despite the diversity of structural types and spans used in the East Bay Crossing, the essence of the structural system is quite similar over its entire length. Each structural span carries two decks

of traffic on reinforced concrete slabs; each slab is supported on three systems of steel beams (transverse purlins, supported on longitudinal stringers, supported on transverse floor beams). The lower deck framing includes lateral bracing, the upper deck floor system does not. Sway bracing is incorporated only in the above-deck framing of the through spans; other spans incorporate no sway bracing at all. Design of the various-length longitudinal framing trusses of the crossing was largely influenced by erection requirements.

Significant Structural Components of the East Bay Crossing:

Cantilever Spans – this was the longest span and heaviest cantilever truss in the United States when it was built. Unusual aspects of its layout include the different pier types at its two ends (west: concrete, east: steel), and its longitudinal anchorage provided only at its west end.

Cantilever Spans Pier E-3 – this reinforced concrete caisson was the largest and deepest ever built. Its 225-ft deep bearing end is founded in a sand layer rather than on rock.

Cantilever Spans Joint L0 – this component connection on each side of the bridge at each of its main supports (E2 & E3) utilizes 18- and 24- inch diameter steel pins to connect five truss members to a common fabricated assembly that caps the supporting steel bent. The detail allows the required movements during cantilever construction, without undesirable secondary stresses that were blamed for collapse of previous major cantilever bridges including the Quebec Bridge. (This unusual detail is shown in Details 1 and 3 of Drawing 15 of this HAER documentation.)

Truss Spans – the split bents that support the trusses at major expansion joint locations allow the required thermal movements without the destabilizing forces associated with multiple rocker bearings supported on a single bent. A similar detail was later used on the Richmond – San Rafael Bridge.

Truss Spans Pier E9 – this large box pier provides a longitudinal anchor point for the multiple approach spans of the bridge. Its configuration provides for direct transfer of forces from the lower chords of the trusses to the main members of the Pier, at a location of curvature and span length transition.

Foundations

Two basic types of foundations support the over-water East Bay Crossing. Reinforced concrete cellular caissons were used for piers near Yerba Buena Island (E-3 to E-5) and pile foundations were used from pier E-6 to the end of the bridge at the Oakland shoreline. The deepest caisson supports pier E3, with a bottom of seal elevation about 230 feet beneath water level.

Pier E-1 and E-2 are the least complicated of the major East Bay Crossing piers because they were built on or near land. Pier E-1 is actually on Yerba Buena Island, carved from a natural knoll called "Army Hill" by the Navy. Pier E-1 is a concrete pier, built on conventional lines and taken to the bedrock of the island. Pier E-2 was built just east of the lands end and was easily

taken to bedrock, which was about 45 feet below the water level. It is a solid concrete pier poured into an open cofferdam.

The most complex piers of the East Bay Crossing are Piers E-3 through E-5. Like the middle piers on the West Bay Crossing, these are cellular in plan and were built using a specially designed caissons that were towed to the site and sunken. These differ a great deal from the West Bay Crossing piers in three respects. First, they do not reach bedrock. Second, the cells are built from rectangular rather than cylindrical cells. Third, a conscious effort was made to reduce the weight of the piers themselves, recognizing that they would be founded on relatively weak soil rather than bedrock.

The caissons for the three major East Bay Crossing piers were similar but of different sizes. Each was formed from a steel rectangle with rectangular chambers. Construction proceeded in much the same manner as the West Bay Crossing piers. Concrete was poured into the walls or voids outside the chambers, until the caisson reached the mud level, building new levels on top as necessary to keep the top of the caisson above water. Mud and other strata were excavated through the rectangular chambers until the caisson sunk to a previously agreed-upon level. When that level was reached, an additional 15 feet was excavated and concrete poured through the excavation chambers, creating a concrete base below the edges of the caisson.

Although not reaching bedrock, those levels below water were spectacular. Pier E-3 was the deepest of all of the piers on the Bay Bridge. It was sunk to a level of -243 feet, deeper than the -220 foot Pier W-3, the deepest on the West Bay Crossing. Pier E-3 also had the largest area of the East Bay Crossing piers. The caisson for it measured 80 feet by 134.5 feet and included 28 rectangular chambers. The caissons for Piers E-4 and E-5 were the same size: 60 feet by 90.5 feet. Each was taken to a depth of -180 feet, in addition to the extra 15-foot scouring below the caisson.

The remaining piers, Piers E-6 through E-23, were built using a pile foundation system with multiple timber piles terminating at load-bearing sand, and clay layers at depths of about 100 feet to 125 feet below water level. All were built using a steel cofferdam that was pounded into the mud and other strata until it reached the desired depth. The area inside the cofferdam was de-watered and the concrete piers were poured on top of the riles under dry conditions. The top ends of the timber piles are beneath a surface mud layer, where they are embedded in a concrete pile cap. The pile caps provide bases for reinforced concrete piers that reach up to water level.

The two types of foundations on the East Bay Crossing are shown in section in Drawing 18 of this HAER documentation. That drawing also illustrates the sequence of construction for the pile foundations at Piers E-6 through E-22.

Towers (Bents)

The term "towers (bents)" used here refers to the concrete or structural steel "X" braced steel supports that extend from the top of the concrete pier to the bottom cord of the trusses on each

side. A shoe that provides a pin connection of the bottom chord of the truss to the tower is anchored to a plate on top of each of the legs. The towers are constructed of angles and plates riveted to together to form a cellular cross section similar to the suspension span towers. The piers range in height according to the grade of the roadway. The towers also differ in section, according to the different roles they play in supporting this structurally complex crossing.

Pier E-1 (the piers are numbered west to east, from Yerba Buena Island to Oakland) is on Yerba Island and is a poured concrete pier that extends to the bottom chord of the cantilever bridge. It serves as an anchor for the west end of the cantilever span, connecting the Yerba Buena Island Tunnel with the beginning of the over-water bridge. It also serves as the eastern support of the steel viaduct that connects the tunnel to the eastern crossing.

The tower piers E-2 and E-3 are the tallest of the East Bay Crossing piers; they support the main span of the cantilever bridge. These towers bear the weight of the cantilever bridge and thus carry the heaviest dead load of any East Bay Crossing piers. Pier E-4 tower serves as an anchor for the eastern end of the cantilever span as well as the western support for the first of the truss spans. Piers E-2 through E-4 include tall X-braced steel towers from the concrete base to the deck level for the cantilever truss. These metal towers resemble architecturally the suspension towers of the West Bay Crossing.

Piers E-5 through E-9 support the truss spans; Pier E-9 also serves the western end of the deck truss spans. Pier E-9 is the most unusual of the East Bay Crossing piers in that it includes a rectangular tower of four columns. The through truss and deck truss elements terminate on the outside edges of this pier, requiring a 50 foot connector between the ends. This 50 foot connector failed during the 1989 Loma Prieta earthquake, the only major damage sustained in that event. The remainder of the East Bay Crossing piers support the deck truss spans. The first seven consist of steel towers on concrete bases; the remaining piers are of concrete over their full heights. These piers get shorter and shorter as the bridge descends toward the toll plaza. The deck truss piers are also very close to one another.

Cantilever Span

The cantilever bridge part of the Bay Bridge is carried on Piers E-1 through E-4. The cantilever bridge follows the essential design of all modern cantilever bridges, comprising five elements: two anchor arms; two cantilevered arms, which are built symmetrical to the end spans; and the suspended span, hung between the ends of the cantilevered arms. Because the suspended span is not supported on piers (it is, as the name suggests, suspended from the ends of the cantilevers), there are only three spans: from the anchor to the major piers on either side of the bridge, and the larger center span. By this arrangement, the center span is by far the longest of the three, including the two cantilever spans as well as the suspended span. In the Bay Bridge, this center span is 1400 feet, an impressive span and among the largest cantilever spans ever built. The anchor spans are 580 feet each.

It was erected from the main piers (E2 and E3) with temporary steel bents in the anchor spans but not in the main span. The main compression members at the bottom of the cantilevers are of built-up riveted steel plates, the main tension members at the top of the cantilevers are of heat treated eyebars. After completion of the anchor span steelwork and the main span steelwork to a length of 412 feet, the center 576 feet of the main span was erected with guy derricks supported from the just-completed trusses. The concrete slab was cast after all steelwork had been erected.

Distinctive elements of the cantilever span are pin-connected assemblies atop the main support members, Piers E-2 and E-3. At these piers, 18 inch and 24 inch steel pins connect five truss members to a common fabricated assembly on either side of the piers. This detail allowed the required movement during cantilever construction, without damaging secondary stresses that had been blamed for the collapse of earlier cantilever bridges during construction.

The cantilever bridge is shown in Drawing 14 of this HAER documentation. That drawing shows the relationship between the anchor arm, cantilever arm, and the suspended span.

Through Truss Span

The through truss spans have both upper and lower decks within the truss framework. There are five through truss spans, located immediately to the east of the cantilever span. Each through truss span is 504 feet long, each comprising twelve 42 foot panels. The trusses are 84 feet tall. The lower deck is attached to the trusses just above the lower chord while the upper deck is attached about one-third of the height of the truss above its lower chords. The trusses are Warren trusses. These through trusses are carried on braced steel towers or bents, similar to those used on the deck truss, or incline section to the east. The split bents that support the through truss spans at major expansion joint locations allow the required thermal movement without the destabilizing forces associated with multiple rocker bearings supported on a single bent. The structural system of the through truss spans is shown in Drawing 16 of this HAER documentation.

Deck truss span

The deck truss spans have the lower deck inside the truss framework, and the upper deck on top of the truss framework. These truss spans extend from pier E-9 to pier E-23 comprising fourteen spans of 288' each. This series of deck trusses are often called the "incline section," denoting its ramping toward the Oakland touchdown. The deck truss spans (called "double-deck truss spans" by their fabricator) are supported on braced steel bents, except for the piers east of E-17, where the trusses are carried directly on the concrete piers. The trusses are 38 feet deep, with the top of the trusses serving as the top deck of the roadway. The structural system of the deck truss spans is shown in Drawing 17 of this HAER documentation.

1.8. Deck System

Although the bridge is carried by various structural elements (suspension bridges, cantilever, through truss and deck truss), the deck system is similar across the length of the structure. Because there are two decks, the bridge requires a truss system to support the two decks. This truss system is similar across the bridge, from the steel viaduct between the San Francisco anchorage to Pier W-1, across the suspension bridges, and across the various elements of the East Bay Crossing. The deck truss spans of the East Bay Crossing are simply the deck trusses, carried on piers. Generally, the deck system is 66' wide and 35' deep, with wind bracing in the lower but not the upper plane and no sway bracing. The floor system consists of reinforced concrete slabs supported on steel longitudinal stringers, which are in turn carried on steel transverse floor beams. Minor variations exist, particularly with respect to the manner in which the deck system was rebuilt in the late 1950s to accommodate truck traffic on the upper deck.

The deck system, of course, is different on the concrete viaducts in San Francisco and on Yerba Buena Island. The double-deck concrete viaducts have been discussed previously.

1.9. Oakland Approaches

The Oakland approaches as built in 1936 were at once simpler and more complex than those in San Francisco. The approaches were simpler in the sense that the bridge touched down on what had been a train yard island, or "mole" as it was called, that had been built into the Bay to provide deep water access for mass transit rail lines. This area was largely open at the time of construction and the approaches did not need to conform to the dense urban setting found in San Francisco. The approaches were more complicated, however, owing to need to connect with a far more complex highway and rail system on the Oakland side.

Between 1936 and 1938, the California Division of Highways built a series of connectors to "distribute" traffic between the bridge and area surface streets. This included a connection with the new East Shore Highway (essentially modern Interstate 80), as well as connections with Ashby Avenue in Berkeley, and Cypress Street and 38th Street in Oakland. The East Shore Highway-Cypress Street-38th Street connection was a series of elevated ramps, similar in some respects to modern freeway-to-freeway interchanges.

Virtually all of the East Bay approaches and related distribution structures have been destroyed. The destruction occurred during the 1950s and early 1960s, when the East Shore and Cypress Street alignments were re-used for freeways, and when the bridge traffic was reconfigured for unidirectional use. The Oakland approaches were further modified in the 1990s as part of the rebuilding of the freeway system following the Loma Prieta earthquake.

1.10. Changes to the Bridge since Construction

The Bay Bridge has been one of the most heavily used structures in the United States, almost from the day it was completed. Not surprisingly, the bridge has been modified extensively

through the years, to retain its structural integrity, to accommodate vastly different traffic patterns, and to deal with natural disasters. While it has been modified incrementally through the years, the vast majority of changes to the bridge may be attributed to two major events: removal of railroad tracks and reconfiguration for two one-way mixed traffic directions between 1959 and 1963; and damage to the bridge in the Loma Prieta earthquake in 1989, leading to substantial retrofitting of all elements of the bridge and ultimately to the decision to replace the entire East Bay Crossing.

Modifications from 1959 to 1963

Between 1959 and 1963, the Bay Bridge was substantially renovated to convert it to unidirectional traffic on each deck and to remove the railroad tracks. The details of this reconstruction are discussed in the "Historic Overview." In general, three major changes were required. First, the upper deck needed to be strengthened to accept heavy truck loading; this deck was designed for automobiles only. In addition, the upper automobile deck in the Yerba Buena Tunnel was lowered to accept taller truck traffic. Second, the tracks on the lower deck were removed and the railroad and truck lanes were rebuilt to accept mixed truck, bus, and automobile traffic. This required lowering the lower deck through the tunnel to allow the upper deck to be lowered as well. Third, the approaches on both ends as well as the ramps on Yerba Buena Island had to be fundamentally rebuilt to accept the unidirectional flow. The 1959-63 work coincided with freeway construction on both ends of the bridge, further complicating the process of rebuilding the approaches.

The 1959-63 work affected all aspects of the bridge but is most evident in the approaches and on the upper deck framing. The San Francisco and Oakland approaches bear little resemblance to their appearance in 1936, owing to the 1959-63 work and other construction associated with freeway connections. The upper deck of the Bay Bridge was strengthened chiefly by adding cover plates to the transverse floor beams and by adding additional rolled girders beneath the original stringers to increase their strength. The 1959-63 work, of course, also removed the transit rail lines, transforming the function as well as the appearance of the structure.

The San Francisco Approach

The remodeling consisted mostly of removing columns that supported the upper deck roadway from the fifth-street-to-SF-anchorage viaduct. The columns would otherwise have obstructed traffic on the new eastbound lower deck. To facilitate removal of the center columns, the outer columns were reinforced with new bolsters/pilasters on the outside faces of the remaining columns at the edges of the roadway, and the floor beams/bent caps were reinforced with new concrete and post tensioning to transfer the loads that were carried by the center column out to the remaining columns.

Additional remodeling of the main-line structure consisted of adding a new lower deck west of the Terminal ramps. This new structure consists of steel plate girders carrying a concrete slab-and-stringer deck, supported on reinforced concrete columns. The terminal ramps were widened and otherwise augmented to support bus operations of the Terminal.

The remains of the viaduct in San Francisco are identified as Bridge Number 118L and 118R. These numbers have been assigned by the California Department of Transportation, which owns the bridge as well as the approaches. The alignment of the main viaduct was not exactly that of either 118L or 118R, which is part of Highway 101. The westerly leg of the original viaduct, near its touchdown at Fifth Street, serves today as an off-ramp for U.S. 101.

The off-ramp that left the main viaduct between Rincon and First streets is largely intact and is identified as Bridge Number 34-116F. It still serves as an off-ramp. There was a smaller on-ramp for eastbound bridge travelers, again connecting with the waterfront area but on the opposing side of the bridge from what is now called Bridge Number 34-117S. This looping ramp began at Sterling, a small street just east of First Street. The on-ramp looped beneath the bridge, parallel to Bryant Street south of the bridge, and took a tight-radius curve to join the bridge viaduct at the equivalent of Essex Street, immediately opposite the off-ramp (34-116F). Most of this on-ramp still exists and is identified as Bridge Number 34-117S. This ramp is now an off-ramp for westbound traffic.

Interurban traffic was diverted to a dedicated ramp, an elevated concrete and steel structure that looped some two-thirds of a mile to and from the Transbay Terminal at First and Mission streets. That ramp and the old interurban elevated loop still exist and are used today to carry bus traffic to and from the Transbay Terminal. The loop is a 3,439 foot elevated structure of riveted steel girders on concrete and steel bents. Various bridge numbers apply to this structure; these numbers, however, refer to the bridges over surface streets and not to the bus loop as an integrated elevated bridge.

Drawing 20 of this HAER documentation illustrates some aspects of the reconstruction of the bridge in the late 1950s and early 1960s, including the reorientation of the San Francisco approach. The detail, "San Francisco Approach" shows the work in San Francisco. The confusing series of directional arrows on that drawing reflect the effects of imposing unidirectional traffic on a bridge that was not designed to accommodate such traffic flows.

The West span

The remodeling of the West Bay span consisted mainly of reinforcing the upper deck to carry heavier truck loads, and of removing the rails and widening the slab on the lower deck. Adding cover plates to the transverse floor beams strengthened the upper deck. The cover plates were pre-cut, jacked to a prescribed load, and then fastened with bolts or rivets to the existing lower flange of the floor beams.

Yerba Buena Island

The remodeling consisted mostly of work associated with removing the columns that supported the middle of the upper deck, and lowering the upper deck so that adequate headroom would be provided for tall trucks on the upper deck. Additional work was performed to bring both sides of the lower deck to a uniform grade for one-way highway use. The column removal and upper deck lowering work required replacing the upper deck floor with a new floor at a lower elevation that spanned all the way across the tunnel without intermediate support. The purpose was to provide a clear span across all of the lower deck lanes, requiring removal of the support columns for the upper deck. This was performed without closing lanes to traffic on either deck.
The new floor consists of pre-tensioned concrete tees, which were installed one at a time beneath a short temporary bridge that allowed both decks to remain in service during the reconstruction.

Drawing 20 of this HAER documentation illustrates the reconstruction of the upper and lower decks in the Yerba Buena Island tunnels.

The East Span

The remodeling of the East Bay Crossing in 1959 consisted mainly of reinforcing the upper deck to carry heavier truck loads, removing the rails and widening the structural slab on the lower deck, and re-framing the transition at the east end so that five lanes of traffic can exit the lower deck to the south. The upper deck was strengthened by adding cover plates to the transverse floor beams (similar to the procedure used on the West Bay Crossing), and by adding additional rolled girder shapes beneath the original stringers to increase their strength. These were made to act compositely under both dead and live load by pre-bending them upward in the middle prior to connecting them. The rails were removed from the lower deck to allow for widening the reinforced concrete slab. The heavier stringers that were already in place to carry the rail car loads were left in place to support the new slab.

The major reconstruction at that time was associated with re-framing the alignment transition at the east end. At this location, where the East Bay Crossing is framed with girders in an extended abutment-like structure, the transverse framing was lengthened and strengthened to remove existing columns from the revised highway alignment. Drawing 20 of this HAER documentation shows the nature of the work accomplished on the through truss spans on the East Bay Crossing.

Changes resulting from the Loma Prieta Earthquake

The East Bay Crossing suffered significant damage in the 1989 earthquake. Immediately following the earthquake, both upper and lower 50-foot spans atop Pier E-9 were replaced; these were the only elements to collapse during the quake. Significant interim strengthening has been undertaken since then, including replacement of the collapsed girders and slabs at E9, and strengthening the reinforced concrete piers east of E9. Major underpinning of the abutment area consisting of replacing columns and footings with new units that are stronger and more ductile, has also been done.

Major changes were made to the Oakland and San Francisco approaches in the late 1980s and early 1990s to accommodate changes to connecting freeways that were damaged in the earthquake. On the Oakland side, the I-880 freeway, called the Cypress Structure near the approach to the bridge, was rebuilt on a different alignment, requiring an entirely new set of connectors. In San Francisco, the Embarcadero Freeway was demolished following the earthquake, requiring a new set of approaches to compensate for the loss of that direct freeway connection.

1.11. Proposed Work

San Francisco Approach

The San Francisco Approach is slated to be removed and replaced as part of the current seismic upgrade project for the Bay Bridge. An interim safety retrofit has been built, however, consisting of tension ties along the concrete cross beams framing the upper deck, providing a more secure anchorage of the beams to the columns.

The West span

The seismic strengthening of the West Bay Crossing currently being engineered and built is proposed to consist principally of 1) strengthening the towers with new steel plates, 2) adding new lateral bracing to the upper plane of the trusses, 3) strengthening the truss cross section against sway with new cover plates, 4) strengthening selected truss members to provide more axial and bending load capacity, 5) strengthening anchorages and foundations, strengthening the reinforced concrete Pier W-1, and perhaps adding center-span cable-to-truss ties at midspan of the 2310"spans.

Yerba Buena Island

The seismic strengthening of the Island Crossing that is currently being designed and built will evidently consist of 1) strengthening the tunnel components against the increased seismic earth pressures, 2) strengthening the reinforced concrete framing east of the West Bay Crossing anchorage, and 3) strengthening the viaduct east of the tunnel portal. The steel truss spans will be removed as part of the East Bay Crossing replacement. The tunnel wall strengthening will consist of adding an inner shell of modern construction to increase strength and ductility, and may cover the original tile in the tunnel. The framing strengthening will utilize steel shells on the columns and additional concrete and reinforcement of beams and girders. There is some possibility that part of the Island Crossing's East Viaduct will also be removed to allow realignment associated with the East Bay Crossing replacement.

The East Span

The East Bay Crossing is slated to be removed and replaced as part of the current seismic upgrade project for the Bay Bridge. An interim seismic strengthening, described above, has performed to reduce risk of seismic damage while the replacement bridge is designed and built.

2. PATTERNS OF BAY AREA TRANSPORTATION LEADING TO CONSTRUCTION OF THE BAY BRIDGE

However significant it may be in the history of bridge engineering and in other respects, the Bay Bridge is first and foremost a transportation structure. In its most elemental form, the bridge provides a surface transportation link between Oakland and San Francisco. While it would make a major contribution to the field of bridge engineering and forever change the patterns of community development in the Bay Area, the bridge was conceived and built as a link in the transportation network of the area. Changes in transportation, of course, are not divorced from changes to the society and economy of the region. Indeed, transportation developments, particularly in California, have profoundly affected all aspects of economic and social history. If the Bay Bridge changed the course of history in the Bay Area, however, it did so as a transportation structure.

When it was built, the bridge was but one link, albeit an immensely important one, in a complex network of transportation facilities – navigational facilities, railroad lines, mass transit lines, ferries, and highways.[1] Seemingly, the Bay Bridge had little to do with any of these transportation modes except the automobiles, trucks, buses, and trolleys it was designed to accommodate. It was such a huge and useful structure, however, that it revolutionized the entire transportation system of the region, affecting the network and not merely discrete elements of it.

To appreciate the long-range significance of this bridge, we must understand the system that existed before it was built. What was the transportation problem the bridge was intended to solve, and to what extent was that problem solved? To answer these questions, the context – the situation that existed in the Bay Area at the time the bridge was designed and built – must be examined.

2.1. Status of Navigation in the Bay Area Prior to Construction of Bay Bridge

Like most American frontier cities, San Francisco was settled initially by sea and only later was linked to the rest of California by effective ground transportation modes. As Kevin Starr observes: "No American city is more fortunately, or more unfortunately, sited than San Francisco, surrounded by water on three sides. San Francisco stands in splendid isolation, a virtual island off the coast."[2] The East Bay cities were also settled initially through port developments but were much more quickly provided with ground transportation links. The differential rate of establishing ground links, of course, can be accounted for by the geographical facts of the Bay Area: San Francisco is situated at the tip of a long peninsula and is physically

[1] Air travel was a sixth element of transportation in the Bay Area, and received a great deal of discussion during the decade of the 1920s. Airport development was so primitive in 1932, however, as to warrant no discussion in the present context. Buses would also grow in importance to the transportation system of the area, but not until after the Bay Bridge had been completed.

[2] Kevin Starr, *Endangered Dreams: The Great Depression in California* (New York: Oxford University Press, 1996), 324.

linked only to that peninsula. Oakland and the other East Bay cities are connected to the California mainland, although San Pablo and Suisun Bays – both part of the same estuary as San Francisco Bay – were also impediments to an easy flow of ground transportation to the Central Valley and other parts of California.

Navigation in the Bay Area prior to construction of the Bay Bridge may be seen as comprising two basic categories: ocean-going navigation and intra-Bay ferry service. San Francisco dominated ocean-going navigation in the Bay Area from the Gold Rush through the 1950s. Indeed, the dominance of the port of San Francisco did not end until the emergence of containerized cargo handling in the early 1960s, which required vast port acreage that was simply unavailable in San Francisco. This revolutionary development was unforeseeable in 1930 and, of course, played no part in the planning for the Bay Bridge. The Bay Bridge was designed with the expectation that the handling of transoceanic cargo would long remain an important part of the economy of the City and County of San Francisco.

Nonetheless, the dominance of San Francisco was already eroding by 1930, attributable chiefly to the aggressive and successful campaign of the City of Oakland to develop its port into a major contender for cargo handling.[3] Hampered for years by uncertain ownership, the Oakland waterfront developed slowly throughout the 19th century. An 1892 U.S. Supreme Court ruling confirmed ownership of most of the waterfront to Oakland and opened the door for aggressive development by the city and in conjunction with construction of major railroad links to the port area. Aided greatly through harbor improvements by the U. S. Army Corps of Engineers, the Oakland harbor gained increasing business in the years just before and after American involvement in World War I.[4] In 1927, the city created an independent Port Department (now the Board of Port Commissioners) and the modern Port of Oakland was created. During the decade between 1921 and 1931, both Oakland and San Francisco experienced explosive growth in commercial shipping, although the pace of activity subsided between 1929 and 1931 due to general declines in the American economy. The growth in shipping tonnage, however, was clearly in Oakland's favor. Until the Port of Oakland was organized, shipping tonnage in San Francisco was more than double that in Oakland. By 1931, the difference was much less; Oakland handled about three-quarters the tonnage of San Francisco.[5] The trend would continue through World War II, until the Port of Oakland surpassed and ultimately overwhelmed San Francisco in the post-war era. East Bay leaders were no doubt keenly aware of these trends and fought hard to preserve shipping channels on both sides of the bridge.

A second important element of shipping in the Bay Area was the perceived importance of the area to the military. At the time the Bay Bridge was first seriously considered in the early 1920s,

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[3] The history of the Port of Oakland is detailed in a special 1977 edition of *Portprogress*, a journal of the Port, entitled "125 Years of Oakland Waterfront Growth, as Compiled on the 50th Anniversary of the Oakland Board of Port Commissioners, 1927-1977."

[4] The Corps program is detailed in Joseph Hagwood, *Engineers at the Golden Gate: A History of the San Francisco District, U.S. Army Corps of Engineers, 1866-1980* (San Francisco: Corps of Engineers, 1980).

[5] Hagwood, *Engineers at the Golden Gate,* 151.

the American military establishment, particularly the Navy, was developing plans for multiple new facilities in the Bay Area. Although it is one of the great American harbors, San Francisco Bay was not home to a substantial naval presence until the years just before World War II. Faced with an urgent need for a West Coast ship repair station in the late 1840s, the Navy had selected the easily defended but shallow Mare Island Strait as home for its first major Navy station. The inadequacies of the shallow Napa River-based shipyard, however, would become painfully evident during the early 20th century, as major battleships came to dominate the capital fleet. When the Great White Fleet stopped in San Francisco Bay for repairs, for example, none of the ships could be taken to Mare Island; work on those ships could be accomplished only at the privately owned shipyard at Hunters Point in the southern part of San Francisco.[6] Between 1900 and the late 1930s, the Navy made clear its intent to establish new facilities in California, leading various California cities to vie with one another to secure some or all of the expansion of naval facilities.[7] The Navy built a relatively minor training station on Yerba Buena Island in 1900 but had abandoned it in favor of a San Diego site in 1923. Indeed, the abandonment of this island-based training station was a crucial factor in determining changes in the alignment of the Bay Bridge between early planning in 1921 and selection of a preferred alignment in 1930. The Bay Bridge was ultimately built on piers at the edges of the parade ground of the old training station, a location that would have been unthinkable, had not the Navy moved the station to San Diego a decade before bridge construction began.[8]

Ultimately, the Navy moved most of its California stations to San Diego. In 1930, however, it was not clear whether San Diego, Los Angeles, or the San Francisco Bay Area would be selected as a locale for that expansion. The Navy, for its part, was content to let competition go forward as the various cities promised more and better local concessions to attract Navy construction. The concentrated period of planning for the Bay Bridge – 1921 to 1930 – coincided with the most intense negotiations between the Navy and the various California cities. In the Bay Area, San Francisco, Oakland, and Alameda were actively involved in what was essentially a bidding war. All would ultimately be fitted with major Navy facilities during the late 1930s – San Francisco with Hunters Point Shipyard and the training station at Treasure Island; Oakland with a Naval Supply Depot, and Alameda with a Naval Air Station. Of note, all of those stations, however, were built *after* the Bay Bridge had been completed.

The uncertainty about where the Navy would build was of great importance in considering whether or how to build a Bay Bridge because the bridge, if not properly planned, could interfere

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[6] For more information about the private and later the Navy shipyard at Hunters Point, see: JRP Historical Consulting Services, "Historic Context and Inventory and Evaluation of Buildings and Structures, Hunters Point Shipyard, San Francisco, California," September 1997.

[7] The inter-city competition for military bases is a major subject of Roger W. Lotchin, *Fortress California: From Warfare to Welfare, 1910-1960*. (New York: Oxford University Press, 1992).

[8] One of the existing historical overviews of Yerba Buena Island is: JRP Historical Consulting Services, "Cultural Resource Inventory and Evaluation Investigations: Yerba Buena Island and Treasure Island, Naval Station Treasure Island, San Francisco, California," March 1997. In this report, this island will be called Yerba Buena, even though it was commonly called Goat Island over much of the 1920-1940 period, and is so identified in historical documents cited in this report.

with both the shipping channels for great naval vessels as well as the proposed land sites for those stations. The Navy objected to the Bay Bridge during most of the period 1921-1930, chiefly on the basis of the need to protect both the navigational channels and the land sites for potential stations. The Navy's objections, coupled with the Army's mission to protect all shipping channels – commercial as well as military – were the principal factors that prolonged the design and construction schedule by more than a decade.

A second and more important element of navigation, at least in terms of bridge design, was the emergence of passenger and vehicular ferry services as links in the Bay Area transportation network. Passenger-only ferries were essentially adjuncts to the interurban train service, carrying transit users from a rail line on one side of the Bay to the beginning of the rail line on the other; generally, this commute movement was from the East Bay to San Francisco. Vehicular ferries were links in an entirely different commute pattern and served as adjuncts to the highway system. Vehicular ferries carried vehicles and their passengers from the end of the roadway on one side of the Bay to the beginning of the road on the other; again, this commute traffic moved generally from the East Bay to San Francisco.

As part of its 1929-30 traffic studies for the Bay Bridge, the State of California researched trends in passenger and vehicular ferry usage. Both were of great consequence to the financial viability of the proposed bridge because it was assumed that the bridge would reduce if not eliminate ferry services and that the foregone vehicular ferry fees would form the principal basis for bridge tolls. The State assumed it could capture some part of the money paid by users of passenger ferries in fees on interurban lines using the new bridge. In short, the transfer of ferry fees to bridge tolls was seen as the primary source of revenue for construction costs of the bridge.

The raw numbers and trends in ferry service, as might be expected paralleled the trends in interurban and automobile use in the Bay Area. Between 1915 and 1929, there was a decline of about 10 percent in passengers using ferries from interurban connections, from 38.75 million in 1915 to 35.92 million in 1929. Interurban-connected ferry use peaked in 1925 at 41.28 million per year, reflecting a decline of more than 12 percent over the next four years. By contrast, the trend in vehicular ferry service was a dramatic increase, although the raw numbers were much smaller than for the passenger ferries. In 1915, 1.75 millions passengers had traveled with their vehicles across the Bay; by 1929, that number was 10.17 million, an increase of about six-fold.[9]

The growth in the use of vehicular ferries may be attributed to a large degree to the general increases in automobile registration and use in the Bay Area during the 1920s. That growth may be explained more specifically, however, by the improved levels of service provided by the ferry operators, particularly the Golden Gate Ferries line. Before World War I, passenger ferries had carried automobiles across the Bay only as space was available. It was not until 1920 that a line, Golden Gate Ferries, was organized specifically to handle automobiles. The line, headed by Aven Hanford, initially served the Sausalito to San Francisco commute but quickly branched out

[9] Hoover-Young San Francisco Bay Bridge Commission, "Report to the President of the United States and the Governor of the State of California," August 1930, 71 (hereafter, cited as Hoover-Young Commission).

to serve the East Bay as well. Particularly successful was a run from Berkeley to the Hyde Street Pier in San Francisco. Ferry service at the Berkeley Pier, for example, was initiated in 1926; by 1929, 1.12 million people used that service annually. In 1928, Golden Gate Ferries extended service from Point Richmond to the Ferry Building.[10]

The Southern Pacific Railroad was involved in the automobile ferry service as well, on its own and through its Northwestern Pacific Railroad subsidiary, which served Marin County. The Southern Pacific joined forces with the Golden Gate Ferries in 1929, creating the Southern Pacific Golden Gate Ferries, Ltd., which had a near monopoly over the automobile ferry traffic. By 1930, then, the Southern Pacific Railroad was the principal carrier of automobiles across the Bay, competing to no small extent with its own interurban passenger service across the Bay.[11]

While the Bay Bridge had no specific navigational function, navigational issues would dominate debate about the bridge. Most discussions focused on the need to maintain free access to the emerging Port of Oakland, as well as the potential of the bridge to eliminate the costly and slow vehicular and passenger ferry services. The need to preserve shipping lanes to Oakland led to some of the most dramatic engineering problems in designing the bridge.

The single most dramatic and direct impact of building the Bay Bridge was the decline of ferry service between the East Bay and San Francisco. This large and profitable enterprise was decimated once the Bay Bridge was built. Ferry service would soon disappear almost completely on the San Francisco Bay, not to be revived for more than half a century.

2.2. Status of Railroad Freight Lines and Through Passenger Lines Prior to Construction of Bay Bridge

The through railroads represented the first useful ground transportation link between the various parts of the Bay Area, as well as the first workable link between the Bay Area and the rest of California and the nation. This network was first assembled in the late 1860s but grew increasingly sophisticated and interconnected throughout the 19th and early 20th centuries. By the time the Bay Bridge was authorized, the regional and national rail network had reached its apogee; never before or since has the area been served so well by major freight lines.
The Central/Southern Pacific Railroad dominated the railroad network of the Bay Area, as it did throughout California. By the early 1930s, however, the Southern Pacific's stranglehold on California rail service had begun to fall apart. The Southern Pacific itself had been profoundly transformed during the early decades of the century, during the so-called "Harriman era," in which the line was controlled by E. H. Harriman and operated in close conjunction with the

[10] George H. Harlan and Clement Fisher, Jr., *Of Walking Beams and Paddle Wheels: A Chronology of San Francisco Bay Ferryboats* (San Francisco: Bay Books Limited, 1951); George H. Harlan, *San Francisco Bay Ferryboats* (Berkeley: Howell-North Books, 1967).

[11] The passenger and automobile system of the Southern Pacific Railroad is detailed in Southern Pacific Bulletin, *Bay Memories*, 1938. This is a nostalgic look at the ferry system at the time it was folding, reprinted from articles in the Southern Pacific Bulletin.

Union Pacific. In addition, competition in through-rail traffic came with the arrival of the Atchison, Topeka and Santa Fe, which built its line into Richmond in the 1890s and the Western Pacific Railroad, which built into Oakland in the years just before World War I.

The essential rail network, then, was in place long before the Bay Bridge was built but the situation was not static. Two trends highlighted the activities of the established rail lines in the years just before the Bay Bridge was built. First, all three of the major lines, particularly the Southern Pacific, continued to invest in greater efficiencies in the rail network of the Bay Area. The Southern Pacific was the first entity to bridge San Francisco Bay when in 1910 it built a long trestle and swing-span bridge between Dumbarton Point in Alameda County and Redwood City in San Mateo County.[12] The railroad Dumbarton Bridge would point the way for the first highway bridge across the Bay, the privately financed Dumbarton Bridge, which was built in 1927. The Southern Pacific built a far more important structural link in 1930 when it completed the Martinez Bridge between Benicia and Martinez.[13]

Second, during the 1920s the Southern Pacific had begun to expand its non-railroad transportation systems. Through its interurban lines, passenger ferry service, and automobile ferries, the Southern Pacific had built itself into a key link in the integrated transportation network of the area by 1930. The proposed Bay Bridge would have dramatic and in part very negative impacts for the Southern Pacific Railroad, affecting both its interurban lines and its ferry service, in a manner that planners for the bridge anticipated would be catastrophic.

Perhaps the most interesting aspect of planning for the Bay Bridge is that plans almost never considered providing capacity for through rail traffic. If there were a weak link in the railroad network of the Bay Area, it was the absence of a direct connection between the two major economic and population centers, Oakland and San Francisco. In the earliest serious considerations of the Bay Bridge during the 1920s, proponents assumed that the structure would include a through railroad link, along with automobile, truck, and interurban facilities. This idea, however, was abandoned by 1927, chiefly because the addition of heavy freight would have posed almost insurmountable engineering problems for an already difficult bridge, not the least of which was the need to maintain grades that would have interfered with navigation.[14] By 1930, the rail network had matured to a point in which this direct connection was not a pressing need. Oakland and San Francisco were already linked, albeit circuitously, via the Dumbarton Bridge and through connections in the South Bay. The rail system, despite some imperfections, was sufficiently mature in 1930 that no party, not even the Southern Pacific, showed any real interest in using the Bay Bridge for a direct link between San Francisco and the East Bay.

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[12] Bernard C. Winn, *California's Drawbridges, 1853-1995: The Links to California's Maritime Past* (San Francisco: Incline Press, 1995), 37.

[13] John W. Snyder, "The Southern Pacific Builds a Bridge... The Saga of the Martinez Bridge," *Railroad History*, Bulletin 161 (Winter 1989).

[14] A proposal for including heavy rails on a vehicular bridge would re-surface in the 1950s as part of the so-called Southern Crossing bridge at the southern ends of Oakland and San Francisco.

2.3. Status of Interurban Rail Service, Prior to Construction of Bay Bridge

As with freight and through passenger rail service, the so-called interurban lines -- commuter rail lines -- were at the peak of their development by the time the Bay Bridge was authorized. Never before or since has mass transit enjoyed such intensive coverage, especially in Alameda and San Francisco counties. Mass transit suffered a tremendous decline after the Bay Bridge was constructed, only to be revived during the 1970s through construction of the Bay Area Rapid Transit (BART) system and revitalization of bus transit.

Mass transit in San Francisco and the East Bay followed much different paths of development. The street railway system of San Francisco developed almost exclusively to serve that city; rarely were the San Francisco trolleys and cable cars used to commute beyond San Francisco itself.[15] By 1930, most of the mass transit network in San Francisco was municipally owned; only the Market Street Railway was privately owned. Ridership on the San Francisco railways, whether publicly- or privately held, peaked during the mid-1920s but declined rapidly during the remainder of that decade.

East Bay interurbans, by contrast, were privately owned at the time the Bay Bridge was built and existed primarily to move workers from the East Bay suburbs to their jobs in San Francisco. The interurban systems had always operated in conjunction with privately owned ferry lines, with each transit company owning its own ferries. In this sense, it is a somewhat artificial distinction between the navigational aspects of the ferry lines and the mass transit aspects of the interurbans; the two were simply different transportation modes within an integrated network.

The concept of an integrated rail-ferry service began with the Central (Southern) Pacific Railroad in the 19th century. The Southern Pacific had provided some type of passenger rail service in the East Bay since the 1860s and began integrated interurban and ferry service from the Oakland Mole in the 1880s. Its system was electrified in 1911, and provided passenger interurban-ferry connections via the Oakland Mole as well as a mole on Alameda island. At the time of its electrification, the Southern Pacific's interurban lines from the Oakland Mole included two Oakland lines, two Berkeley lines and a San Leandro line; there were two lines in Alameda leading to the Alameda Mole.[16]

Although the Southern Pacific was first to provide service, the Key System dominated the East Bay interurban market by 1930. Francis Marion Smith, the founder of the Key System, built his system around lines that fed into his deep water harbor near the Port of Oakland, allowing one to continue the journey to San Francisco by ferry.[17] Smith and his successors assembled the Key System from existing small steam lines as well as through new construction. Most of the system

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[15] The history of the San Francisco railways is discussed in Chapter II of Seymour Adler's *The Political Economy of Transit in the San Francisco Bay Area* (Berkeley: Institute of Urban and Regional Development, 1980).

[16] Paul C. Trimble, *Interurban Railways of the Bay Area* (Fresno: Valley Publishers, 1977), 10.

[17] Harry W. Demoro, *The Key Route: Transbay Commuting by Train and Ferry* (Glendale, CA: Interurban Press, 1985).

had been electrified by the turn of the century. Like the Southern Pacific, the Key System owned its own ferry service, which was served by its grand Key System Mole, a bermed jetty that extended into the Bay at a juncture of the Key System rail lines, at the Oakland-Emeryville city limits. The Mole, assembled in the early decades of the 20th century, established a highly efficient inter-modal connection, with adequate trackage and several good ferry piers, from which the passengers could conveniently transfer from rail lines to the ferries for the short (about 2.7 miles) ride to San Francisco. By the late 1920s, there were eight major Key System lines in the East Bay, extending to Piedmont, Claremont, Berkeley, and various parts of Oakland. The system also included light streetcar service, which fed into the heavier interurban lines.

The Key System had been established by Smith with an eye toward real estate development as well as transit service and he and his associates subdivided areas served by the new lines. The real estate business ultimately proved more profitable than the transit system. In 1927, Smith and his partners declared bankruptcy for the Key System but maintained their real estate work. San Francisco banking interests, led by Alfred J. Lundberg, reorganized the Key System and restored interurban service on a somewhat scaled-back basis.[18]

The popularity of the interurban commute and associated real estate development had encouraged a settlement pattern that, somewhat ironically, was used to justify the need for a predominantly highway bridge. The interurbans had facilitated population growth in the East Bay along predictable lines, a pattern of settlement densities that sustained commuter ridership on the lines. In time, the impressive ridership of the interurbans would be used as a basis to justify construction of the bridge; the fact that tens of thousands of commuters were willing to pay substantial fares for a relatively slow commute via train and ferry was used by bridge proponents to argue the economic viability of a predominantly vehicular bridge, which would be faster and cheaper than the system already being used.

All preliminary plans for the Bay Bridge, whether those of private developers, the City and County of San Francisco, or the State of California, used interurban traffic as a means of gauging potential revenues for the proposed bridge, as well as a way of deciding where the bridge should be located. The state-federal Hoover-Young Commission, studying the issue in 1929 and 1930, compiled an exhaustive traffic study on transbay travel, as developed by its consultant, Lester S. Ready of San Francisco.[19] This study, in turn, relied heavily upon earlier studies, as developed by the consultants to the City of San Francisco. Together, these studies documented interurban and ferry service between 1915 and 1929, while providing projections through 1940.

The studies portrayed an interurban-ferry traffic that was vigorous and substantial but somewhat in peril. The data showed that traffic was extraordinarily high in 1915, a figure skewed by the World's Fair of that year in San Francisco, decreasing dramatically in 1916 but rising steadily between 1916 and 1925. Between 1925 and 1929, however, the transbay mass transit ridership declined steadily on all lines: the Key System, the Southern Pacific Oakland pier lines, and the

[18] Adler, *Political Economy of Transit*, 58.

[19] Hoover Young Commission, Part C, "Traffic Survey," July 19, 1930.

Southern Pacific Alameda lines.[20]

The traffic on both the interurban-related and vehicular ferries was overwhelmingly that of commuters who lived in the East Bay but worked in San Francisco. As part of his traffic analysis, Ready conducted original research on the origin and destination for thousands of people who took the ferries from San Francisco to the East Bay. Ready passed out cards to more than 24,000 interurban passengers and more than 10,000 users of vehicle ferries, to determine where they worked and where they lived. The origin and destinations were broken into 98 "zones", with 49 being San Francisco addresses and the other 49 East Bay locations. The cards were handed out to ferry users leaving San Francisco between 4:00 and 6:00 PM, geared toward obtaining data regarding commuters to San Francisco as they were heading home from work.

The results of Ready's survey, combined with his use of aggregate statistics, showed several clear patterns regarding the commute from the East Bay to San Francisco. First, far more people were commuting by interurban and ferry than were commuting by automobile and ferry -- 35.9 million by interurban versus 10.2 million via the vehicular ferries. Second, there was an unmistakable shift from interurban to automobile commuting -- a six-fold increase in vehicular ferry service versus a 10 percent decline in the interurban ferries. Third, the San Francisco and East Bay origins and destinations reflected typical commuter patterns, with the San Francisco destinations clustered in a few areas in the downtown, while the East Bay origins were scattered throughout many communities, principally Oakland, Berkeley, and Alameda. Fourth, none of the commuters, whether by interurban or automobile, were traveling very far. Commuters living south of the Oakland city limits or north of Berkeley accounted for tiny proportions of the total. Fifth, the automobile commuters were generally traveling a little further than the interurban commuters. Finally, as might be expected, the interurban commuters came from communities in which access to interurban lines were most convenient, while automobile commuters came from communities that were well served by the Golden Gate Ferries.

Unfortunately, the fact that Ready used 49 zones in the East Bay makes it somewhat difficult to summarize about communities because the areas are generally so small. Some zones, for example, had fewer than 10 commuters. The general patterns for interurban and automobile commuting may be detected by focusing on the 10 zones that produced the largest number of commuters. These are shown below:

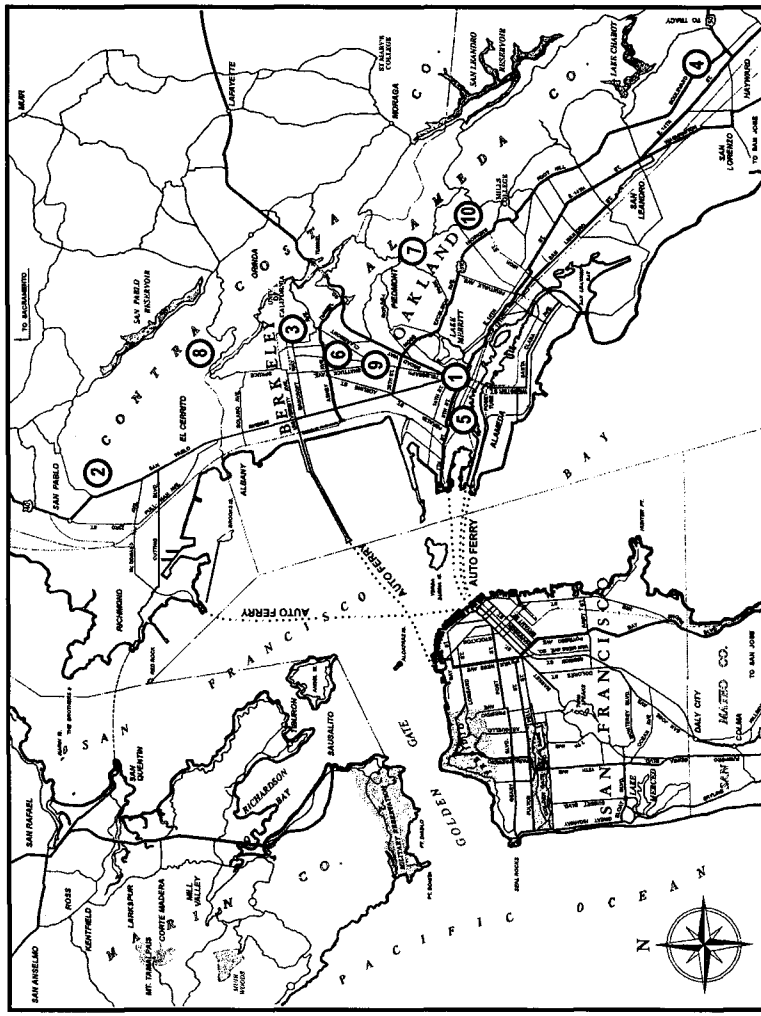
[20] Hoover-Young Commission, Table 10.

AUTOMOBILE COMMUTERS, BY TEN MOST POPULAR EAST BAY ZONES

Rank	Location	Number (percent)
1	Oakland, Market St. east to Lake Merritt	2565 (24.36)
2	Richmond, north of McDonald Avenue	1006 (9.55)
3	Berkeley, south of University and east of Grove	846 (8.04)
4	All points south of Oakland	696 (6.61)
5	West Oakland (west of 7th)	613 (5.87)
6	Berkeley south of Ashby and east of Grove	304 (2.89)
7	Oakland Hills north	297 (2.82)
8	Berkeley Hills	267 (2.54)
9	North Oakland	262 (2.49)
10	Oakland Hills south	240 (2.28)

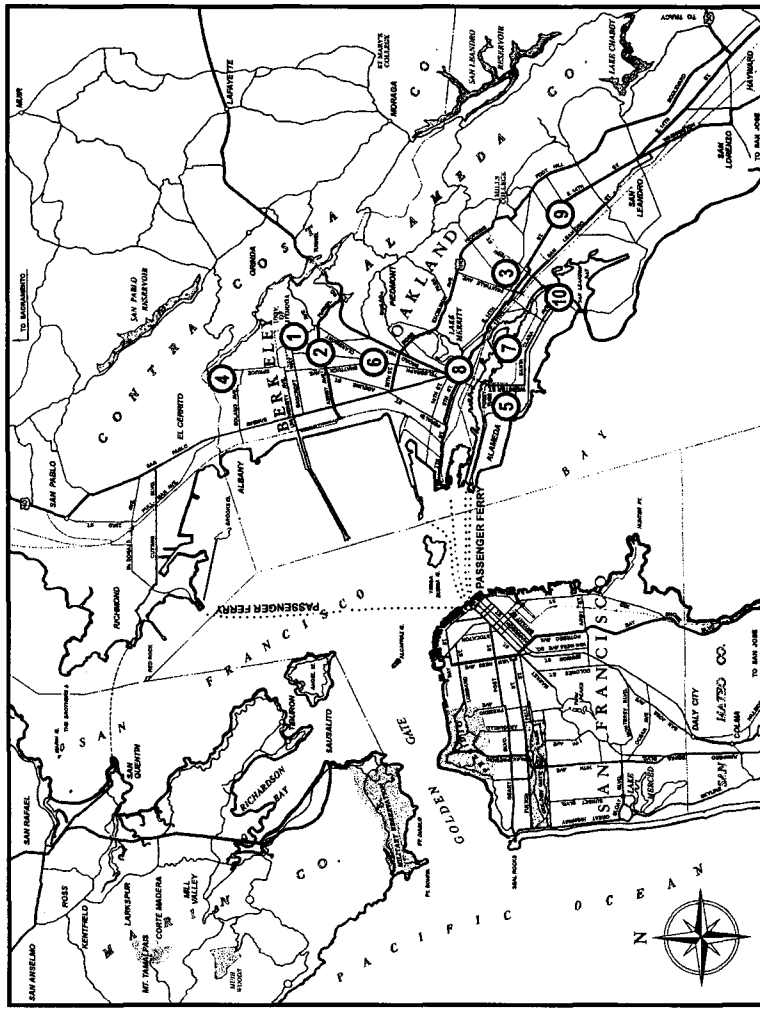
PASSENGER SERVICE COMMUTERS, BY MOST POPULAR EAST BAY ZONES

Rank	Location	Number (percent)
1	Berkeley, south of University and east of Grove	2750 (11.24)
2	Berkeley, south of Ashby and east of Grove	2189 (8.95)
3	South Oakland (by High Street)	1487 (6.08)
4	Berkeley Hills north	1447 (5.91)
5	North Alameda	1279 (5.23)
6	North Oakland	1290 (5.23)
7	Central Alameda	1194 (4.88)
8	Oakland, Market Street east to Lake Merritt	1139 (4.65)
9	South Oakland (by 73rd Avenue)	1108 (4.53)
10	South Alameda	1061 (4.34)



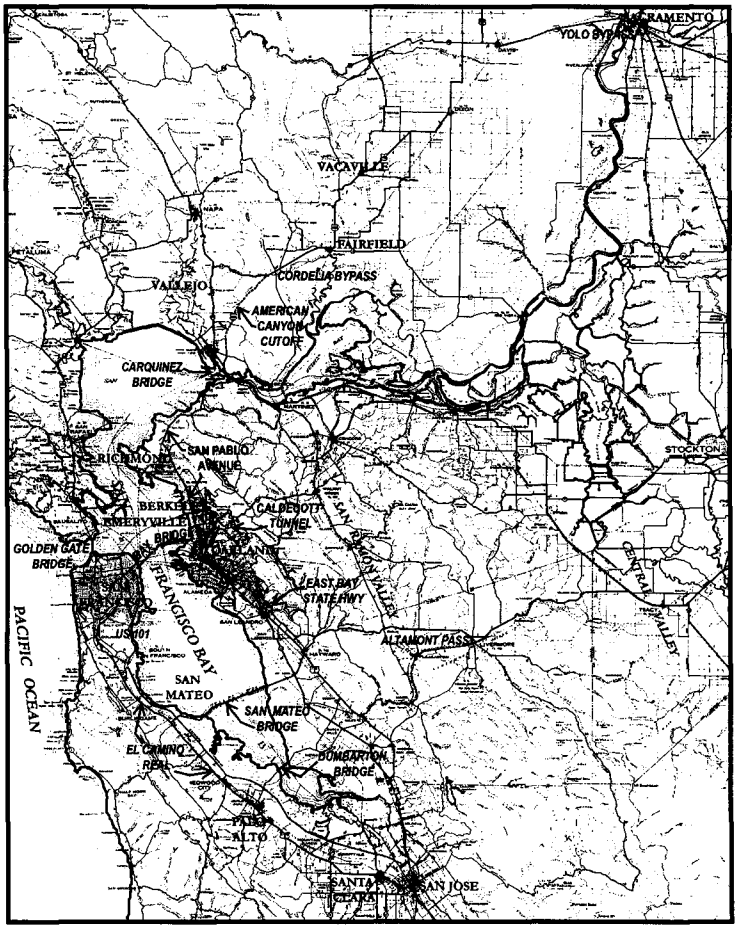
Map of East Bay Vehicular Traffic Zones

ource: Report of The Hoover-Young San Francisco Bay Bridge Commission, 1930
ocation: Bancroft Library University of California, Berkeley



Source: Report of The Hoover-Young San Francisco Bay Bridge Commission, 1930
Location: Bancroft Library University of California, Berkeley

Map of East Bay Passenger Ferry Zones



Source: Automobile Club Roadmap, 1935.
Location: Bancroft Library University of California, Berkeley

Major Transportation Improvements in the Bay Area, 1920-1930

The differences between automobile and interurban points of origin generally follow logical patterns. Areas such as Alameda that were well served with interurban trains and ferries had high representation in that category. Distant areas like Richmond that had good vehicular ferry service but no interurban service were over-represented in that category. The results of a few zones, however, are surprising. One zone in Oakland, for example, covered an area from Market Street east to Lake Merritt, an area well served by the interurbans. Yet it accounted for almost a quarter of the automobile commuters and less than five percent of interurban commuters.

Although the decline in interurban use, 1920-1930, was used as a basis for improving services, the consistently high ridership was also used as a basis for justifying the expense of the bridge and for locating it in roughly the alignment of the ferry service. While many argued for a Southern Crossing, connecting Hunters Point in San Francisco and Bay Farm Island in Alameda, traffic engineers argued that a Southern Crossing was economically infeasible chiefly because it could not serve the same traffic patterns served by the interurbans.

At the same time that interurban-ferry traffic was strong but declining, vehicle-ferry traffic was relatively weak but rising. The Bay Bridge on an alignment parallel to the interurban-ferry service was seen as the best of all solutions: serving the settlement patterns developed to a large extent by the interurbans, serving the trolley lines themselves and speeding the trip into the city, while serving the growing and increasingly important vehicular traffic between the East Bay and San Francisco. At the same time, tapping into the huge interurban-ferry demand was seen as indispensable in paying for the bridge.

As an immediate consequence, the Bay Bridge put an almost instantaneous end to the transbay ferry service. In time, it would also contribute to the demise of the interurbans. There is little indication that this end was a goal of bridge planners or that the demise of the interurban service was foreseen. Indeed, trolleys were seen as major revenue generators for the new bridge and were fitted with dedicated lanes on the structure as well as separate approaches and a terminal on the San Francisco side. The addition of the interurbans greatly increased the cost of the bridge, owing to the heavier loading for train traffic. Simply stated, the Bay Bridge was designed to accommodate both interurban and vehicular traffic; joint use was literally built into the structure. The Bay Bridge was seen as a superior solution to the problem of joining interurban lines on the two sides of the Bay, superior to the ferry system. The Bay represented a gap in the interurban system of the Bay Area and the Bay Bridge was designed as a link across that gap.

Nonetheless, the planners of the Bay Bridge were aware of the dynamics in traffic that might result from an improvement as monumental as the Bay Bridge. The Hoover-Young traffic studies in 1929 and 1930 hinted that construction of the bridge might "deflect" some passenger traffic from the interurbans to automobile use. The reasons were simple: the Bay Bridge would cut 30 minutes from the commute of an automobile crossing of the Bay but only 10 minutes from the commute of an interurban passenger.[21] The financial projections for toll revenues assumed a modest figure – 10 percent reduction of interurban use – resulting from "deflection" from trains

[21] Hoover-Young Commission, "Report to the President."

to automobiles.

If there was one fundamental error in the planning for the Bay Bridge, it was in the underestimation of the vehicular use of the bridge and overestimation of interurban use. Much of the great increase in vehicular use may be attributed to factors unforeseen at the time, particularly the coming of World War II five years after the bridge was completed and the continued population growth after the war. The increase may also be attributed, however, to a much higher rate of "deflection" from the trains to automobiles; the interurban ridership was decimated after the end of World War II and the private companies began filing for permission to abandon the line shortly after the end of the war.

2.4. Status of Highway Development in the Bay Area, Prior to Construction of Bay Bridge

Of the major modes of transportation, highways were least developed at the time the Bay Bridge was authorized. The highway system of the Bay Area and California generally would be revolutionized in the post-World War II era, when the number of highways and numbers of highway lanes increased dramatically. By comparison with the level of development in navigation and freight and interurban rail lines, the highway system in the Bay Area was still in its infancy in 1930.

Nonetheless, the highway network of the Bay Area had matured greatly since the early 1920s, owing chiefly to the construction of major state highways. The State Highway System ultimately dates to 1896, when the first road – an abandoned toll road between Placerville and Lake Tahoe – was taken over by the state.[22] The institutional arrangements for state highway construction and maintenance evolved slowly over the following decades. In 1907, the California legislature created the Department of Engineering, enabling it to build new highways on the basis of annual appropriations by the legislature. A major step forward was passage of a bond measure in 1909, giving the Division of Engineering a more secure source of funding for highway work. Even better funding was provided by vehicle registration fees, which were initiated in 1914. Additional bond measures were passed in 1916 and 1919. The most significant step in securing dependable funds for highway construction came in 1923, when the state for the first time enacted a gasoline tax, earmarking half of all funds for state highway construction, with the other half reserved for local roads. [23] The gasoline tax was increased by 50% in 1927, with all of the increase dedicated to state highway construction. The 1923 and 1927 gasoline taxes ushered in one of the most prodigious periods of highway construction in California history, rivaling the early freeway construction era of the 1950s. The tax revenues reserved for state highway construction brought in funds at a rate that was sufficient to finance highway construction in all

[22] Raymond Forsyth and Joseph Hagwood, *One Hundred Years of Progress: A Photographic Essay on the Development of the California Transportation System* (Sacramento: California Transportation Foundation), 1998.

[23] A succinct summary of highway financing is provided in C. V. Pavetti's "History of Highway Financing and Allocation Process in California," Highway Planning and Research Branch, California Department of Transportation, 1983.

parts of the state. Federal aid for highway construction, initiated in 1916, also grew at an accelerated rate during the 1920s.

The growth in highway construction in California during the 1920s was much higher than the national average, as was automobile registration and use, but the state was not alone in this regard. Historians have credited a range of automobile-related developments, from highway construction to suburban housing tracts, for fueling the prosperity of that decade. As Thomas Cochran has observed: "No one has or perhaps can reliably estimate the vast size of capital invested in reshaping society to fit the automobile.... This total capital investment was probably the major factor in the boom of the 1920s, and hence in the glorification of American business."[24]

The Bay Area, the most densely settled region of California in 1920, garnered a substantial proportion of state highway construction funds during this period. Virtually every modern highway in the Bay Area was either initiated or improved by the State of California during this period. The situation may be illustrated with reference to four of the most important roads in the area: U.S. 101 along the Peninsula, following the general route of the modern Bayshore Freeway; the East Bay state highway, essentially the alignment of the modern I-880; the road from Vallejo to Oakland, the equivalent of the modern I-80 corridor; and the road from the San Ramon Valley to Oakland, the equivalent of modern Route 24.

Until the 1920s, the main roadway from San Jose to San Francisco was the El Camino Real, roughly the alignment of the Spanish-Mexican link between the missions in Santa Clara and San Francisco. Not surprisingly, the State of California recognized the importance of the El Camino to the emerging state highway system. Contract No. 1, the first to be financed by the 1909 bond act, was on this route.[25] Many small Peninsula communities developed along the side of the El Camino Real and along the Southern Pacific's peninsula line, which closely paralleled the roadway. With rapid increases in automobile use during the 1920s, the old wagon road was inundated with traffic. By the late 1920s, the El Camino was the most heavily traveled roadway in the State Highway System.[26]

During that decade, civic and political leaders in the peninsula cities (led by San Francisco) pressed for a two-pronged solution to traffic congestion: widening the El Camino and building an entirely new highway alignment along the edge of the Bay to the east, an alignment that would be called the Bayshore Highway and which is essentially that of the modern Bayshore Freeway. The El Camino Real was widened as a stopgap measure, achieving its modern proportions during the 1920s.[27] The roadway was generally widened from 20' to 40' along most of its length, although in places it was widened to 50' in a 100' right of way.

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[24] Quoted in: James L. Flink, *The Car Culture*. (Cambridge: MIT Press, 1975), 141.

[25] Forsyth and Hagwood, One *Hundred Years of Progress*, 20-21.

[26] Col. John H. Skeggs, "The Modern El Camino Real" *California Highways and Public Works* (May 1930): 6.

[27] Skeggs, "The Modern El Camino Real," 6.

The more significant development, for relief of traffic congestion and as a milestone in highway design, was the construction of an entirely new roadway along the Bay. The character of this new highway was described by Col. John Skeggs, the District Engineer for the Division of Highways: "The answer to the imperious demands of the traffic was soon discovered by civic leaders and engineers of the city and state, and consisted of two parts: first, the widening and improvement of El Camino Real, which was undertaken forthwith; second: a new, broad highway from near the center of the city to San Jose, located as far east as practicable, of the existing highways and the towns strung like beads along it."[28] The Bayshore Highway was still under construction in 1930; 16 miles had been completed by 1929, from San Francisco to San Mateo. The roadway was a stunning achievement for the 1920s; as the District Engineer noted, "This work, in both instances [inside and south of San Francisco] involved construction of the heaviest character and on a scale never before undertaken by either the city or the state." The paved roadway was 100' wide inside a right of way that was generally 125'. This massive (at least in the context of the 1920s) paved surface was essentially a proto-freeway which could easily be adapted for freeway use a little later. The first segment of the Bayshore Highway would be upgraded to freeway status in 1947; it was the first freeway in the Bay Area.[29]

The Division of Highways undertook parallel developments in the East Bay, although construction there lagged behind that on the Peninsula. Col. Skeggs noted this parallel in observing that the state highway between Oakland and San Jose "has gradually assumed the importance to Oakland, San Jose, and east bay territory which the Peninsula Highway bears to San Francisco, San Jose and peninsula territory."[30] In 1915, the state highway was built to an 18-foot paved surface in a 24-foot right of way. Throughout the 1920s, the state rebuilt this roadway in sections, with each new segment being wider than the last. The first sections were widened to a 30-foot paved roadway. Sections built in 1928 included a 60-foot roadway inside a 100-foot right of way, as well as stretches of 40-foot roadway in a 100-foot right of way. While not as wide as the Bayshore Highway, the East Bay Highway was also a freeway in the making, a gigantic highway in the context of the times. The Eastshore Freeway, completed during the 1950s, would not, however, reuse much of the alignment of the East Bay Highway.[31]

This work on both sides of the Bay was underway at the time the Bay Bridge was approved. The District Engineer noted the relationship between these roads and the proposed bridge: "This section of highway [the East Bay Highway] holds a particularly important position with respect to east bay communities due to the excellently paved connections at many points leading to both the transbay bridges. Northbound travel is afforded quick access to San Francisco via the San Francisco Bay bridge and the Bayshore Highway. Southbound traffic enjoys equally good connections with the Dumbarton Bridge leading to Palo Alto and adjacent peninsula territory."

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[28] Col. John H. Skeggs, "The Bayshore Highway Dedication," *California Highways and Public Works* (November 1929): 9.

[29] B. W. Booker, "Freeways in District IV," *California Highways and Public Works* (March-April 1957): 1.

[30] Col. John H. Skeggs, "Important Progress on East Bay Highway," California *Highways and Public Works* (July-August 1930): 14.

[31] Booker, "Freeways in District IV," 1.

In addition, design work was completed during the 1920s on a northern extension of the East Bay Highway, bypassing much of the congested state highway along San Pablo Avenue through Berkeley, Emeryville, and parts of Oakland. Like the Bayshore highway on the Peninsula, this new road was to be built on an entirely new alignment, chiefly on Bay fill to the west of the natural shoreline. The East Bay Highway north of Emeryville was not completed by the time of the opening of the Bay Bridge. This fact was fortuitous in that it allowed Division of Highways planners to connect the new road to the bridge approach, in a complex, freeway-like interchange called the "Distribution Structure," which linked the new and old north-south highway, as well as east-west highways in Oakland to the bridge approach.[32]

The Vallejo to Oakland roadway, now a part of Interstate 80, was a minor road until the late 1920s, when construction of the Carquinez Bridge (as well as new roadway construction to the east, including the Yolo Bypass west of Sacramento) made this the preferred connector between the Bay Area and points east. The Carquinez Bridge revolutionized traffic patterns between Sacramento and the Bay Area. It was completed in 1927 by the American Toll Bridge Company, which was controlled by one of the founders of the Golden Gate Ferries company. The Carquinez Bridge ensured that transcontinental traffic, as well as more localized traffic from the Central Valley would be routed through Vallejo and the East Bay, as opposed to other alternative routes, such as the older alignment through the Altamont Pass.

The Carquinez Bridge was completed at about the time that debates over the Bay Bridge entered their most crucial stage. Although the structure itself could accommodate heavy traffic, the modern bridge was grafted onto a system of inadequate highways on both sides of the Carquinez Strait, particularly in Solano County. If the bridge builders were to fulfill their promises, those roadways would need to be improved. This work was underway in 1930 and would be completed just in time to feed traffic to the Bay Bridge. Like the Bayshore and East Bay highways, the new road between the Carquinez Bridge and Sacramento was conceived as an entirely new alignment, separated from historic roads as much as possible. As the District Engineer explained, "considerable thought was given to a direct road which would be away from the present road for almost its entire distance."[33]

By the time the Bay Bridge was built, however, the State had completed only selected portions of the planned improvements between Sacramento and Vallejo, bypassing the most onerous traffic jams. The Division of Highways completed the Cordelia Bypass in 1929. This was a 1.2 mile stretch of new road north of the old town of Cordelia. This bypass was soon extended east to Fairfield. In the early 1930s, two additional bypasses were built, including a long and expensive bypass of the City of Vacaville and an even more expensive "American Canyon Cut-Off,"

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[32] Earl Lee Kelly, "Main Highway Arterials Lead to Bay Crossing," *California Highways and Public Works* (November 1936): 20.

[33] R. E. Pierce, "American Canyon Cut-off Opened; Will Save Hour Between San Francisco and Capital," *California Highways and Public Works* (November 1936), 28. The connection between this road and the opening of the Bay Bridge is best indicated by the fact that this article on the American Canyon work appears in an issue of this Division of Highways publication that is otherwise dedicated to ceremonies celebrating the opening of the Bay Bridge.

designed essentially to bypass Vallejo. The Vallejo bypass included six miles of new road, which took "traffic off a considerable length of narrow, crooked streets in the city of Vallejo, and eliminates five grade crossings with railroads." Taken in conjunction with changes on the same alignment between the Carquinez Bridge and Oakland, these improvements were seen as shaving an hour from the driving time between Sacramento and the Oakland approach to the Bay Bridge, making it "an easy two-hour trip at the present speed limit between Sacramento and San Francisco." The Division of Highways saw these improvements to the Sacramento-San Francisco alignment as having more than local importance. "Of the three transcontinental highways converging at Salt Lake City—U.S. 30, 40, and 50 – two of them, U. S. 40 and 50, lead directly to the San Francisco-Oakland Bay Bridge," via the improved road through American Canyon.

The route from the San Ramon Valley to Oakland illustrates both the prodigious rate of highway construction during the decade before the Bay Bridge was built, as well as the uncertainties that existed with respect to how highway work should be financed. The mountain range that separates the East Bay and the San Ramon Valley forced traffic between these areas to travel dozens of miles through Richmond or the South Bay to reach Oakland. The situation improved somewhat in 1903, when Alameda County built the Broadway Tunnel, high on the hillside between the two areas. This 1040-foot, wooden-lined tunnel was useful for limited purposes but was essentially unusable for truck traffic and too difficult and slow for automobile commute traffic. Motorists pleaded for a new tunnel but the project stalled, at least in part, because the tunnel would begin and end in different counties. The solution was creation of what was called a Joint Highway District, a little-used device through which local governmental entities could organize to pool property taxes and other local revenues, as well as receipts from state gasoline taxes, to build a shared facility. The tunnel, ultimately called the Caldecott Tunnel, was approved in 1929 but was not actually completed until 1937, about a year after the Bay Bridge. A major share of the construction was financed by the Public Works Administration, a New Deal agency.[34] Although designed and built through the cooperation of local governments, the Caldecott Tunnel and connecting roads would soon be incorporated into the State Highway System.

These four major highways were the most important but by no means the only highways to be built or re-built during the 1920s. Cumulatively, these highway improvements, coupled with the tremendous increases in automobile registration during that decade, revolutionized automobile traffic in the area. Although the automobile had not displaced the trolley or train as the preferred means of transportation, it was well on its way to doing so. The highway improvements in the Bay Area had several implications for the Bay Bridge. First, the pace of work served as an indicator that automobile traffic was the growth sector in the transportation network of the area. For whatever reason, Californians were quicker to adopt the automobile as a mainstay than were people in other regions. In 1929, Californians owned one car for every 2.7 people; in the

[34] Frank Lortie, "Historic Resource Evaluation Report, Caldecott Tunnel, Bridge # 28-15, 04-ALA-24, P.M. 5.7," California Department of Transportation, October 1995.

northeast, that figure was 5.6, in the south 7.1, and in the other western states 4.0.[35] The Bay Bridge was planned for much the same reason that such great investments were made on other roadways in the Bay Area.

Second, these highways would ultimately serve as feeders for the Bay Bridge. Just as the interurban lines fed both ends of the Bay Bridge alignment, so too did most of the major highway projects built during the 1920s. The U. S. 40 alignment, including the Carquinez Bridge, pointed transcontinental traffic and traffic from the Central Valley into Oakland. The Peninsula and East Bay highways brought traffic from both shores of the Bay to Oakland and San Francisco. The Caldecott Tunnel, although it was finished after the Bay Bridge, would point San Ramon Valley traffic nearly on a straight line with the tollbooths of the Bay Bridge.

The situation with highway development was in some respects analogous to that of the interurban traffic, in which the through traffic was stacked up on both sides of the Bay, seeking a link between Oakland and San Francisco. The automobile backup was not as pronounced as the interurbans, simply because more people commuted via interurban than by automobile. But the trend toward highway commuting was so pronounced it could not be ignored. That trend was ultimately reflected in the design of the bridge, which allocated lanes to automobiles, trucks, and trolleys on the basis of 50-25-25 percent. The Bay Bridge was never conceived as anything but a multi-modal facility, but the allocation of capacity reflected a keen awareness on the part of the designers as to the fast-growing importance of the automobile within the larger transportation system of the Bay Area.

2.5. Summary of Transportation Considerations Leading to Construction of the Bay Bridge

The Bay Bridge was designed to solve transportation problems as elected officials and transportation planners perceived them during the period, 1929-1933. The Bay Area at the time was fitted with a reasonably effective transportation network that comprised ferries, riverboats, and ocean-going vessels on the Bay, an integrated rail network, an extensive electric commuter rail network, and an increasingly sophisticated highway system. The Bay Bridge was not seen as the answer to all transportation problems in the area: the chief purpose for which the structure was designed was to improve highway and mass transit services between the East Bay and San Francisco.

The planners of the bridge were aware, however, that they were creating a great structure that would affect the Bay Area in ways that could not be foreseen entirely. At the dedication of the bridge in 1936, William McCracken, the mayor of Oakland, saw vast possibilities for it: "What they have produced," he said, "is a world-wonder, significant in its economic, human, and spiritual advantages to all of California."[36] The engineers who designed the bridge saw the

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[35] C. H. Purcell, "California Highway Expenditures as Compared with Other States," *California Highways and Public Works* (March-April 1929), 2.

[36] "Burning Barriers, Governor Merriam Opens San Francisco-Oakland Bay Bridge," *California Highways and Public Works* (November 1936): 1.

advantages in terms that were somewhat less lofty but nonetheless significant. Earl Lee Kelly, the Director of Public Works for the State of California, also speaking at the dedication ceremony, looked into the future and saw a diverse and efficient transportation network that was centered on this great new structure. Looking ahead to 1950, Kelly predicted the bridge would be carrying some 77.6 million people from Oakland to San Francisco each year, with 16 percent traveling by automobile, 32 percent by bus, and 51 percent by train.[37] He predicted that the bridge could accommodate this traffic "without congestion" through the year 1975.

The designers of the bridge were better at engineering than traffic forecasting. The Bay Bridge was congested on the day of the dedication ceremony and has remained that way almost without interruption. The traffic mix was never remotely what Kelly had predicted; the interurbans folded within two decades, buses never carried the proportion of expected traffic, and the automobile traffic vastly exceeded predictions. The failure of the bridge to perform as planned may be attributed to many factors, most of which could not be foreseen when the bridge was designed or built. That failure cannot, however, be attributed to the intent of the designers. The Bay Bridge was planned, designed, and built with a goal of improving existing mass transit and highway systems. That goal was literally built into the structure; its form included dedicated lanes for the various modes of transportation. The Bay Bridge was designed to serve the transportation system of 1929 but came of age in an entirely different world, a world in which the automobile was quickly gaining precedence over other transportation modes.

[37] Earl Lee Kelly, "Bridge a Mighty Symbol of California Genius and Vision," California *Highways and Public Works* (November 1936): 13.

3. THE ROLE OF THE CITY AND COUNTY OF SAN FRANCISCO IN PLANNING THE BAY BRIDGE DURING THE 1920S

Although it was built during the 1930s, the Bay Bridge was planned conceptually during the 1920s. And although the State of California designed and built the structure, the City and County of San Francisco played a pivotal role in bringing the bridge from idea to reality. Serious discussions about building the bridge began in 1921; by 1930, the Bay Bridge had been approved for construction, its alignment set, and most of the institutional arrangements for its construction and operation had been developed. The context for planning this great bridge, then, was not the economic gloom of the Great Depression but rather the vibrant and expansive economy and culture of California during the 1920s as well as the optimism and activism of City and County of San Francisco leaders. This chapter details the important role of San Francisco civic and political leaders in ensuring construction of the Bay Bridge.

3.1. The General Role of San Francisco as an Advocate for Transportation Improvements in the Bay Area during the 1920s

The decade of the 1920s was a watershed in the development of California, in all aspects of its social, political, economic, and cultural life. The economy of the state boomed, with agriculture, oil, motion pictures, and a host of other industries leading the way. The population of the state increased from 3.4 to 5.7 million during that decade, although the majority of that increase occurred in Southern California. The population growth in Alameda and San Francisco counties was nonetheless dramatic, rising from a combined 850,853 in 1920 to 1,125,974 in 1930, with the increase split between the two counties in roughly equal numbers.[38]

If it was a turning point in economic growth, it was also an era in which optimistic visions of the future enthralled Bay Area planners, particularly the civic and political leaders of San Francisco. Author Daniel P. Gregory observes: "After World War I, San Francisco's outlook began to shift away from rebuilding and toward expansion. Faith in the future, in progress and growth, was strongly reinforced by the evidence of how far the city had already come."[39]

This economic boom resulted in, and to a significant degree was fueled by, major increases in automobile ownership and use. The general increase in automobile use and economic growth went hand in hand.[40] The growing economy induced both population growth and increased automobile registration. The automobile in turn facilitated a pattern of industrial and population dispersal that was unthinkable in earlier decades. The confluence of these trends was most pronounced in Southern California, where population centers developed into what has been called

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[38] These population figures are from Hoover-Young Commission, "Report to the President," 74.

[39] Daniel P. Gregory, "A Vivacious Landscape: Urban Visions between the Wars," a chapter in Paolo Polledri, ed., *Visionary San Francisco*. San Francisco: San Francisco Museum of Modern Art, 1990, 78.

[40] The close relationship between the growth of automobile use and the economic prosperity of the 1920s is a central focus of James L. Flick, *The Car Culture*. Cambridge: MIT Press, 1975.

a "fragmented metropolis."[41] In the Bay Area, the trend toward population and workplace dispersal was less pronounced but nonetheless significant. While the automobile may have been somewhat less important in the development of the Bay Area during this decade than was the case in Southern California, private vehicular traffic was emerging as the key growth element in the transportation network of the area.

Transportation planning in the Bay Area during the 1920s may be seen as a time in which planners and citizens in the area for the first time dared to dream of solutions to the problems that had plagued the area for nearly a century. Great plans were made during this decade and many were actually implemented. The problems transportation planners faced were specific to the geography of the Bay Area -- the series of bays that separated the communities, large and small, as well as the hills that surrounded the communities. The Bay Bridge was but one of a series of monumental transportation projects undertaken or planned in the Bay Area during the 1920s. To this list must be added: the Carquinez Bridge; the Caldecott Tunnel; the Golden Gate Bridge; expansion of the Municipal Railway in San Francisco; the Dumbarton Bridge; the San Mateo Bridge; and construction of major roadways in both the East Bay and Peninsula. These many transportation projects have one thing in common: they conquered the natural barriers of the Bay Area. In addition, most of these projects also were instigated by the City and County of San Francisco, which took the lead in regional transportation planning during these years.[42]

The drive for regional planning gained momentum during this period of expansive economic and demographic growth. Regional planning involved a host of issues, many of which revolved around public works investments -- highway construction, water development, mass transit, and so forth. In all of these areas, San Francisco took the lead, although many other Bay Area cities were wary of the potential domination implicit in a San Francisco-led regional program. Perhaps the best expression of the challenges and opportunities of regional planning was a 1925 report written by Harland Bartholomew on the infrastructural impediments to regional planning. The Bartholomew Report emphasized the need for coordinated transportation planning and zoning to develop a workable transportation network throughout the region.[43]

A key figure in Bay Area public works and planning during this period was Michael M. O'Shaughnessy, who served as city engineer for San Francisco between 1912 and 1934. O'Shaughnessy's role in the development of San Francisco in some respects paralleled that of William Mulholland in Los Angeles. During the early decades of this century, Los Angeles and San Francisco, fierce competitors for domination as civic centers of the state, undertook some of the most daring public works projects in the history of American cities. The best-known accomplishments were the building of two huge aqueduct systems: the Owens Valley project of the City of Los Angeles and San Francisco's Hetch Hetchy system. This era of great public

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[41] Robert M. Fogelson, The *Fragmented Metropolis, Los Angeles, 1850-1930* (Cambridge: Harvard University Press, 1967).

[42] The leadership of San Francisco in Bay Area regional planning is treated in detail in: Mel Scott, *The San Francisco Bay Area: A Metropolis in Perspective* (Berkeley: University of California Press, 1985).

[43] Scott, *The San Francisco Bay,* Chapter 12, "Fred Dohrmann and the Regional Plan Association."

works, however, did not end with water resource development. M. M. O'Shaughnessy played an especially important role in San Francisco in that he was a city engineer in charge of a wide range of public works, unlike William Mulholland, whose work was limted to water resources. Even while Hetch Hetchy was under construction, San Francisco under O'Shaughnessy's direction was deeply involved in a wide range of transportation issues, including additions to the municipal railway system, construction of major highway tunnels, and realignment of many city streets.

The most dramatic transportation improvements pursued by San Francisco during the 1920s were the Golden Gate Bridge and Bay Bridge. As Daniel Gregory notes, the general commitment for civic improvement was most tangibly evident in support for building these two great bridges: "Support for civic beautification was combined with an aggressive boosterism to create an atmosphere of excitement and urgency about the future. Commercial rivalries with Los Angeles and other cities heated up. Bridges, in particular, became synonymous with future growth and prosperity."[44]

Leaders in San Francisco played two roles, affecting the eventual construction of these bridges: a general support for their construction, whether by San Francisco or another party; and specific planning for their construction, again, whether by the city or another party. While involved with both bridges, the city's role was far more important in plans leading to the Bay Bridge. O'Shaughnessy himself was involved in the studies leading to construction of both bridges, although the circumstances were different in each case. O'Shaughnessy met J. B. Strauss, the Chief Engineer of the Golden Gate Bridge, during the Panama-Pacific International Exposition, where Strauss had developed an amusement ride based upon the general principles of a bascule bridge. O'Shaughnessy discussed with Strauss the possibility of a bridge across the Golden Gate and the two were in close contact on the idea for years. O'Shaughnessy would divorce himself from that project during the 1920s, leaving it to Strauss not only to plan the bridge but also to sell the idea to wary taxpayers in Northern California counties.[45] O'Shaughnessy was an important early advocate for the Bay Bridge as well, although he would not figure directly in the later discussions of the bridge design.

The efforts of San Francisco were not restricted to those of elected officials or appointees. Throughout the 1920s, private business organizations provided key financial and political support for construction of some type of transbay bridge. The initial exploration of the Bay floor foundations, for example, was funded by the San Francisco Motor-Car Dealers, which mounted a spirited campaign for a bridge, beginning in 1921.[46] The San Francisco Chamber of Commerce

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[44] Gregory, "Vivacious Landscape," 86.

[45] John Van der Zee, *The Gate: The True Story of the Design and Construction of the Golden Gate Bridge* (New York: Simon & Schuster), 1986.

[46] *San Francisco Chronicle*, June 4, 1921, p. 8; June 8, 1921, p. 3. The lead role of the Motor-Car Dealers' Association is indicative of the problem that bridge supporters were seeking to address: the inability to get to San Francisco by automobile. The Motor-Car Dealers' Association, however, was not opposed to non-automobile traffic on the bridge. In a statement of policy in June 1921, the association declared: "Any bridge proposition must include facilities for railroad, electric interurban, motor cars, trucks and pedestrian transportation." See: "The Fabric of Their Vision: Motor Car Dealers' Part in Bay Bridge History," *Motorland*, January-February, 1937, 6. The San Francisco

was resolute in its support for a transbay bridge, particularly after Leland Cutler took over leadership of the group. Cutler would stay with the Bay Bridge campaign through its completion in 1936, when he served as moderator of celebrations in San Francisco. Various other private organizations, including the Downtown Association, were active and vocal supporters of any type of bridge, whether publicly or privately owned.

3.2. The Specific Role of Private and Civic Leaders of San Francisco in Planning the Bay Bridge during the 1920s

Apart from its general role in promoting regional transportation improvements, the City and County of San Francisco had a specific legal role to play in approving any private proposals for a bridge between San Francisco and Oakland. The legal basis for its involvement was state law, which at the time gave counties control over toll roads or bridge franchises within their jurisdictions. In the not-uncommon event that a toll bridge crossed county lines (rivers and bays often define those lines), the franchise authority rested with the jurisdiction on the "left bank" of the crossing, which in the case of a San Francisco-Alameda county facility, was San Francisco.[47]

The fact that only private proposals were entertained during the 1920s was symptomatic of major bridge construction practices in California (and the United States) during these years. Three major bridges (other than the Bay Bridge and Golden Gate Bridge) were built or planned in California during this decade: the Carquinez Bridge, Dumbarton Bridge, and San Mateo Bridge. All were private toll bridges. In the absence of other institutional arrangements, only private toll structures were seen as feasible during this decade. The City and County of San Francisco would, by the end of the decade, lead the movement for a publicly-owned Bay Bridge. The City could not, however, entertain such a massive structure on its own and for most of the 1920s civic leaders were content to pursue the only available alternative.[48] During the course of the decade, the success of revenue-based bond financing, used for construction of the publicly-owned Delaware River Bridge and others, would attract the attention of transportation planners throughout the United States, including those in California. Early in the decade, however, little consideration was given to any proposals other than those from private parties.

Various private proposals made their way to the City and County of San Francisco during the years just before and after American involvement in World War I. Because they had jurisdiction

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newspapers were also active participants in the efforts of the 1920s, which the *Chronicle* referred to as a "movement" and a "campaign." San Francisco was joined by the efforts of some East Bay cities, including Berkeley and Oakland.

[47] C. H. Purcell, Charles E. Andrew, and Glenn B. Woodruff, "San Francisco-Oakland Bay Bridge: A Review of the Preliminaries," *Engineering News-Record* (March 22, 1934): 371; California Highway Commission, "Investigation and Report on Toll Bridges in the State of California," *Appendix to the Journals of the Senate and Assembly of the Forty-Eighth Session of the Legislature of the State of California*, Vol. 4 (Sacramento: California State Printing Office, 1929), 19.

[48] Only a few civic leaders gave serious consideration to a publicly owned bridge, built and administered by San Francisco. This issue was debated in a special issue of *The City*, March 27 1927, entitled, "The San Francisco Bay Bridge Problem."

over the franchise and saw the bridge as a key step in regional progress, city officials in San Francisco pursued the matter with some enthusiasm. In 1921, with 13 private applications in hand, San Francisco applied to the War Department to initiate the process of obtaining necessary permits to span the navigable waters of San Francisco Bay.

Prior to submission of this application, however, the city contracted with John Vipond Davies and Ralph Modjeski to conduct preliminary borings into the Bay floor to determine the feasibility of constructing a substantial structure there, whether a bridge or tunnel or some combination of these. Davies was known for having designed several of the early tunnels in New York City; Modjeski was known nationally for his design of long, high bridges.[49] Modjeski would later serve as the Chair of the Board of Consulting Engineers for the Bay Bridge. As noted, the Motor-Car Dealers' Association of San Francisco raised the $12,000 for this work.

In October 1921, the War Department held public hearings on these various proposals. On December 1, 1921, the department delivered what seemed to be a deadly blow to the advocates of a transbay bridge. The edict from the department laid out five conditions, all of which worked against what would ultimately be approved for the site:

1. No bridge of any kind will be approved north of Hunter's Point.
2. No low bridge will be approved north of San Mateo.
3. A tunnel would be approved at any location if kept below a depth of 50 ft. and if proper provision were made for taking care of tidal prism.
4. A combined bridge and tunnel would be approved if the tunnel were kept below a depth of 50 ft. and if a 3,000-foot open channel were left on the San Francisco side, suitable provision being made for the tidal prism where bridge and tunnel join.
5. No more than one crossing is to be approved at present north of San Mateo.[50]

This position by the War Department, while seemingly final, did not deter private interest in the project nor did it discourage the officials of San Francisco from entertaining new proposals. The city continued to submit new applications to the District Engineer, Army Corps of Engineers in San Francisco, nearly on an annual basis. The civic and political leadership would continue to press the War Department throughout the 1920s.

The situation in 1926 was detailed in an article in the *Engineering News-Record*. At that time, the city had received 17 proposals; that number would grow to 38 by 1928. The 17 proposals from 1926 illustrate both the attention this project had gained and the diversity of opinion about how the crossing could be made. The proposals had attracted the services of some of the most famous civil engineers working in the United States at the time: Ralph Modjeski, Charles Derleth, Jr.,

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[49] The career of Davies is treated briefly in: Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* (New York: Alfred A. Knopf, 1995). The career of Modjeski, who played a crucial role in designing the Bay Bridge, will be detailed in later chapters.

[50] Purcell, Andrew, and Woodruff, "San Francisco-Oakland Bay Bridge: A Review of Preliminaries," *Engineering News-Record* (March 22, 1934): 372.

John B. Leonard, J. B. Strauss, W. L. Huber, C. E. Grunsky, George Goethels, J. A. L. Waddell, Gustav Lindenthal, and others.[51] Many were on more than one team: Modjeski was on three teams, and Goethels and Lindenthal on two each. As one measure of the caliber of expertise on the various engineering teams, the various teams included the designer of record for the Golden Gate Bridge (Strauss), the Ben Franklin Bridge (Modjeski), the Carquinez Bridge (Derleth), the Hell's Gate Bridge (Lindenthal), and the Panama Canal (Goethels). The teams also included two of the five engineers (Modjeski and Derleth) who would form the Board of Consulting Engineers for the Bay Bridge when it was designed by the state in the 1930s.

The bridge alignments for these proposals varied widely. Of the 17 projects, the *Engineering News-Record* discussed the alignment of 14. Of these, four proposed what would later be called the "Southern Crossing," between Hunters Point in southern San Francisco and Alameda. Only three proposed to incorporate Yerba Buena Island into the bridge alignment. The other bridges followed a course between the southern crossing and Yerba Buena Island, most touching down either at the Southern Pacific's Alameda Mole or on Alameda Island.

The proposals also varied widely as to bridge types. These are summarized only briefly in the publication and the plans were likely were only very conceptual in nature.[52] The largest group of proposals (seven) was for "high steel trusses," presumably through trusses and not cantilevers, because cantilevers were called out independently in other proposals. There were also three proposals for cantilever spans, including one unusual plan by J. B. Strauss for a combination of cantilever and bascule spans. There were two proposals for suspension bridges. The remaining plan was for tunnels, including one unusual combination (proposed by Modjeski and Davies) for a high bridge as well as three tunnels.

San Francisco leaders were likely overwhelmed by conflicting forces in the debate over the bridge: by the obdurate position of the War Department, by the great diversity of proposals submitted by so many private developers, and by the unflinching support for some type of Bay Bridge among civic and political leaders in the city. City officials decided to support independent research on the subject, to select among the many alternative approaches and to establish data to convince the War Department that a bridge could be built without impeding navigation in the Bay. There seems little doubt that the City and County of San Francisco and its allied business interests were themselves convinced that the bridge was feasible. In 1927, the city provided $40,000 for additional research on the feasibility and preferred design for a trans-bay structure.

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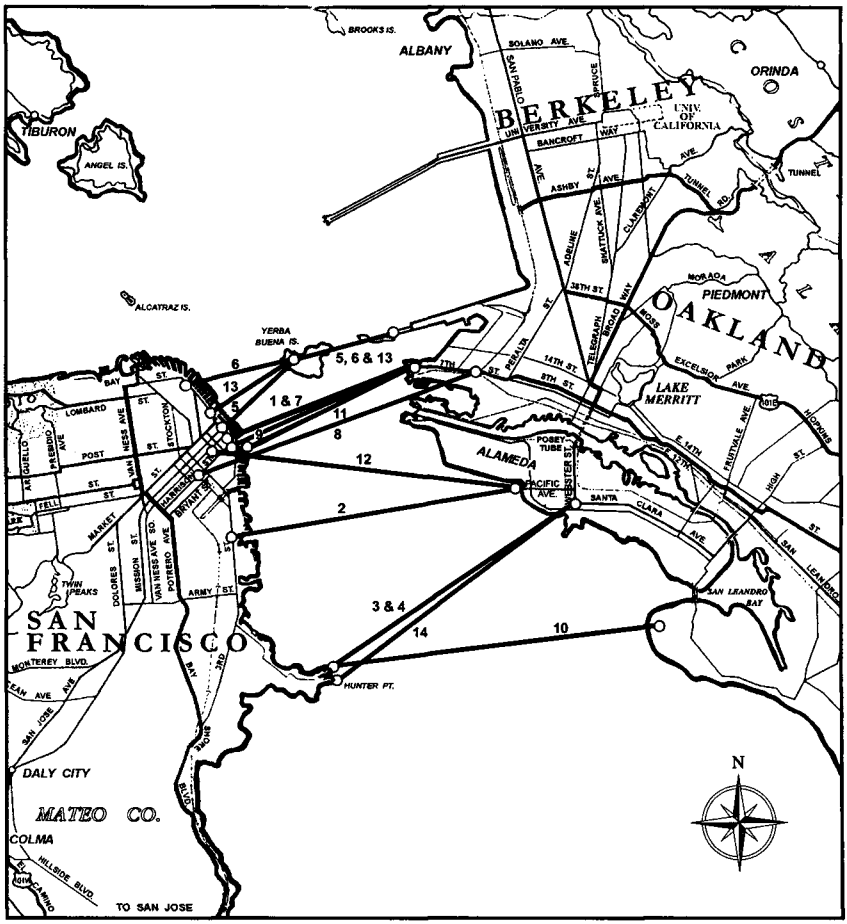
[51] "San Francisco Bay Bridge Projects Total 17," *Engineering News-Record* 97:18 (October 28, 1926), 720.

[52] These projects are described in greater detail in: San Francisco Bureau of Governmental Research, *The City* (March 28, 1927), the entire issue of which is devoted to "The San Francisco Bay Bridge Problem."



Source: Engineering News - Record 97:18 (October 28, 1926)
Location: Bancroft Library University of California, Berkeley

Map of 1926 Private Proposal Alignments

The team selected by the city to conduct this study comprised Robert Ridgway, Arthur N. Talbot, and John Galloway, all structural engineers. Galloway was a native-born Californian who, among other achievements, had served as chief engineer for the Healy-Tibbetts Construction Company. He was an active consulting engineer in San Francisco after 1892, doing work in hydroelectric plants, major buildings, as well as bridges.[53] Talbot was a retired professor of civil engineering from the University of Illinois.[54] Ridgway, the chair of the board, was the Chief Engineer of the Board of Transportation in New York City.[55] The team was selected in part for its expertise and in part because none of the three were involved with any of the private franchise applications. The last point was important inasmuch as the best-known bridge engineers in the United States were already involved as consulting engineers on one or more of the teams.

Ridgway, Talbot, and Galloway released their findings in an extensive report, dated May 5, 1927.[56] The report was informed, not only by the engineering studies but also by major traffic studies as well. The team addressed the three key issues that would dominate all subsequent planning for the bridge: location, bridge types, and mix of traffic (specifically, whether to accommodate rail service as well a vehicular traffic). It also struggled with two issues that affected the entire project: the geology of the Bay and finding a way to fund construction.

With respect to location, the Ridgway board selected an alignment that differed from any of those proposed by the private applicants, and which also differed from the alignment that was ultimately selected. The numerous private companies had proposed multiple variations, based upon three San Francisco locations, three East Bay locations, and whether or not Yerba Buena Island was used. In San Francisco, the choices were: Telegraph Hill; Rincon Hill; and Hunters Point. The location in San Francisco was key from the standpoint of service as well as technical feasibility. A Hunters Point location avoided the deepest waters of the Bay but provided the lowest level of service to automobile as well as transit traffic. A Telegraph Hill crossing provided the highest level of service but posed potentially intractable engineering problems. The Rincon Hill site provided less-than-ideal service to the users (it was then far south from downtown) and had unknown problems in terms of the geology of the Bay. The East Bay terminus posed similar types of tradeoffs. The Alameda terminus made sense only if the southern crossing alignment was selected, i.e. the Hunters Point to Alameda alignment. The other alternative sites were the Alameda Mole and the Key Route Mole, both of which were attractive because they offered several miles of man-made land which decreased the total length of the bridge. The choice of whether or not to use Yerba Buena Island was addressed by the Ridgway Board chiefly in terms of the usefulness of the island to the selected alternative. The board analyzed three strictly linear east-west alternatives -- Telegraph Hill to the Key Route Mole; Rincon Hill to the Alameda Mole; and the southern crossing from Hunters Point to Alameda.

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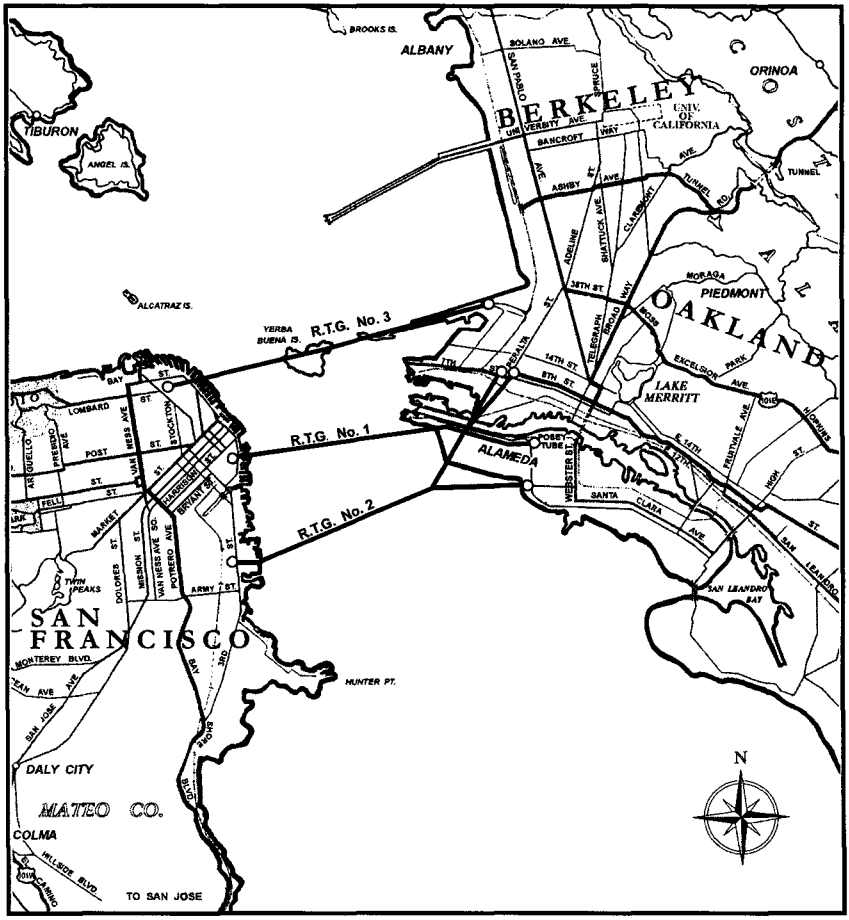
[53] *American Society of Civil Engineers Transactions* (hereafter cited as *ASCE Transactions*), 109 (1944), 1451-56.

[54] *ASCE Transactions*, 108 (1943), 1710.

[55] *ASCE Transactions*, 106 (1941), 1527.

[56] Robert Ridgway, et al, "Report of Board of Engineers, Transbay Bridge, San Francisco, May 1927." This rare report may be found at the Transportation Library, California Department of Transportation, Sacramento, at the Engineering Library, University of California, Berkeley, and at the library of the Institute for Transportation Studies at the University of California, Berkeley.

The board did not consider any alternatives that involved bends in the bridge, such as the alignment that was ultimately selected. The only straight-line alternative that involved Yerba Buena Island was the Telegraph Hill to the Key System Mole alignment. The board ultimately recommended the Rincon Hill to Alameda Mole alignment, without the use of Yerba Buena Island. The southern crossing alignment was listed as second most preferable, while the Telegraph Hill to Key System Mole was ranked last. The rationale for the preferred alternative had to do with level of service for automobiles as well as interurban rail lines on both sides of the Bay.



Source: Report of Board of Engineers, Transbay Bridge, San Francisco, May 1927
Location: Bancroft Library University of California, Berkeley

Map of Ridgeway Report Alignments

With respect to traffic mix, the board considered variations on three traffic modes: automobiles and trucks; interurban rail; and main line rail service. The board decided against use of the bridge for main line rail, owing to the high cost of reinforcing the bridge for heavy rail loading as well as the longer approaches that would have been needed to accommodate rail grades. The board was adamant, however, in accommodating both vehicular and interurban rail services. Indeed, much of the rationale for selecting its preferred alternative had to do with the ease of connecting interurban lines on both sides of the Bay, as well as the difficulties in accommodating vehicular service at the Hunters Point and Telegraph Hill touchdowns in San Francisco. As to bridge type, the board strongly favored a cantilever span on the west crossing and a bascule or some other type of movable span on the east crossing. The board concluded that a suspension bridge was infeasible owing to the "physical conditions" of the crossing. It recommended a cantilever bridge for the long spans of the West Bay shipping channel, simple truss spans for most of the east crossing, and inclusion of a movable span to accommodate shipping in the East Bay.

The board's preference for the Rincon Hill-Alameda Mole alignment was a summation of the perceived advantages in terms of bridge type and service to vehicular and interurban traffic. The advantages were these:

> It affords the most available direct route between the business centers; all the existing interurban lines may reach the bridge; the Alameda and Oakland termini reach the principal traffic highways; the San Francisco terminus is accessible from the entire street system of the city and is close to the business and shopping districts; interurban and main lines passenger stations may be provided; there is storage space for interurban cars; the land values on Rincon Hill are not high; no obstacles are placed across Oakland Harbor; there is no interference with the projected Alameda harbor; the largest existing wharves on the San Francisco water front lie seaward of the bridge; the clearances are all that commercial interests require; there is no interference with the proposed Alameda Naval Base and only minor interference with the naval anchorage grounds; the existing ferry lanes are left free; Rincon Hill is an excellent point on which to terminate the bridge; any future rapid-transit system may easily be connected to the interurban system; and the present street-car systems can readily be diverted to the terminals.[57]

The ease of connecting interurban lines was emphasized in the preference for connections on both sides of the Bay. The same point worked against the Telegraph Hill touchdown because there was no site for a terminal. In addition, Telegraph Hill was inadvisable, in the view of the board, because it offered little room for vehicular traffic circulation and because property acquisition costs would be high. The Oakland Mole touchdown in the East Bay was discouraged because it offered no way to connect with the Alameda-based interurbans. The southern crossing was discouraged because of the much longer connections for both the interurbans as well as vehicular traffic bound for the business districts of Oakland and San Francisco.

[57] Ridgway, et al, "Report of the Board of Engineers."

The board left to others, however, to deal with the two most intractable problems associated with the Bay Bridge: the geology of the Bay and the problem of how to finance the work. The two were inseparable, as the board stated directly in its recommendations. The board could make no estimate of the cost of the bridge in the absence of "vitally necessary information regarding foundation." In the absence of a cost estimate, the board made no recommendations about how the project could or should be financed. It did speculate, however, that the conditions of the Bay floor "must be expected to present great difficulties and extremely expensive construction," noting further that "at best the building of the piers will be a difficult and hazardous undertaking." [58]

The three-member board was reluctant to draw conclusions regarding the economic feasibility of the bridge, absent more data about the Bay floor. It recommended three actions by the City and County of San Francisco: 1) adoption of alternative 1 (the Rincon Hill to Alameda Mole alignment), accompanied by a request for approval by the War Department; 2) conducting of borings in the Bay to determine "foundation conditions," and 3) preparing of preliminary designs and a cost estimate to determine the economic feasibility of the project.

The Ridgway Report was an officially-sanctioned study by the City and County of San Francisco but had little status within the political and regulatory process through which the Bay Bridge would be approved. Its conclusions were not adopted as policy by the city or any other governmental entity in California. The report did not conclude that the bridge was technically or financially feasible, although it strongly suggested that a bridge could be built. It recommended a good alignment for the bridge (although not the one actually built) and it recommended that supporters of the bridge proceed to seek approval of a bridge along those lines.

The most important contribution of the Ridgway Report was the fact that it gave the community something tangible to rally around. Throughout the remainder of the decade, private groups and official representatives of the City and County of San Francisco took their case to any available body that might be able to help make the bridge happen. This included numerous hearings before the War Department, Congress, and the California legislature. The efforts of the civic and political leaders of San Francisco overcame six crucial legislative and administrative hurdles: creation of the California Toll Bridge Authority by the California Legislature in 1929; adoption of the Bay Bridge as a state-owned and financed structure in 1930; convening of the Hoover-Young Commission in 1929-30; approval of a permit by the War Department in 1931; approval of bridge construction bonds by the Reconstruction Finance Corporation in 1933; and approval of the project and its financing by Congress in 1933. Since there was no specific bridge design to support until 1933, the Ridgway Report as well as the report of the Hoover-Young Commission were the only concrete proposals around which city leaders could rally. The importance of the Hoover-Young Commission is discussed in chapter 5 of this report. The role of San Francisco leaders and others in legislative and administrative hearings is detailed in chapter 6.

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[58] "Downtown Location Recommended for San Francisco Bay Bridge," *Engineering News-Record* (May 19, 1927): 821.

3.3. Significance of the Actions of the City of San Francisco and Private Developers

The efforts of private developers and the City and County of San Francisco during the 1920s brought the idea of the Bay Bridge from the stage of speculation to serious discussion. While the San Francisco effort did not answer all of the questions about the bridge, it framed the questions in manageable terms, giving Congress, the President of the United States, the California Legislature and governor sufficient confidence that the questions could, in fact, be answered.

Indeed, the San Francisco effort, highlighted by the Ridgway Report went a long way toward answering three important questions: alignment; traffic mix; and bridge types. In terms of alignment, the Ridgway report fixed the location in San Francisco and narrowed considerably the range of options on the Oakland side. The Rincon Hill location was never seriously challenged because the board made such a convincing case for it, in terms of the level of service to interurbans as well as automobiles and trucks, and because the real estate was affordable. The ultimate alignment would deviate considerably from the Ridgway Report recommendations, especially with respect to the use of Yerba Buena Island and the Key System Mole. As will be shown, however, the Hoover-Young Commission, which decided the alignment issue, would do so by mixing and matching the three alternatives posed by the Ridgway Report. The ultimate alignment was a variation on the Ridgway recommendation, not an entirely new concept.

In terms of bridge types, the Ridgway report was less influential. The report held that a suspension span was impractical and focused instead on cantilever spans. The Hoover-Young Commission and later Department of Public Works would continue to follow the lead of the Ridgway Report for several years; not until 1932 did planners finally decide that a suspension span was feasible. The Ridgway Report, did, however, establish that multiple bridge types would be needed for the crossing, based upon the changing geology of the Bay, setting the stage for one of the most notable aspects of the bridge design.

The report was also definitive with respect to the mix of traffic. It made a convincing case in three areas. First, it stated an obvious point: that the bridge should serve automobiles and trucks, which comprised an important and growing transportation mode in the area. Second, it confirmed that the bridge should serve the interurbans, which the commission estimated would comprise the bulk of the traffic on the bridge. Finally, the report recommended strongly against any effort to fit the bridge for main line rail traffic. The automobile-truck-interurban mix was never seriously challenged after 1927.

Finally, the report paved the way for future studies. It framed clearly two questions that would be left unanswered until the early 1930s: the conditions of the geology of the Bay; and the likely cost of the project. The question of how to fund the bridge was not answered by the Ridgway Report, although it would be answered in part two years later, when the State of California adopted as official policy that the bridge would be built and owned by the state. The geologic issues would not be resolved until 1930.

On balance, the Ridgway Report must be seen as the first of three major steps in the planning and building of the Bay Bridge, along with the Hoover-Young Commission Report of 1930 and the final recommendations of the Board of Consulting Engineers, completed in 1933. On one hand, the Ridgway Report is somewhat less important than the others because a number of its recommendations were not followed. On the other hand, it was highly important on the basis of the fact that it was prepared so early, nearly a decade before the bridge was opened. Whether equal to or less important that the other two planning documents, the Ridgway Report must be regarded as a key step toward construction of the bridge. It had political implications that rivaled its technical importance. The report served as a catalyst for San Francisco civic and political leaders, encouraging them to believe that the bridge was technically and economically feasible. San Franciscans would continue to play a leading role in lobbying for approval of the Bay Bridge in a myriad of official venues, from the State Legislature to Congress to the War Department to the Reconstruction Finance Corporation. These efforts, which began in earnest with publication of the Ridgway Report, continued uninterrupted until construction began in early 1933.

4. THE HOOVER-YOUNG COMMISSION AND ITS ROLE IN THE BUILDING OF THE BAY BRIDGE

If the Bay Bridge was built at a critical juncture in the transportation history of California, it was also constructed at a turning point in the economic life of the nation. Planning for the bridge began during the 1920s, when general economic growth, rising automobile use, and raised expectations of the power of government to solve transportation problems gave Californians the courage and vision to believe that such a massive project was feasible. In the years preceding the bridge's construction, however, the American economy was devastated by the Great Depression, the worst economic disaster in the nation's history.

The new economic environment of the Great Depression provided an entirely new rationale for constructing the bridge: putting people back to work. It is no coincidence that some of the greatest public works projects ever built in the United States were constructed during the decade of the 1930s, when public works were seen as the best available counter-measure to combat staggering unemployment. Although President Franklin Roosevelt is most closely associated with this approach, it was President Herbert Hoover who initiated federal involvement in some of the grandest public works projects in California history, including the Bay Bridge and the Central Valley Project. If there is one political leader who can be singled out for championing construction of the bridge, it is Hoover. Among his other contributions, Hoover was responsible for convening the Hoover-Young Commission which, more than any other deliberative body, was responsible for the Bay Bridge being built.

4.1. Herbert Hoover and His Role in Championing the Bay Bridge

The presidency of Herbert Hoover has been the subject of considerable historical controversy in recent decades. Until recently, historians had concluded that Hoover did little to combat unemployment during the early and most difficult years of the Great Depression. Newer interpretations, however, emphasize that Hoover had a different approach to combating unemployment, relative to Franklin Roosevelt's New Deal, but that he did offer some activist solutions to the problem.[59] In particular, these historians emphasize Hoover's belief that public works projects could be accelerated to provide needed employment opportunities.

Hoover's support for the Bay Bridge, however, long predated his presidency and the Great Depression. He supported the bridge based upon its potential contribution to transportation in the Bay Area, not merely because its construction would generate employment. Hoover was an engineer and a Californian, both of which contributed to his interest in the long debate over the Bay Bridge. He was also an important political figure long before he was president; indeed, many would argue that he accomplished more during his long tenure as Secretary of Commerce than he did as president.[60] During those years, Hoover did what he could to support construction

[59] The Hoover historiography is discussed in James Stuart Olson's, *Herbert Hoover and the Reconstruction Finance Corporation, 1931-1933* (Ames, Iowa: The Iowa State University Press, 1977).

[60] This is the general conclusion of Anthony Rumasco, *The Poverty of Abundance*, (New York: Oxford University

of the Bay Bridge, although with limited success. Without presidential support, he could do little to advance the bridge except to serve as an intermediary between California interests and the War Department. As he recalled:

> I attempted to conciliate the military and engineering conflicts, but my authority, without the backing of the President, was insufficient. Also, opinion in the Bay cities concerning the proper and feasible route was divided, and acrimonious debate was going on. At that time there seemed to be no way of financing a project so ambitious as this.[61]

The situation changed dramatically, however, when Hoover ran for president in 1928. Campaigning in San Francisco, he openly endorsed construction of the bridge and promised to see that it would be constructed. Elected with broad support, Hoover was given the opportunity to fulfill that pledge after his inauguration in 1929. There is reason to believe President Hoover would have followed through on his support for the project, even had there been no economic emergency. The depression, however, dominated all aspects of Hoover's administration. It is unlikely that Hoover would have contemplated construction of this, one of the greatest public works projects in American history, without also considering its impact on the economy of the Bay Area and the nation.

Within months of his inauguration, Hoover began discussions with California Governor Clement C. Young on two massive public works projects that had been debated within California throughout the 1920s: the Bay Bridge and the Central Valley Project. Ultimately, Hoover and Young would call for creation of two commissions – both called Hoover-Young Commissions – to study how the state and federal governments could work cooperatively toward their completion. Both would ultimately succeed, although in fundamentally different ways. The Bay Bridge was completed as a state project in 1936; the CVP would be built as a federal undertaking, with the bulk of construction occurring in the 1940s and 1950s.

Hoover announced creation of the Bay Bridge Hoover-Young Commission – officially known as the Hoover-Young San Francisco Bay Bridge Commission – in a press conference of August 13, 1929. Not surprisingly, he emphasized the importance of the project to the economy of the Bay Area and California, as well as its usefulness as a transportation facility:

> There can be no question as to the necessity of such a bridge for the economic development of these communities. In addition to the cities of San Francisco, Oakland, and Alameda, the Governor of California through recent legislation has recently taken an interest in this problem. In order that we may have an exhaustive investigation with a view to a final determination which I hope will be acceptable to all parties, I have consulted the Secretary of War and the Secretary of the Navy as well as Mr. Meek, the representative of Governor Young, and I shall appoint a Commission comprising two

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Press, 1965).

[61] Quoted in Robert Hessen, *Herbert Hoover and the Bay Bridge: A Commemorative Essay* (Stanford: Hoover Institute, 1986), 4.

> representatives from the Navy, two from the Army, and I shall ask the authorities of San Francisco to appoint one member, the authorities of the east side of the Bay to appoint another member. I shall ask the Governor to appoint one or two members and I shall appoint a leading citizen, Mr. Mark Requa if he will undertake it, in the hope that we may arrive at a determination of the common interest.[62]

With that pronouncement at the presidential level, the commission was established and the Bay Bridge was given arguably its most important sign of political support.

4.2. Members of the Hoover-Young Commission

As Hoover indicated in his press conference, the Hoover-Young Commission would comprise representatives from the Army and Navy and members from San Francisco and the East Bay cities. He indicated at the outset that Mark Requa would chair the commission. Requa had three major qualifications for the job: he was an old friend of the president; he was a prominent Republican; and he was an engineer with a lifetime history of accomplishment. Hoover also appointed to the commission Charles D. Marx, a longtime engineering professor at Stanford University who had taught Hoover as an undergraduate. Although he was retired in 1929, Marx was a respected member of the engineering community and a close personal friend of the president. In the view of one historian, Marx's appointment "signaled the army and the navy that their representatives on the commission must be open-minded and not tied to traditional prejudices against a transbay bridge."[63]

As Hoover specified, the Commission included two members each from the Army and Navy; these were: Rear Admiral Luther E. Gregory, U.S. Navy. (Retired); Rear Admiral W. H. Standley, U.S. Navy; Brigadier General G. B. Pillsbury, U.S. Army; and Lt. Col. E. L. Daley, U.S. Army. San Francisco and the East Bay were represented by George T. Cameron, the Vice-Chair, and Senator Arthur H. Breed, respectively. Cameron was editor of the *San Francisco Chronicle*; Breed was a State Senator, representing Alameda County.[64] Arguably, the most important member, or at least the most active, was its secretary, C. H. Purcell. Purcell was in 1929 the Highway Engineer of the California Division of Highways. From the standpoint of design as well as political acumen, Purcell may be seen as the one individual most responsible for the building of the Bay Bridge. Although he would serve as the head of the Division of Highways or the Department of Public Works through the early 1950s, Purcell was a relatively new arrival in California in 1929, having been appointed as Highway Engineer in 1928.

It is difficult to underestimate the importance of the Hoover-Young Commission to the history of the Bay Bridge; it is unlikely the bridge would have been built during the 1930s, had not this commission been convened. The commission played a pivotal role in deciding upon three key

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[62] Hessen, *Herbert Hoover and the Bay Bridge*, 5.

[63] Hessen, *Herbert Hoover and the Bay Bridge*, 5.

[64] The governor's representatives were announced on October 3, 1929. *San Francisco Chronicle*, October 4, 1929, Part II, 2.

aspects of the Bay Bridge: its location; the basic geometry of the bridge, particularly with respect to vertical and horizontal clearances; and its finances. In short, the Commission established both the conceptual design of the bridge and decided how it would be financed.

Recognizing this key role, it is somewhat surprising how little the commission actually met and discussed the issue. The Commission first convened on October 7, 1929 in the office of Governor C. C. Young. It met on October 7, 8, and 9 of 1929 and adjourned until July 22, 1930. It met three times in July of 1930 and issued its final report on August 6, 1930. The commission disbanded once the final report had been issued.

4.3. Role of the Bridge Department, Division of Highways in the Commission Deliberations

The first action of the Hoover-Young Commission was to request a series of studies, to be performed by the Department of Public Works; this study task was assigned to the Division of Highways. Specifically, the Commission made the following motion, at its initial meeting:

> Resolved that the Department of Public Works of the State of California be asked to make an engineering, economic, and traffic study and furnish the Commission with all data obtained for the purpose of determining the relative value of the several proposed locations for a connection between San Francisco and Alameda counties.[65]

This resolution had the effect of making the Department of Public Works staff to the Commission. Because the Department of Public Works had a minimal staff of its own – it was an administrative body, in charge of various functional divisions – it turned to the Division of Highways, which had an extensive staff with transportation planning experience, to prepare the necessary reports.

The timing of this request advanced the cause of building the Bay Bridge in that it gave an immediate assignment for the bridge engineers of the Division of Highways, and carried with it the funds to conduct that work. Major events that concern the Bay Bridge were clustered tightly during the years 1929-31; most of these events are discussed in Chapter 5 below. With respect to the Hoover-Young Commission studies, the key development was creation by the California Legislature of the California Toll Bridge Authority, or CTBA, in 1929, just prior to convening of the Hoover-Young Commission. The CTBA act, in addition to establishing an authority to build the bridge, also included an appropriation of $50,000 to study its feasibility. At that point, however, the CTBA existing only as a panel of five high-ranking elected or appointive officials (the governor, lieutenant governor, director of finance, chair of the highway commission, and director of public works), with little in the way of staff support. The California Department of Public Works, which was essentially the staff to both the CTBA and the Hoover-Young Commission, elected to use most of its appropriation to support the request of the Hoover-Young Commission, leaving the CBTA essentially moribund during this period. The department made the logical choice in assigning these studies to the Bridge Department of the Division of

[65] Hoover-Young Commission, 5.

Highways. In time, most of the people involved with the Hoover-Young studies would be asked to join the staff of the Bay Bridge Division of the Department of Public Works, the formal organization that was responsible for designing and building the bridge. (The Bridge Department of the Division of Highways had its offices in Sacramento; the Bay Bridge Division of the Department of Public Works had offices in San Francisco.)

C. H. Purcell, the Highway Engineer of California, and Charles Andrew, Bridge Engineer for the Division of Highways, headed up the Hoover-Young studies, assisted by the staff of the Bridge Department. Their work took place in a period of about eight months. Given limited time and resources, Purcell and Andrews decided to build upon the findings of the 1927 Ridgway Report, which they cited repeatedly in the 1930 final report for the commission. It will be recalled that the recommendations of the Ridgway Report emphasized the crucial need to answer two questions: What was the condition of the Bay floor; and was the bridge financially feasible? Purcell and Andrew devoted most of their attention and resources to providing answers to those two questions. In addition, they re-opened the question of the alignment of the bridge, pending the outcome of other major questions, both of which had powerful impacts on the alignment issue. Finally, Purcell and Andrew made some attempt to define the bridge types that would be appropriate for the crossing, although that issue was left largely unresolved when the commission released its final report in 1930.

4.4. Locational Studies and Data from Borings

With respect to the condition of the Bay floor, Purcell and Andrew noted in the 1930 Hoover-Young Commission report:

> The wide expanse of the bay across which any bridge must pass was unprospected as far as depths to suitable foundation were concerned. This fact was noted by Messrs. Talbott, Ridgway and Galloway, in their 1927 report. No intelligent cost estimate could be arrived at until such borings were made, and even the possibility of building a bridge could not be determined on any complete line.[66]

The first order of business, then, was to conduct borings, a task that was contracted to the firm of Duncanson-Harrelson Company, an active Bay Area construction company. The borings could not be conducted, however, until the Bridge Department had decided upon a range of bridge alignments, which would define the locations for the borings. Again, Purcell and Andrew turned to the 1927 Ridgway Report to limit the range of alternatives. The 1927 report had identified three straight-line alternatives: Location 1, from Rincon Hill to the Alameda Mole (the preferred alternative in that report); Location 2, from 16th Street in San Francisco to Alameda; and Location 3, from Telegraph Hill to the Key Route Mole, via Yerba Buena Island. To this list, the Bridge Department added additional alternatives, generating seven separate alternatives or sub-alternatives, as discussed separately below.

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[66] Hoover-Young Commission, "Report to the President," 99.

Locations No. 1-A, 1-B, and 1-C.

The three Location No. 1 alternatives extended from Alameda to San Francisco. Location No. 1-A extended from the Alameda Mole (now part of NAS Alameda) to Pier 32 in San Francisco, near the corner of Beale and Brannan. The San Francisco terminus for this alignment was about 1/2 mile south of Rincon Hill. Under this alternative, traffic tubes were to connect the roadway between the Alameda Mole and the City of Oakland on the East Bay. [67] Locations 1-A, 1-B, and 1-C were relatively minor variants on the Location 1, with variations only as to the location of the east abutments. All variations of Location 1 required a very long bridge, with no intervening island anchorage, as was ultimately provided by Yerba Buena Island.

Location No. 2.

Location No. 2 extended from 16th Street in the Mission District of San Francisco to a location on the island of Alameda. It was thus located about one mile south of Location 1, on both the east and west sites. This alternative was one suggested in the Ridgway Report.

Location No. 3.

Location No. 3 was quite similar to what was actually built, differing only as to the San Francisco abutment. Location No. 3 used the Key Route Mole between Oakland and Yerba Buena Island, as does today's Bay Bridge. In San Francisco, however, the bridge touched down at Pier 22, in the vicinity of Telegraph Hill.

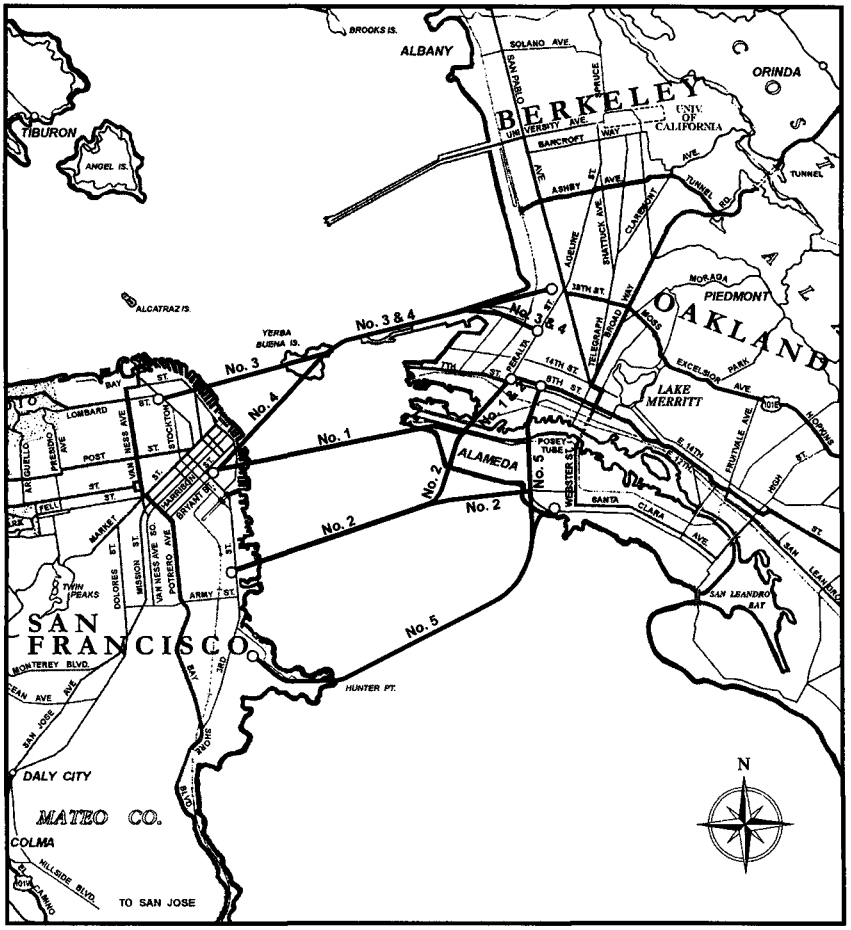
Location No. 4.

This emerged as the preferred alternative and was essentially what was built, with minor variations. In San Francisco, the touch down point was Rincon Hill. This alignment proceeded northeast to Yerba Buena Island and from the island to the Key Route Mole, with the eastern leg being identical to the eastern portion of Location No. 3.

Location No. 5.

This location linked Hunters Point in San Francisco with the natural mainland of Alameda. This alignment would be re-studied in the 1950s, commonly called the Southern Crossing.

[67] Alameda Island was much smaller in 1930 than it is today; much of the current island was filled to create the Naval Air Station there, just prior to World War II.



Source: Report of The Hoover-Young San Francisco Bay Bridge Commission, 1930
Location: Bancroft Library University of California, Berkeley

Map of H.Y.R. Bridge Alignments

The results of borings were both encouraging and discouraging for every alignment. The key conclusions drawn related to the depth to bedrock on the western span, either the western half of the bridge for Locations 1, 2, and 5, or the distance between San Francisco and Yerba Buena Island for Locations 3 and 4. The findings were discouraging for Locations 1, 2, and 5, and this, more than any other single factor, accounts for selection of the Yerba Buena Island-based alternative. In Location 1 and 1A (these were identical on the San Francisco side), bedrock was reached at depth -229', i.e. 229' below mean high water, at one key pier site west of San Francisco. Although that depth was very great, the 1 and 1A borings were the most encouraging of the three rejected alignments. At Location 2, bedrock was reached at a depth of -293' at a key western pier. The conclusion from this boring was straightforward: "It is very doubtful whether any safe bearing for such a pier could be obtained above elevation -293... For this reason the possibility of building a bridge on this location is doubtful and the line has been abandoned."[68] At Location 5, the borings extended to -233.5' without reaching bedrock, leading the engineers to conclude that "rock elevations are beyond the reach of practicable foundations."[69]

The results of the borings were far more encouraging on the west spans of Locations 3 and 4. At both locations, bedrock was reached at comparatively shallow depths for major pier locations: at -211' on Location 3 and -163.5' on Location 4. The advantageous depths were encouraging for both locations, although it was concluded that "Location No. 4 is the most favorable because of the lesser depths to shale."[70] The general conclusion about the western half of Location No. 4 was that "a high ridge of shale and sandstone extends from Pier 24 across the main channel to Goat Island." As noted, Location No. 4 was the alignment that was built. To a significant degree, the Hoover-Young sponsored borings determined the alignment between San Francisco and Yerba Buena Island, on the basis of this favorable ridge of rock.

On the east side of the bridge, however, the results were discouraging for every alternative. The borings typically extended down more than 300' and rarely made conclusive contact with bedrock. This was true of the Location 3-4 alignment (Locations 3 and 4 were coterminous on the east crossing). Three borings were made east of Yerba Buena Island. The first was 830' east of the island; "jet refusal" (presumed to be bedrock) was encountered at -269'. Another, 270' east of the island, encountered rock at -216'. In response to these findings, the Division of Highways Engineers tentatively concluded that the east spans would not (perhaps could not) be taken to bedrock. They remained hopeful that the main span just east of the island could be taken to bedrock but concluded that all other spans would be founded on hard sands. The report observes: "East of Goat Island the cantilever span adjacent to the island can be founded on shale. The remaining part of the structure is composed of 300 foot viaduct spans and can be safely supported on piles driven in sandy clay."[71]

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[68] Hoover-Young Commission, "Report to the President," 118.
[69] Hoover-Young Commission, "Report to the President," 126.
[70] Hoover-Young Commission, "Report to the President," 125.
[71] Hoover-Young Commission, "Report to the President," 125.

The foundation studies resulted in three important conclusions. First, the observed ridge between San Francisco and Yerba Buena Island was the single most important finding, leading the Division of Highways engineers to overrule the earlier conclusion of the Ridgway Report regarding the best alignment. That ridge offered bedrock foundations at very great but seemingly feasible depths and that fact, more than any other finding, determined the western location of the bridge. Second, the borings indicated that the situation was very challenging on the east crossing, irrespective of location. That conclusion freed planners to resolve the east crossing based upon other criteria. Their choices were limited, however, because of the previous conclusion that the west side of the bridge should be built to Yerba Buena Island. In effect, the high ridge on the west side determined the location for the east crossing as well. Finally, Division of Highways engineers had already concluded in 1930 that it was likely that the east crossing piers could not be taken to bedrock. Engineers would continue to grapple with this issue for another three years, before the decision was finally made to found the east crossing on sandy clays.

4.5. Traffic Studies and Their Impact on the Bridge Location

The second critical element of the Hoover-Young Commission studies was an analysis of traffic patterns between the East Bay and San Francisco, prepared by a consultant, Lester Ready. There were four possible applications for this study. First, it could be used to determine whether there was a need for the bridge. Second, it could help determine the best location for the bridge, to serve the traffic most efficiently. Third, traffic studies could help guide bridge design, leading to a structure that could accommodate the anticipated level and mix of traffic. Finally, the study was crucial to the financial analysis of the bridge because its revenue-generating capacity was based upon anticipated traffic and the sustainable tolls. Although less dramatic than the findings of the foundation studies, the traffic studies were a very key element of the work of the Hoover-Young Commission.

As summarized earlier, the traffic figures that pertained to the Bay Bridge were those for commuters living in the East Bay and working in San Francisco. The Hoover-Young traffic analysis studied this commute pattern in detail and found that the homes of the commuters were centered in the Berkeley-Oakland-Alameda area, whether people commuted by automobile or interurban. Predictably, the interurban commuters were clustered in communities that were well-served by the trains, while automobile commuters included many who were in more distant areas not served by the interurbans. The 1930 perspective on a distant commute, however, differed a great deal from modern ideas. The survey, for example, included all commuters south of Oakland in a single "zone," and that zone accounted 6.6 percent of the automobile commuters and less than two percent of interurban commuters.

The principal conclusion drawn from the traffic study was that the bridge should begin and end near the centers of each end of this commute, with one center being at or near downtown Oakland, the other being at or near downtown San Francisco. This conclusion applied equally to interurban and vehicular traffic, because the center of traffic was quite similar in each case. The reason for keeping the bridge termini near the two downtowns had to do with more than convenience; it had a profound impact on revenues as well. The Ready report devoted a great

deal of attention to the relationship among locations, tolls, and revenue. According to the report, the financial viability of the project depended upon the number of tolls as well as the toll itself. The numbers of paying customers was seen as depending upon both location and the toll rate. If the bridge were inconvenient or the toll too high, the numbers of users would decline. Conversely, a well-sited bridge would attract customers even if the rate were high, as long as there was a valuable level of service, measured in terms of convenience or time saved. This would be true for both types of traffic; the public, Ready presumed, would be prepared to pay a premium for convenience.

Ready also hinted at possible changes in traffic pattern due to the bridge's construction. He anticipated two types of diversion: a partial or total collapse of the ferry business; and diversions of some part of the interurban traffic to automobile traffic. His anticipation of the decline of the ferries was based upon common sense and the experience of other bridge projects. The Delaware River Bridge, for example, not only destroyed the ferry business but also resulted in automobile usage that far exceeded the traffic that had been carried by the ferries.[72] As to diversion of interurban traffic to automobile traffic, this impact was expected because of the differential in time saved as a result of bridge construction, vehicular versus interurban. He estimated that a bridge built on Location 3 or 4 would save 30 minutes for the average automobile commuter, traveling from the East Bay to San Francisco. The interurban user, however, would save only 10 minutes. "Increased vehicular traffic and deflection of passengers from interurban trains may be expected," Ready concluded.[73] By contrast, Ready concluded that the alignment from Hunters Point to Alameda would actually cause most vehicular commuters to drive 12 miles out of their way, resulting in a net loss of time.

Ready's analysis supported the choice of Location 4, although he felt that Location 3 was equally advantageous. The greatest importance of Ready's analysis was not locational but financial because his traffic estimates formed the basis for revenue estimates by the Division of Highways. The economic analysis section of the Hoover-Young Commission report accepted Ready's traffic forecasts but applied a complex series of assumptions about population and automobile registration increases, as well as an assumption regarding increases in traffic associated with the convenience of the location. As a basis for computing income based upon vehicular traffic, the report assumed a 10 million vehicle usage by 1940, with a three percent increase thereafter, indicating a vehicular count of 12.6 million in 1950. (Actual vehicular traffic in 1950 was 33 million.) Using these estimates, the report concluded that the bridge could support a cost of construction of $72 million, based upon a series of assumptions about toll rates, which were expected to decline over the years from an initial toll of 65 cents, as well as a series of assumptions about bond rates and expected maintenance costs.[74]

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[72] Hoover-Young Commission, "Report to the President," 54.
[73] Hoover-Young Commission, "Report to the President," 53.
[74] Hoover-Young Commission Section IV, "Economic Studies."

4.6. Studies of Bridge Types and Other Structural Issues

As a final matter, the Division of Highways engineers had to grapple to some degree with a design for the bridge because the financial viability of the project hinged in part on its cost. The section of the report dealing with design is one of the smallest, although it probably required the greatest commitment of time; Section 3, "Design Data," is nine pages long in a report that includes 209 pages of text. In the short period of time available to them, the state engineers addressed a host of design issues, all of which affected costs significantly.

The essential design criteria, as outlined in the report were: capacity (vehicular lanes and rail lines); horizontal clearance (distance between piers); vertical clearance (height); and grades. The text does little more than explain the assumptions that were used in each area. By the time this report was completed, the Division engineers had decided upon Location 4 as the preferred alternative and the discussion of design criteria focuses on that location, with much lesser discussion of the others.

In terms of vertical clearance, the engineers assumed a need for a mid-channel height of 220', which was adequate for all traffic known to enter the harbor. Their discussion of horizontal clearances is notable because of the degree to which these assumptions proved inadequate, in satisfying the Department of War members of the commission and in subsequent design considerations. The criteria used for the Hoover-Young studies assumed a need for at least one 1600' span between San Francisco and Yerba Buena Island, and at least one span of 650' between Yerba Buena Island and Oakland. The War Department and shipping interests would subsequently insist on far greater horizontal clearance and that fact would profoundly affect the selection of bridge types on both crossings. The criteria for grades assumed the need for a grade of no greater than 3 1/2 percent for vehicles and no greater than three percent for electric trains.

The criteria for capacity are of interest because they reflect the conclusions of all of the previous traffic and economic studies. Capacity reflected not only the perceived need for the bridge but also the calculated ability of the bridge to pay for itself. The criterion was this: "The structure capable of carrying the anticipated traffic should have a capacity of six lanes for highway traffic and at least two operative and one passing or emergency track for interurban trains." [75]

Elsewhere in the report, Division of Highways engineers offered sketchy discussions of structural elements required at each of the locations. Because Location 4 was so strongly preferred, a far greater degree of detail was offered for it. The structure on Location No. 4 was described with respect to six elements: arrangement of traffic lanes (section); bridge types on West Bay Crossing; roadway structure across Yerba Buena Island; bridge types between Yerba Buena Island and the East Bay; traffic distribution in San Francisco; and traffic distribution on the East Bay.

[75] Hoover-Young Commission, "Report to the President," 160.

As to traffic lanes, the Division of Highways report offered two alternatives. In one, there would have been six lanes of general vehicular traffic (automobile and truck) on the upper deck and four lanes of railroad track on the lower deck. In another alternative, there would have been six automobile traffic lanes on the upper deck, with two railroad tracks and two truck lanes on the lower deck. Sidewalks were included with both alternatives, built on the upper deck.[76]

As to West Bay Crossing bridge types, the Division of Highways recommended construction of four 1700' cantilever spans, with 600' anchor spans at either end. Yerba Buena Island was to be crossed "by a cut, fill, and viaduct." The East Bay Crossing was seen as comprising one 720-foot deck cantilever adjacent to the island, followed by 21 300' steel deck spans. The bridge types were illustrated in the report. As noted, the eastern cantilever was a deck cantilever type, while the larger West Bay Crossing cantilevers were of a more conventional through cantilever type. The cut through Yerba Buena Island was a deep trench, extending from elevation 300' to about 150', with viaducts at either end.

Traffic distribution in the East Bay was described briefly: "The highway traffic is distributed by two roads to Yerba Buena Avenue and Twenty-second street, each passing through a subway under the Southern Pacific tracks. Railway connections are made directly into the present track systems of the Key Route and Southern Pacific railroads."

The traffic distribution in San Francisco was described in much greater detail:

> Highway traffic in San Francisco is carried on Harrison street to a plaza located between Fourth and Fifth streets and Folsom and Bryant streets. A ramp for truck and automobile traffic takes off the approach viaduct at First and Essex streets and discharges traffic to the Embarcadero and waterfront. Interurban railroad traffic loops off the approach viaduct on First street and runs over an elevated loop on First street to Minna street; from which it proceeds west on Minna street to Sixth street; south on Sixth street to Clementina street, then east to First street.
>
> Four loop stations are contemplated. In the estimates given it is proposed to receive and discharge main line railroad passengers to and from the main line railroad in Oakland at the first street loop station. It may be found necessary, however, to establish a terminal station on Rincon Hill for this purpose. Connection to such a station could easily be made to the bridge.[77]

The discussion of structural elements is remarkable in two respects: how brief it is, and how different it was from the bridge that was built in 1933-36. There is essentially nothing about the structure described in 1930 that resembled the structure that was built. Only three elements are roughly the same: the traffic mix, as described in the second alternative; the traffic plaza between Fourth and Fifth streets; and the off-ramp for delivering traffic to the Embarcadero. In every

[76] Hoover-Young Commission, "Report to the President," 137.

[77] Hoover-Young Commission, "Report to the President," 137-138.

other respect, the Hoover-Young studies identified a very different bridge. This last point is of interest chiefly because it shows how little of the design work had been accomplished by 1931. State political and civic leaders were no doubt of the impression that much of the work had already been accomplished, as a result of the lengthy Hoover-Young Commission studies. In actual fact, virtually none of the design problems had been resolved by 1930. The location had been set and the general traffic mix more or less resolved. In all other respects, the Bay Bridge was yet to be designed.

4.7. Recommendations of the Commission

The Hoover-Young Commission received copies of the Division of Highways studies on July 19, 1930. It re-convened on July 22, and met again on July 28, 29, 30, 31, as well as August 4, 5, and 6, before adjourning permanently on August 6, 1930. It entertained public testimony only on July 28 and 29, 1930. Political and civic leaders from San Francisco and the East Bay addressed the committee, generally supporting any type of bridge between the two points. The only expression of disappointment came from the City of Alameda, which was to have been the eastern terminus of the bridge under the Ridgway Report plan but not under the plan of the Hoover-Young Commission.

The bulk of these meetings were dominated by two tasks: the elimination of all alternatives other than Alternative 4; and the negotiation of vertical and horizontal clearances that would be acceptable to the Army and Navy representatives. The first task was handled sequentially; at each meeting, the group would vote to eliminate one of the alternatives, until, on August 4, it voted its sense that "the only practicable site for a high level bridge across the Bay is Location 4, from Rincon Hill to Goat Island."[78]

Negotiations between the Californians and the Army and Navy members were somewhat more delicate. Admiral Standley, speaking for the Navy, and Lt. Col. Daley and Brig. Gen. Pillsbury, speaking for the Army, read into the record long statements, reiterating their long-held opposition to any transbay bridge north of Hunters Point. The Navy began its statement: "We desire to present to the Commission for consideration certain inherent objections to a bay bridge of the type and in the position shown as Location No. 4."[79] The Army statement similarly expressed concern about the bridge as an impediment to all types of navigation, commercial as well as military. Nonetheless, both reluctantly accepted the apparent inevitability of a bridge, and expressed their support for Location No. 4 over the others. The Navy, for example, concluded: "No bridge north of Hunter (sic) Point is free from naval objection, but a bridge on Location No. 4, 'Rincon Hill-Goat Island' is the least objectionable from the standpoint of national defense."[80]

With the grudging support of the military in hand, the commission adopted 13 measures, or "conclusions." These were:

[78] Hoover-Young Commission, "Report to the President," 11.
[79] Hoover-Young Commission, "Report to the President," 22.
[80] Hoover-Young Commission, "Report to the President," 23.

(a) To meet the present and future needs of the several communities a crossing for traffic between San Francisco and the East Bay cities is necessary.
(b) Consistent with meeting the traffic needs and engineering requirements the type and location of a bay crossing should be such that it will not unreasonably obstruct future navigation nor cause serious interference with or constitute a serious menace to the operations of the Navy in time of war.
(c) Because of the limitations, cost of construction and operation a vehicular tunnel under the bay is inadvisable.
(d) As indicated by the rock explorations the only location upon which to base a high level bridge is on a line from Rincon Hill to Goat Island.
(e) A bridge on the location designated as Location No. 4, from Rincon Hill via Goat Island thence parallel to the Key Route mole, is practicable from an engineering standpoint. It is economically feasible under a proper fiscal plan and will adequately serve the traffic.
(g) The bridge shall provide at least six lanes for vehicular traffic and in addition five lanes for interurban and heavy automobile truck traffic.
(h) The bridge between San Francisco and Goat Island shall consist of not more than four main spans, the westerly one of which shall have a horizontal clearance of not less than 1750 feet between fenders.
(i) The vertical clearance of the two center spans shall be not less than 214 feet above M.H.H.W. [mean higher high water] at the center of the spans, and this height shall be maintained for approximately 500 feet on either side of the center of the span, and minimum vertical clearance at the San Francisco pier head line shall be 180 feet above M.H.H.W.
(j) The [East Bay Crossing] shall have a minimum vertical clearance of 180 feet above M.H.H.W and a minimum horizontal clearance of 600 feet between fenders. Consideration shall be given in the final plans to a minimum clearance of 700 feet between fenders.
(k) The final design should be such that it will conform with the scenic beauty of San Francisco Bay.
(l) The details of construction of the bridge structure is the function of the State of California working through the California Toll Bridge Authority. Consideration of traffic distribution on both sides of the bay is of prime importance and should be worked out in cooperation with the authorities of the municipalities in interest.
(m) A right of way across Goat Island must be obtained from the Navy Department and be approved by Congress.[81]

The conclusions of the commission may be grouped according to those that were contested and those that were not, with the length and specificity of the conclusion serving as a indicator of a contested conclusion. The longest conclusions were those relating to vertical and horizontal clearance, reflecting the strong opinions of the military leaders, balanced against the equally

[81] Hoover-Young Commission, "Report to the President," 2-3.

strong positions of the state leaders. Conclusion (b) best reflects the compromise reached between these interests: "Consistent with meeting the traffic needs and engineering requirements the type and location of a bay crossing should be such that it will not unreasonably obstruct future navigation nor cause serious interference with or constitute a serious menace to the operations of the Navy in time of war." Conclusion (l) reflects a different type of compromise, between state planners who wanted maximum flexibility in design and local officials, who were very concerned about access: "(l) The details of construction of the bridge structure is the function of the State of California working through the California Toll Bridge Authority. Consideration of traffic distribution on both sides of the bay is of prime importance and should be worked out in cooperation with the authorities of the municipalities in interest."

4.8. Significance of the Hoover-Young Commission in Building the Bay Bridge

The design of the Bay Bridge was built around agreements and conclusions obtained in three pivotal documents or sets of agreements: the 1927 Ridgway Report; the 1930 Hoover-Young Report; and the positions of the Board of Consulting Engineers, reached between 1931 and early 1933. Each had a particular role. The Ridgway Report committed the leaders of San Francisco and East Bay cities to a downtown-to-downtown alignment, beginning at or near downtown San Francisco and terminating either in Alameda or Oakland. The Hoover-Young Commission brought into this agreement the acquiescence of the State of California and the federal government, and resolved the bridge location, traffic mix, and roadway sectional design. The Board of Consulting Engineers would decide upon the remaining structural elements of the bridge.

All three were of tremendous importance in ensuring the bridge would be built. The case could be made that the Hoover-Young report was the most important of the three, in that it resulted in conceptual agreement among long-time antagonists that the bridge should and could be built, and on the essential characteristics of the bridge. Six years later, the bridge was open to the public. Many argued at the time that then ex-president Herbert Hoover deserved the honor of cutting the ceremonial chain and dedicating the bridge to the public. To the extent that Hoover succeeded in removing the political barriers to the bridge's construction, that suggestion had validity.

5. LEGISLATIVE AND REGULATORY IMPEDIMENTS TO BUILDING THE BAY BRIDGE, 1927 TO 1933

The Hoover-Young Commission removed the most serious challenge to construction of the Bay Bridge: the refusal of the War Department to issue a permit for its construction. War Department opposition, however, was not the only legal or regulatory roadblock; the political landscape was littered with such impediments, any one of which could have prevented the bridge's construction.

Step by step between 1927 and 1933, leaders from the Bay Area overcame these various obstacles. Initially, San Franciscans led this effort, bolstered by the findings of the Ridgway Report. Gradually, they were joined by leaders from the East Bay cities and by state officials. During these years, the coalition of Bay Area cities and state officials faced five important challenges: 1927-28 hearings at the War Department and in Congress; 1929 legislation in the California Legislature to create the California Toll Bridge Authority; the final 1931 permit from the War Department; 1932 hearing before Congress to modify the role of the Reconstruction Finance Corporation; and 1932-3 hearings before the RFC to approve the establish the conditions of the loan. These five steps are detailed in this chapter.

5.1. 1927-28 hearings at the War Department and in the U.S. Senate

San Francisco officials recognized in 1927 that the principal impediment to construction of a transbay bridge, at least one north of Hunters Point, was the opposition of the War Department. City leaders had been rebuffed so often by the War Department that they resolved to take another tack: to seek direct congressional approval of a transbay bridge, with or without the acquiescence of the War Department. Specifically, the city sought direct congressional approval for construction of a bridge on the preferred alignment from the 1927 Ridgway Report. Hiram Johnson, longtime U.S. Senator from California, introduced that legislation.

Before turning to Congress, however, the San Francisco leadership made one last attempt to change the views of the War Department. In June 1927, the City and County of San Francisco sent a large delegation to Washington, D.C. to urge War Department approval of the preferred alternative from the Ridgway Report. The delegation included Mayor James Rolph, City Engineer M. M. O'Shaughnessy, several supervisors, the city attorney, and others. As one delegate, Supervisor Franck Havenner, told War Department representatives, the Ridgway Report galvanized local support: "The people of San Francisco are of one mind for the bridge and they have accepted with unanimity the plans of the experts."[82] The appeal was again rejected, chiefly on the basis of Navy concerns over unimpeded access to San Francisco by the fleet.

This War Department rejection, released in October 1927, convinced many San Francisco leaders that no recourse was available other than direct appeal to Congress. "Road now Clear for Direct Appeal to Congress for Bridge," read the headline of an October 15 editorial in the *San Francisco Chronicle*. "Congress will, we trust, be better able to look at the question of a bay bridge from

[82] *San Francisco Chronicle*, June 22, 1927, 4.

the broad standpoint of the general good," the editorial continued, "Looked at in the broad way it will be obvious that San Francisco bay will be bridged some day and, therefore, might as well be bridged now."[83]

One crucial set of hearings was conducted before the Commerce Committee of the U.S. Senate in March of 1928. Among those testifying were Mayor James Rolph (who would be elected governor of California in 1930), U.S. Senator Hiram Johnson, City Engineer O'Shaughnessy, and others. The issue at hand was a bill by Senator Johnson that would have approved the permit for construction of the Bay Bridge, over the objections of the War Department.[84] The bill failed, chiefly because of strong objections raised by the War Department and the Navy. The Johnson bill was the last attempt by San Francisco leaders to seek on their own the approval of the Bay Bridge; all subsequent efforts would be geared toward approval of a project that would be owned and built by the State of California. Although they ended in failure, the long independent actions by officials of San Francisco paved the way for the state project.

5.2. Creation of the California Toll Bridge Authority in 1929

In 1929, civic leaders in the Bay Area and political leaders in Sacramento abruptly changed the eighty-year old policy of the State of California with respect to toll bridges. Until 1929, all toll bridges in California had been privately built under franchises from the county in which they originated. After 1929, the official policy and practice of the state was that all toll bridges were to be publicly owned and managed by the State of California. This change in policy affected all toll bridges in California but none more profoundly than the Bay Bridge. The decision to create the California Toll Bridge Authority appears to have been motivated in part to advance plans for the Bay Bridge, but also to establish some degree of control over existing toll bridges, particularly the Carquinez and Dumbarton. The leadership in this effort came from Bay Area legislators and civic leaders, although the legislation had the consistent support of Governor C. C. Young.

The initial action was legislation introduced in 1927 by State Senator Roy Fellom of San Francisco. Fellom was first elected to the senate in 1920 and continued to serve through the early 1930s.[85] His measure, approved by the legislature and signed into law in May 1927, directed the California Highway Commission to conduct an investigation of the operation of toll bridges in the state "with reference to the taking over of any existing bridge by the state."[86]

The 1927 legislation appears to have been motivated by dual concerns: San Francisco's frustration with getting a bridge built; and the growing dissatisfaction of Bay Area motorists with tolls on the two privately built toll bridges in the area. As noted, the Bay Area by 1927 had two large privately built bridges and another underway: the Carquinez Bridge and the Dumbarton

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[83] *San Francisco Chronicle*, October 15, 1927, 24.

[84] The hearings for this bill are described in some detail in Keven Starr's *Endangered Dreams*, 326-327.

[85] *Califonria Blue Book or State Roster* (1932), 41.

[86] Legislative Calendar, California Senate.

Bridge were in operation and the San Mateo Bridge was under construction. Although the Carquinez and Dumbarton bridges were only a few years old at the time, they were already causing some concern among the motoring public, chiefly on the basis of high tolls. The tolls on these bridges were extraordinarily high: the toll for the Carquinez Bridge, for example, was 84 cents in 1928, or about $8.40 in 1994 dollars.[87]

The investigation resulted in a report that was completed in 1928 but released to the legislature in 1929. It concluded that bridge tolls were higher than they needed to be, chiefly because of the costs of borrowing and promotion incurred by private parties, costs that would not be borne by the State of California. The report concluded that the state could build and operate toll bridges at lower costs, and recommended that the state act quickly before any more advantageous toll crossings, such as the Carquinez Bridge crossing, fell into private hands.

The 1928 investigative report is of some interest because it was partially the work of C. H. Purcell and Charles Andrew, the heads of the Division of Highways and the Bridge Department at the Division of Highways, respectively. Both had been hired to work at the division at about the time the investigation was ordered, Andrew in 1927, Purcell in 1928. These two men would play key roles in designing and building the Bay Bridge; indeed, Purcell and Andrew arguably did more than any other two individuals in guiding the bridge to successful completion. Their involvement with the bridge as early as 1928 only reinforces that argument.

The 1928 report appears to have solidified support among state political leaders and Bay Area legislators and civic leaders around two propositions: that existing toll bridges should be purchased by the state; and that any future toll bridges should be built by the state, especially the Bay Bridge. In October 1928, San Francisco officials organized a meeting at City Hall, inviting political and civic leaders of San Francisco and ranking officials of the State of California. Attendees included C. H. Purcell and Charles Andrew from the Division of Highways, B. B. Meeks of the California Department of Public Works, M. M. O'Shaughnessy, and several San Francisco supervisors. The specific agenda of the meeting was how to advance construction of the Bay Bridge. The meeting closed with the conclusion, however, that the state should pursue the idea of state ownership of all toll bridges. Meeks was quoted as saying that "all such bridges [toll bridges] should be a part of the State highway system." City leaders were quoted as saying that "If the State gets back of the bridge, it will practically assure favorable action by Congress, and will remove certain opposition."[88] Two days later, Governor Young expressed his support for the general propositions agreed to in the San Francisco meeting.[89] He said: "I favor legislation to

[87] California Highway Commission, "Investigation and Report on Toll Bridges in the State of California," *Appendix to the Journals of the Senate and Assembly of the Forty-Eighth Session of the Legislature of the State of California*, Vol. 4 (Sacramento: California State Printing Office, 1929). The factor for equating modern dollars with those in the late 1920s and early 1930s is between 10 and 12, depending upon the year. With 1984 as a base, the San Francisco-Oakland consumer price index was 146.3 in 1994. In 1928, that figure was 14.8. The figure went down during the deflation of the 1930s, bottoming out in 1933 at 11.8. Arsen J. Darney, *Economic Indicators Handbook, Second Edition*. Detroit: Gale Research, Inc. 1994, 770-771.

[88] *San Francisco Chronicle*, October 3, 1928, 17.

[89] *San Francisco Chronicle*, October 5, 1928, 1.

put into effect machinery for carrying out a revenue bond plan of financing as outlined by Meek. I feel the benefit to be derived by the State from construction of a San Francisco bay bridge warrants the State inaugurating such a plan." In coming days, civic leaders from throughout the Bay Area endorsed the proposal, including a very strong expression of support from San Francisco Mayor James Rolph.[90]

State Senator Fellom of San Francisco introduced the necessary legislation on January 18, 1929, the first day of the legislative session. With minor revisions in committee, the bill passed both houses unanimously in May and the bill was signed into law on June 10, 1929.[91] The legislation represented a fundamental shift in state policy, for toll bridges in general and for the Bay Bridge in particular. In its key provisions, this law and companion measures:

1. Declared it the policy of the state to acquire all existing toll bridges.
2. Amended the law so as to vest the power to grant franchises for private toll bridges in the department of public works.
3. Created the California Toll Bridge Authority, a board consisting of the governor, lieutenant governor, director of public works, director of finance, and the chairman of the highway commission.
4. Designated the department of public works as the agent of the commission to design, construct, and operate toll bridges.
5. Authorized the authority to "lay out, acquire and construct a highway crossing from the city of San Francisco to the county of Alameda."
6. Appropriated a revolving fund of $50,000 for preliminary investigations.[92]

The legislature's decision to create a separate entity -- the CTBA -- and to use the name, authority, suggests the origin of the arrangement. An "authority" has been regarded as a public agency empowered to conduct business with a greater degree of flexibility and business-like procedures than is typically the case. In one definition, an authority was seen as a "governmental business corporation set up outside the normal structure of a traditional government so that it can give continuity, business efficiency and elastic management to the construction or operation of a self-supporting or revenue producing public enterprise."[93] The model for an "authority" in 1929 was the Port Authority of New York, which was established in 1921 and which had built the Holland Tunnel and was completing the George Washington Bridge.[94]

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[90] *San Francisco Chronicle*, October 6, 1928, 13.

[91] California Legislature, "Senate Final History," Senate Bill 700, 1929, 240-1.

[92] Summarized in C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, San Francisco-Oakland Bay Bridge: A Review of Preliminaries," *Engineering News-Record* (March 22, 1934): 372. A concise discussion of the legislative history of the bridge is provided in: C. C. Carleton, "Legal History of the Transbay Bridge Project," *California Highways and Public Works* (November 1936): 22-23.

[93] The quotation is from Luther Gulick's "Authorities and How to Use Them," *Tax Review* (November 1947); quoted in Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge" (Sacramento: California Legislature, 1953): 12.

[94] See Henry Petroski's *Engineers of Dreams* for a brief history of the Port Authority.

The creation of the CTBA had both short- and long-term implications for the Bay Bridge. In the long run, of course, the CTBA would build the bridge and operate it. In the short term, the act created a legal and institutional arrangement through which the bridge could be built. The existence of the CTBA made the work of the Hoover-Young Commission easier. With respect to how the bridge should be financed and constructed, the Hoover-Young Commission simply recommended: "The legislative authority of the state for the construction of the bridge is vested in the California Toll Bridge Authority. In order that the bridge may be constructed it is necessary that the Bridge Authority authorize and direct is construction." As to the design of the bridge, the commission recommended: "The details of construction of the bridge structure is the function of the State of California working through the California Toll Bridge Authority."[95]

The California Toll Bridge Authority remained a shell organization through 1929 and 1930, while the Hoover-Young studies were underway. The CTBA legislation was approved only weeks before the Hoover-Young Commission was appointed and state and local officials concentrated on the work of the commission. After 1930, however, the CTBA and the Department of Public Works became the focal point for the Bay Bridge campaign, displacing civic and political leaders in that regard. By 1932, C. H. Purcell, the Chief Engineer for the Bay Bridge, would emerge as the chief spokesman for the CTBA and for the State of California, although the older coalition of civic leaders from San Francisco and the East Bay would continue to play important roles.

5.3. 1931 permit from the War Department

The principal contribution of the Hoover-Young Commission was the fact that it silenced the opposition of the War Department. War Department representatives were part of the Commission and essentially signaled their intent to approve the permit by agreeing to its findings. The Bay Bridge Division of the Department of Public Works handled all of the negotiations with the War Department and apparently did not ask Bay Area civic and political leaders to help. These negotiations included some reassessment of earlier proposals on the part of the War Department; the Navy and Army would demand horizontal clearances far in excess of those agreed to in the Hoover-Young Commission report. These demands greatly affected the design of the bridge, resulting in the decision to build a suspension span between San Francisco and Yerba Buena Island and a major cantilever structure on the Oakland side of the bay. These design decisions are discussed in detail in Chapter 7. Beyond those changes, however, the War Department permit was acquired without notable opposition or controversy.

5.4. 1932 hearings before Congress to Modify the Reconstruction Finance Corporation to Enahle It to Approve Bay Bridge Bonds

Nothing so clearly places the Bay Bridge within the context of the Great Depression as the state's relationship with the Reconstruction Finance Corporation. The depression had many impacts on the planning and construction history of the Bay Bridge but none more important than its impact

[95] Hoover-Young Commission, "Report to the President," 3.

on its finances. When the State of California accepted responsibility for building the bridge, it assumed that construction costs would be financed through conventional revenue bonding, in the manner of many of the great bridges built during the 1920s. The collapse of financial institutions in 1929 and 1930, however, crushed those plans. As summarized succinctly in a report of the California Legislative Auditor, "The original conception of financing the project was to sell bonds of the Toll Bridge Authority to private financial interests. However, the financial depression which started in 1930 with the consequential drop in the bond market rendered such a procedure impossible."[96] The crisis in American financial institutions ultimately led to the creation of the Reconstruction Finance Corporation, or RFC, in early 1932; it was through the bonding powers of the RFC that the Bay Bridge was ultimately financed.

Congress and Hoover did not initially see the RFC as a vehicle for financing public works projects. Rather, the RFC was designed to assist the banking community to encourage private lending, which had collapsed with the economic downturn.[97] President Hoover called for creation of the RFC in a December 7, 1931 message to Congress. The measure was approved by Congress on January 22, 1932 and signed into law the same day. During the early months of 1932, the RFC issued millions in loans to distressed banks.

In mid-1932, however, the Democrat-controlled Congress sought to expand the scope of the RFC, or some other agency, to extend loans to states, cities, and counties, to foster employment-providing public works. The leader in this effort was Senator Robert Wagner of New York, chair of the Senate Committee on Banking and Currency and a leading advocate for organized labor. Although Wagner initially supported separate funding by borrowing against Federal gasoline tax revenues, the Hoover Administration would not support such public works investments unless they were managed through the RFC. Specifically, Hoover supported authorization for the RFC to purchase bonds from state or local agencies, bonds which would be financed from revenues associated with the project itself, or "self-liquidating public works" as they were called. The disagreement between Hoover and Congress delayed passage until July of 1932, when a compromise Emergency Relief and Construction Act passed Congress and was signed by the President. Included in that legislation was an authorization for the RFC to purchase more than $1 billion of bonds for self-liquidating public works projects by states and localities.[98]

The State of California in mid-1932 was well on its way in the design of the Bay Bridge but had no assurance that any or all of the work could be financed through private sales of revenue-based bonds. The so-called self-liquidating proposal for the RFC seemed ideally suited to the needs of California and state leaders supported it strongly. Hearings were conducted at various times during mid-1932 on competing Republican and Democratic versions of what would become the

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[96] Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge," 15.

[97] There are many excellent studies of the RFC. For a discussion of the relationship between the RFC and the Bay Bridge, see: James Stuart Olson's *Herbert Hoover and the Reconstruction Finance Corporation, 1931-1933* (Ames, Iowa: Iowa State University Press, 1977); and Jesse H. Jones' *Fifty Billion Dollars: My Thirteen Years with the RFC, 1932-1945* (New York: McMillan Company, 1951).

[98] The legislative history of this act is detailed in Chapter 2 of Olson's *Herbert Hoover and the Reconstruction Finance Corporation.*

Emergency Relief and Construction Act. California was represented before most of these hearings, chiefly to support any version that included federal funding for self-liquidating public works projects. In a pattern that would persist until all political impediments were overcome, Leland Cutler and C. H. Purcell represented the state.[99]

Leland Cutler, a San Francisco insurance executive, was elected to head the San Francisco Chamber of Commerce in 1930. He became a fixture in the lobbying effort for the Bay Bridge before Congress and the RFC, first representing the Chamber of Commerce and later as a spokesman for the State of California, representing the Financial Advisory Board of the California Toll Bridge Authority. Cutler was appointed to the Financial Advisory Board by the CTBA, along with more than a dozen other business leaders from the Bay Area. His work is especially important to historians in that he recorded these events in a long chapter in his autobiography.[100] His efforts were partially rewarded in that he was asked to preside over San Francisco ceremonies dedicating the bridge in November 1936.

Purcell spoke before Wagner's Committee on Banking and Currency, on June 7, 1932. His remarks illustrate the success the state had achieved at that point in designing the bridge as well as its failure in financing it. He noted: "This structure has been underway, from an engineering point of view, surveys and traffic studies, for the past three years, the State having spent over $700,000 in the engineering to date... We have proceeded to the state where construction can begin immediately, were financing available." He went on to note that "at this time" there was no private market for bonds based upon the revenue of the bridge. Purcell also spoke to the economic and political realities of mid-1932, extolling the importance of the bridge in fostering economic recovery and employment. "This structure involves the employment continuously of 7000 men, which does not include the indirect employment made possible by the purchase of structural steel and other materials. This order involves 150,000 tons of steel... It involves 1,250,000 barrels of cement. It involves 50,000,000 feet of lumber in the foundation work."[101]

The Emergency Relief and Construction Act was not specific to the Bay Bridge. "Self-liquidating" loans would be used in public works projects throughout the United States, including the Colorado River aqueduct in Southern California. Purcell and Cutler lobbied for various versions of the bill because the loan program was essential to construction of the bridge. As Purcell noted, the design of the Bay Bridge was well on its way in mid-1932, although he exaggerated in saying "construction could begin immediately"; the plans would not be completed for another six months. Passage of this act did not, however, ensure that the RFC could lend the funds needed for the Bay Bridge. The law created a mechanism through which California and all other states, cities, counties, and special districts could apply for such loans. It would be nearly another year before final RFC approval was granted.

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[99] Hessen, *Herbert Hoover and the Bay Bridge*, 7.

[100] Leland W. Cutler, *America is Good to a Country Boy* (Stanford: Stanford University Press, 1954).

[101] These remarks are included in *Purcell Pontifex: A Tribute* (San Francisco: "Privately Printed by his Friends," 1937),, 22-23.

5.5. 1932-33 Negotiations with the Reconstruction Finance Corporation to Finance Construction

The Emergency Relief and Construction Act greatly expanded the scope of the RFC, forcing the agency to create a new administrative structure. In August 1932, shortly after the bill was signed, the RFC created a new Self-Liquidating Division to handle the public works loans program. Harvey Couch was appointed director of this new division.[102] The State of California submitted its application to the Self-Liquidating Division within a month of its creation.

Between August 1932 and April 1933, the state sent numerous delegations to Washington, D.C. to negotiate the terms of the loan. The negotiations were difficult; some members of the board of the Self-Liquidating Division opposed granting the loan. It appears that two teams of Californians were sent to address the concerns of the RFC: a technical team, headed by Purcell, to address the structural issues of the bridge itself; and a financial team, headed by a Financial Advisory Committee, which had been appointed by the California Toll Bridge Authority to speak in its behalf. The Financial Advisory Committee would continue to serve until all elements of the bridge had been built. A three-member sub-committee included Leland Cutler, Joseph Knowland, the editor of the *Oakland Tribune*, and Harrison Robinson, who served as a its chair. Robinson was an attorney from Oakland.[103] A third team, which might be considered the political team, also met with federal officials on several occasions to demonstrate local political support. In October, 1932, for example, Ogden Mills, the Treasury Secretary in the Hoover administration, came to San Francisco to gauge local support, and met with the mayors of San Francisco, Oakland, and Berkeley, along with prominent labor and business leaders.[104]

The RFC approached self-liquidating loans in a business-like manner, insisting that the applicant provide assurances that the revenue stream could retire the loans. The negotiations between the state and the RFC were sometimes contentious as the RFC questioned the assumptions on which the state's revenue projections had been made. The tenor of the negotiations is illustrated by one incident, as recalled by Cutler and Jesse Jones, the director of the RFC. Early in the course of negotiations, Cutler had appeared before the board of the Self-Liquidating Division. In what was apparently a heated debate, Cutler was asked repeatedly about the traffic estimates for the bridge, existing traffic on vehicular ferries, and other factual points that pertained to the capacity of the bridge to generate enough revenue to pay back the multi-million dollar loan. Cutler did not have the data sought by the board. He recalls that Harvey Couch pulled him aside and said, "Cutler, did you ever play football in college?" Cutler recalls saying that he had played quarterback. To which Couch is said to have replied: "Did you ever take time out when you got in trouble? You're in trouble now, Son; take time out."[105]

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[102] Olson, *Herbert Hoover and the Reconstruction Finance Corporation*, 76.

[103] Jones, *Fifty Billion Dollars*, 168; Hessen, *Herbert Hoover and the Bay Bridge*, 7; Olson, *Herbert Hoover and the Reconstruction Finance Corporation*, 78-80.

[104] *San Francisco Chronicle*, October 6, 1932.

[105] This story is told in various sources, including Cutler's autobiography. This story is told in nearly the same language in Jones' *Fifty Billion Dollars*, 168.

The California delegation continued to appear before the board between August and December of 1932, agreeing to a series of conditions, ranging from the total size of the loan, the toll that would be charged upon completion, the interest on the loan, and myriad other issues. In Cutler's recollection, the board had been persuaded to approve the application, except for the opposition of one board member, Garner Cowles. Cutler recalls that he sought the intervention of two Californians: Ray Lyman Wilbur, the Secretary of the Interior, and President Herbert Hoover. Hoover apparently called a meeting with Cowles and convinced him to drop his opposition.[106]

The Self-Liquidating Division and the RFC presented its final terms to the state on December 12, 1932. An executive session of high-ranking state officials was convened on December 13 in Sacramento to go over the proposed terms. The meeting was attended by Governor Rolph, Purcell and Andrew from the Bay Bridge Division, and Cutler, Knowland, and Robinson from the Financial Advisory Committee. The state signed the contract that day, and the RFC countersigned on December 15, executing the contract subject to changes in state law.[107] The contract required 32 amendments to state law. These changes were made in early 1933, and the RFC gave its final approval on April 27, 1933. The contracts for building the bridge were awarded a few days later.

Contract negotiations were greatly hampered by the inability of the state to reach agreement with the two interurban carriers – the Southern Pacific Railroad and the Key System – over terms for rail use of half of the lower deck. The RFC held fast to its requirement that anticipated revenues back the loans. In the absence of agreement with the railroads, the state could not demonstrate a revenue stream from interurban use. In the absence of that revenue stream, the RFC would not lend money on project elements associated directly with the railroads. Thus, the state sought and received a $62 million loan for a $72 million project, with the stated understanding on the parts of the state and RFC that California would be returning for a loan for the additional $10 million when agreement had been reached with the interurbans.[108]

5.6. Significance of the Efforts by Bay Area Civic and Political Leaders in the History of the Bay Bridge

In October, 1932, the three-member sub-committee of the Financial Advisory Committee (Cutler, Knowland, and Robinson) returned to California from Washington, D.C., knowing that the essential terms of the RFC loan had been agreed to by the RFC board. The members were greeted by a parade along Market Street in San Francisco in their honor, complete with a marching band and speeches at City Hall. Perhaps as a symbolic gesture but probably as a practical measure, the three came to San Francisco from Oakland by ferry; they had debarked

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[106] Hessen, *Herbert Hoover and the Bay Bridge*, 9-10.

[107] *San Francisco Chronicle,* December 14, 1932.

[108] The negotiations with the railroads are detailed in Chapter 11. The details of the side agreement are discussed in: Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge."

from a train in Oakland.[109] The three men were honored several days later at a meeting of the Commercial Club, a meeting attended by business leaders from San Francisco and Oakland.[110]

The celebration on both occasions is somewhat surprising in that nothing concrete had been accomplished in October 1932. The RFC loans were still months from being signed; the bridge was not finally designed; no contracts had been let; and certainly no physical work had been accomplished. A keen understanding of the complex political process was required to appreciate the exact nature of the accomplishment for which the men were being honored.

These celebrations took place because the participants *did* have a keen understanding of the process. Many had been involved in the campaign for the Bay Bridge for more than a decade. A few, such as Cutler and George Cameron, the editor of the *San Francisco Chronicle*, had been involved on a nearly full-time basis (without compensation) since 1929. The three members of the committee were gracious in passing around credit for the accomplishment, mentioning Cameron, Governor James Rolph, Herbert Hoover and others. All remarked upon the unprecedented cooperation between San Francisco and the East Bay cities. "Quietly, efficiently, everyone connected with this enterprise has worked together shoulder to shoulder," Cameron remarked at the meeting of the Commercial Club, "without much publicity."

The participants appreciated the celebrations in October 1932 because they understood that their work was nearly done. San Francisco and, to a lesser degree, Oakland civic, business, and political groups had championed the Bay Bridge through a maze of political hurdles between 1927 and 1932. Over the course of this five year period, the campaign for the Bay Bridge resulted in the creation of official institutions that could plan and promote construction of the Bridge, particularly the California Toll Bridge Authority and the Hoover Young Commission, and the Bay Bridge Division, the engineering organization that designed the bridge. Gradually during the 1929-32 era, the spokespersons for these institutions displaced the civic and business leaders as the official representatives for the Bay Bridge campaign. In time, C. H. Purcell became the one fixed point in that campaign, representing the state whenever he was needed.

The San Francisco and Oakland civic and business leaders had kept the coalition together until these official institutions could be put together. They had also played important parts in those official institutions. George Cameron, for example, had served on the Hoover-Young Commission. Leland Cutler would serve as an official spokesman for the California Toll Bridge Authority, as would Knowland and Robinson. James Rolph was mayor of San Francisco in 1927 but would be elected as governor in 1930 and would preside over the final approval and part of the construction of the bridge before dying in office in 1934.

The 1932 celebrations were premature in terms of solid accomplishments but were understandable in terms of the perceptions of the participants in the negotiations with the RFC. The civic and business leaders had taken the process about as far as they could. After 1932, the

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[109] *San Francisco Chronicle,* October 16, 1932, 3.
[110] *San Francisco Chronicle,* October 19, 1932, 4.

primary responsibility for the bridge passed to state officials, particularly to Purcell. Unfinished business remained but was chiefly technical in nature, something that could be worked out in most cases by agreement among technical experts. The civic and business groups had taken the bridge through a tangled political network; that was the significance of what had been accomplished between 1927 and 1933, and that was very significant indeed.

6. THE CONTEXT OF GREAT BRIDGES FROM THE 1920S AND 1930S

The Bay Bridge was designed and built near the end of what was one of the most remarkable chapters in American bridge construction, a decade from the mid-1920s through the mid-1930s during which some of the best-known and most significant bridges in the United States were erected. Periodically, the pace and scale of bridge construction has accelerated, as bridge engineers, public financiers, and highway planners learned from and built upon prior accomplishments. During these periods of quickened activity, the pent-up demand was satisfied by the construction of bridges over the most difficult crossings. The 1870s and 1880s, for example, represented one such period of prodigious bridge construction; the Eads Bridge in St. Louis, the Brooklyn Bridge in New York, and the Firth of Forth Bridge in Scotland, all landmark achievements in the science of bridge building were built during those decades. The first decade of the 20th century also witnessed a great spate of significant bridge construction. The decade from 1927 through 1937 certainly qualifies in this regard as well.

During the decade from 1927 to 1937, engineers, contractors, and public transportation planners successfully conquered some of the most vexing crossings in the American landscape, and built some of the most beautiful and significant bridges in the world. While arguably one of the grandest of these, the Bay Bridge was but one of many great bridges constructed during this decade. Its success must be appreciated within this context – as one of many great bridges built during a period of prodigious feats of engineering and design.

In addition to its importance in the history of great bridges, this decade was also notable in the history of the engineering profession. During this period, individual engineers sought out and received recognition for designing these great bridges, even though the degree of collaboration necessary to design such bridges increased roughly in proportion to the size of the bridges. From the mid-1920s through the mid-1930s, there emerged a small group of bridge engineers who achieved popular recognition and individual attribution for their efforts.[111] Leon Moisseiff, Ralph Modjeski, David B. Steinman, O. H. Amman, J. B. Strauss and others became, if not household names, certainly widely published and quoted public figures. Rarely before or since have structural engineers been treated to such publicity and awarded such recognition for their work.

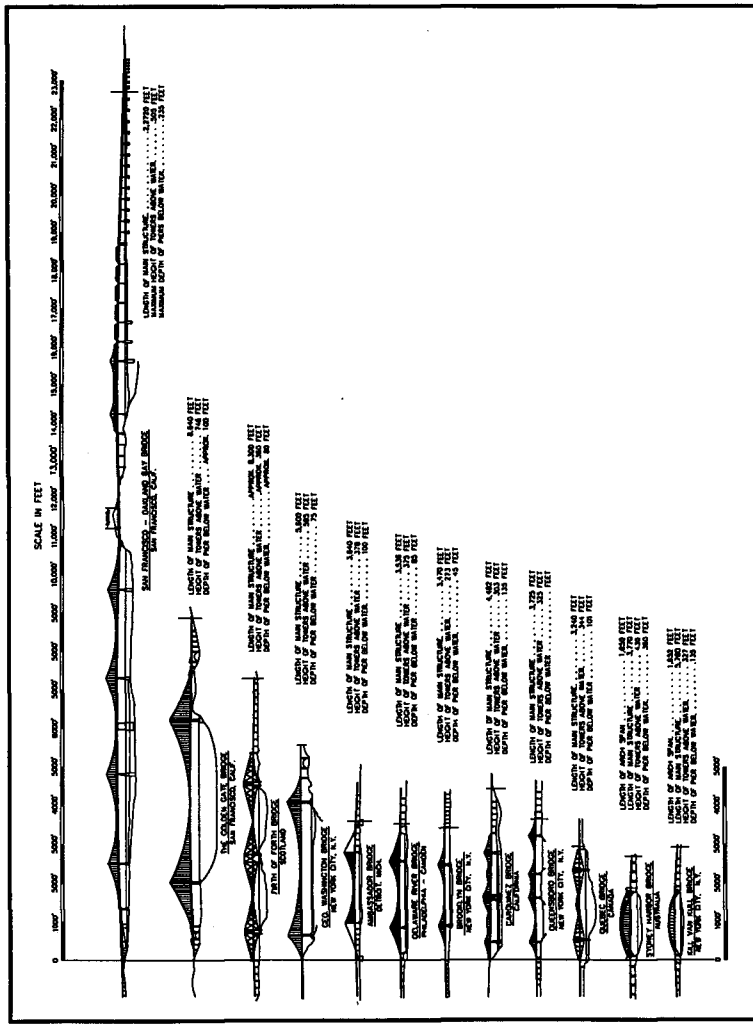
This time period may also be regarded as the era of the revenue bond, which emerged as the funding mechanism of choice for construction of great bridges. The construction of very large bridges had always been limited by the capacity of private firms or governmental agencies to pay for them. Nearly all of the great bridges from the 1920s and 1930s were financed through the revenue bond mechanism, in which the construction bonds were guaranteed by the revenue of bridge tolls. This seemingly prosaic development in public finances contributed, as much as any

[111] The historiography of great bridges is quite extensive. Among the more useful surveys is that of Petroski's *Engineer's of Dreams*. A useful survey of American bridge building, with photographs to match its insightful text, is David Plowden *Bridges: The Spans of North America* (New York: W. W. Norton, 1974). Useful field guides are presented in Donald Jackson *Great American Bridges and Dams* (Washington, D.C.: Preservation Press, 1988) and Eric DeLony, *Landmark American Bridges* (New York: American Society of Engineers, 1993).

technological advancement, to the accelerated rate of bridge construction during this period.

Finally, this decade may be seen as the era of the suspension bridge and, to a lesser degree, the cantilever bridge, as the bridge type of choice for very large spans. The decade began with the Carquinez Bridge, completed in California in 1927, which helped revive the cantilever bridge as a useful long-span type, following disastrous results with the bridge type earlier in the century. The bulk of the great bridges during this period, however, were suspension spans – the Delaware River, or Ben Franklin, Bridge (1921-26), the Golden Gate Bridge (completed in 1937), the George Washington Bridge (completed 1931), and, of course, the West Crossing of the Bay Bridge (completed 1936). The Bay Bridge is noteworthy for the fact that it includes both dominant bridge types and because both were very large and unusual examples of their types.

The Ben Franklin, Golden Gate, Carquinez, and George Washington bridges, along with numerous smaller American bridges and bridges elsewhere, have a direct relationship to the design of the Bay Bridge in several respects. First, the success (and occasional setbacks) of the Carquinez, Delaware, George Washington, and Golden Gate bridges helped pave the way for the technical design as well as the funding mechanism for the Bay Bridge. (The Golden Gate Bridge was built concurrent with the Bay Bridge but planning for its began in the early 1920s.) Each pointed the way for the Bay Bridge in one respect or another. The Carquinez Bridge, as noted, helped solidify confidence in the utility of the cantilever bridge type after years of adverse publicity, owing to failures in Quebec and New York early in the 20th century. (Both bridges failed while the suspended span was being lifted into place.) The George Washington and Ben Franklin bridges helped point the way toward a revenue-bond method of financing a publicly owned great bridge. The Ben Franklin, George Washington, and Golden Gate bridges added enormously to the body of knowledge about all aspects of suspension bridge design, from foundation work, tower design, cable spinning, and other crucial matters.



Source: First Annual Report San Francisco-Oakland Bay Bridge p.27
Location: California Department of Transportation Archives, District 4

Bridge Comparison

The great bridges of the period, 1927-1937, were also directly relevant to the design of the Bay Bridge in that the members of the Board of Consulting Engineers for the Bay Bridge had been involved in every one of those bridges, in one capacity or another. Although there was a great deal of competition for the credit in designing each of these bridges, the famous engineers of the time respected both the great challenges they faced and the talents of their peers. Most the great bridges from this decade were designed and built through a complex interaction of a chief engineer, an assistant to the chief, an engineer of design, a board of consulting engineers, and in many cases a civil service staff. The members of the Board of Consulting Engineers for the Bay Bridge, with the exception of Henry Brunnier, had worked on one or more of the above-named bridges, often with more than one member serving on the staff or as a member of the consulting board.

The Carquinez Bridge is an unusual example of the important bridges of this period because it was a cantilever span and because it was privately financed. Built by the American Toll Bridge Company, this bridge was initially conceived in 1922 and was open to traffic in 1927. This hurried pace was made possible in part because it was privately financed and in part because it was a less complicated span. The simplicity of this bridge is apparent, however, only in relation to the other named bridges; the Carquinez Straits are nearly a mile wide and on a major shipping channel, which required main spans of 1100'. The engineers for the project were Charles Derleth, Jr., Chief Engineer, and David B. Steinman, Engineer of Design. In most general literature, Steinman is credited with the cantilever design for this bridge, a design he decided upon only when it became clear that a suspension bridge could not be accommodated due to the requirements of the shipping channel.[112] Although Steinman had no role in the design of the Bay Bridge, Derleth was a member of the Consulting Board. Steinman and Glenn Woodruff, the engineer of design for the Bay Bridge, would later team up in the design of the great Mackinac Bridge in Michigan.

The Delaware River Bridge, or Ben Franklin Bridge, between Philadelphia and Camden, New Jersey, was built in about the same time frame as the Carquinez Bridge. Construction was delayed, however, through numerous preliminary designs, with various cantilever and suspension bridge types contemplated. When construction began in 1921, however, it was a suspension bridge that was designed by a team with Ralph Modjeski as the Chief Engineer and Leon Moisseiff as the engineer of design. Modjeski would serve as the chair of the Board of Consulting Engineers for the Bay Bridge and would strongly recommend that Leon Moisseiff be brought to the Board as well. The Ben Franklin Bridge was also a monument in the history of bridge financing; it required creation of a bi-state commission to handle its bond sales and construction. It was also a great achievement in suspension bridge design; its 1750-foot main span was the longest in the world at the time it was built, although that distance would be eclipsed quickly by other great bridges from this decade.[113]

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[112] The history of the Carquinez Bridge is told in greatest detail in David B. Steinman and Sara Ruth Watson, *Bridges and Their Builders* (New York: Dover Publications, 1941).

[113] Delaware River Joint Commission, *The Delaware River Bridge, 25th Anniversary,* 1951.

The George Washington Bridge across the Hudson River between Manhattan and New Jersey was the last great American bridge to be designed before work began on the Bay Bridge and Golden Gate Bridge. As such, it was the bridge most often cited as a model by the designers of the Bay Bridge. The George Washington Bridge was, like the Ben Franklin Bridge, a milestone in public financing for bridge construction, having been built only about a decade after the creation of the Port Authority, a bi-state authority with broad powers for public works construction. It was also a milestone in the history of suspension bridge design; the great main span of the bridge was more than twice as long as that of the Ben Franklin Bridge, which itself had been a world's record holder only a few years earlier. The design of the bridge is generally attributed to O. H. Ammann, the chief engineer for bridges for the Port Authority and a tireless proponent of the bridge through the years. [His role as advocate as well as engineer is comparable to that of J. B. Strauss in his advocacy and design of the Golden Gate Bridge.] Ammann assembled a distinguished team of consulting engineers, including Daniel Moran, Leon Moisseiff, and J. B. Strauss. Moran was called in, no doubt, because of the difficult foundation problems posed by the Hudson River bed; Moran was commonly recognized as the "dean" of bridge foundation work as well as work on the foundations for very large buildings. Moisseiff, in addition to his earlier work on the Ben Franklin Bridge, had gained considerable attention for his ability to calculate stresses in long-span suspension bridges.[114] Both Moran and Moisseiff would play similar and crucial roles in the design of the Bay Bridge, with Moran essentially designing the foundation plans for the bridge and Moisseiff performing the final check of stresses, particularly in the suspension span.

Strauss had no formal role in the design of the Bay Bridge; he was designing and building the Golden Gate Bridge at exactly the same time that the Bay Bridge was underway. The George Washington Bridge contributed to the design of suspension bridge towers of the Bay Bridge indirectly in the sense that the towers of the George Washington Bridge were the subjects of considerable professional debate over the proper design aesthetics for such structures. Both the Golden Gate Bridge and Bay Bridge were influenced by the outcome of this debate, which centered on the suitability of steel towers, as opposed to masonry-clad towers, for bridges in prominent urban settings.[115] Ammann, influenced by the architect Cass Gilbert, had planned to clad the steel towers of the George Washington Bridge in stone but the stone was omitted for the sake of economy. The ensuing debate over whether to complete the cladding led many to conclude that steel towers in aesthetically pleasing forms were quite appropriate for such important settings.

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[114] The importance of Moisseiff's mastery of these calculations is discussed in detail in Petroski's *Engineers of Dreams*. This would be his most lasting contribution to the West Crossing of the Bay Bridge as well.

[115] The importance and intensity of this debate over the George Washington Bridge towers is summarized in several sources, including Petroski, Plowden, Jackson, and others (see Bibliography).

The Golden Gate is the bridge to which the Bay Bridge is most often compared because of physical proximity and the fact that they were under construction at the same time. Like the Bay Bridge, the Golden Gate Bridge was famous for its engineering superlatives, including the fact that it included by far the longest suspension span in the world. The bridge is also widely recognized for the gracefulness of its design. The two bridges had been debated and planned for about the same length of time, roughly from 1921 through their construction in the mid-1930s. The Golden Gate Bridge was, in many respects, even more difficult to finance than was the Bay Bridge; it was ultimately funded through creation of a unique special district, involving counties throughout Northern California. The design of the Golden Gate Bridge also evolved through several generations of planning; in 1921, J. B. Strauss proposed a combined cantilever-suspension bridge one writer has called an "eyesore."[116] The graceful design that exists today would evolve over the 1920s, as Strauss worked closely with engineer Charles Ellis and others.

When financing appeared to be sufficiently settled to proceed to final design, Strauss assembled a distinguished group of consulting engineers, many of whom had worked on the predecessor great bridges of this decade and would work on the Bay Bridge as well. The Board of Consulting Engineers for the Bay Bridge included O. H. Ammann, the chief engineer of the George Washington Bridge, and Leon Moisseiff, who had a part in designing virtually every great bridge from this decade. Charles Derleth, Jr., the dean of the College of Engineering at the University of California, was on the board as well; Derleth, as noted, had been the chief engineer for the Carquinez Bridge. The great suspension span would also solidify the confidence of engineers in the use of such spans, although the earlier success of the George Washington Bridge likely made a greater contribution to that increased confidence.

There were numerous other bridges built or contemplated during this decade that had some bearing, great, or small, on the design of the Bay Bridge. The Kill van Kull Bridge between Staten Island and New Jersey was the second most ambitious project of the Port Authority, after the George Washington Bridge. A steel arch structure, this bridge was built with a consulting board that included Daniel Moran and Leon Moisseiff, both of whom would serve on the board for the Bay Bridge, as well as J. B. Strauss.[117] Ralph Modjeski had designed the Huey Long Bridge in New Orleans which was under construction at about the time of the Bay Bridge; Moran was involved in the foundation work there. The Long Bridge was among the first large public works projects to be funded under the Reconstruction Finance Corporation's Self-Liquidation program; as noted, the Bay Bridge was also financed under this program. Ralph Modjeski also designed the substantial and locally impressive Martinez-Benicia Bridge, built by the Southern Pacific Railroad in 1930. Modjeski subcontracted with Moran for design of the tricky foundation work for this bridge.[118]

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[116] Van Der Zee, *The Gate,* 48.

[117] Petroski, *Engineer's of Dreams*, 256.

[118] John W. Snyder, "The Southern Pacific Builds a Bridge... The Saga of the Martinez Bridge," *Railroad History*, Bulletin 161 (Winter 1989), 67-93.

The importance of the Bay Bridge does not diminish when assessed within the context of the dozens of great bridges that were built within the same decade. It is a somewhat fruitless exercise to attempt to establish whether any of these great bridges is ultimately more important than the others.[119] The Bay Bridge was regarded as a great challenge by all involved with it, particularly the engineers of the State of California, none of whom had previously worked on a span of this magnitude. It is a credit to their good sense that they brought to their design team a distinguished board of consulting engineers. The members of that team had worked independently or in cooperation with other board members on all of the other major bridges in the United States from that period. At least in terms of cost, length, depth to foundation, and structural complexity, the Bay Bridge was the greatest achievement in one of the most productive decades in the history of bridge-building, and came into being through the efforts of the best and most experienced talent available.

[119] In 1955, the American Society of Civil Engineers selected the "Seven Wonders" of civil engineering, its official list of the most important engineering structures in the country. The Bay Bridge is the only bridge on the list.

7. HOW THE BRIDGE WAS DESIGNED, 1931 THROUGH 1933

As noted, it was customary during the decade, 1927-1937, to attribute the design of great bridges to the work of individual engineers. That individual credit, particularly for very large bridges, defies logic: no one person could hope to have designed on his or her own a very large structure. At best, the individual engineer might be credited with providing the vision of how the bridge should look and the inspiration for how to solve the immense technical problems inherent in such great spans. As Henry Petroski observed in *Engineers of Dreams:* "Though it is true that no individual engineer, no matter how great, can single-handedly do everything – from detailed calculation to supervision of construction – required to bring a major span to fruition, great bridges do appear to have had masterminds behind them, albeit masterminds with many helper minds."[120]

Of all great American bridges, the Bay Bridge seems to have been the most anonymously designed. There is little doubt that Ralph Modjeski, for example, is credited in popular and technical literature with designing the Ben Franklin Bridge. In the popular press, J. B. Strauss was given nearly unanimous credit for designing the Golden Gate Bridge, despite John Van Der Zee's careful studies to the contrary.[121] Authorship of the Bay Bridge, however, is rarely mentioned and is given widely different treatments when it is. Shortly after the bridge was completed, the popular press gave the credit to Charles H. Purcell, the Chief Engineer. These popular accounts were collected and published in book form in *Purcell Pontifex: A Tribute.*[122] In more recent accounts, however, the consensus that Purcell designed the bridge appears to have vanished. In his excellent survey, *Great American Bridges and Dams*, Donald Jackson gives credit for the design to Purcell and Glenn Woodruff, the Engineer of Design who was third in the command structure for the State of California when the bridge was designed.[123] Kevin Starr, in his recent history of California during the 1930s, generally gives Woodruff credit for the design, along with the other "straightforward civil servants" working for the State of California.[124] Where the other bridges are treated as having been designed by individuals or reflecting the vision of individuals, the Bay Bridge seems to have emerged from a committee, with no one really in charge. Henry Petroski captures the current thinking about the Bay Bridge by noting that: "Among the reasons for its [the Bay Bridge's] relative obscurity must also be counted the fact that this bridge had no single prominent and dominant dreamer like a Roebling, Lindenthal, Ammann, or Strauss serving as executive director and providing a visible personality to the project."[125]

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[120] Petroski, *Engineers of Dreams*, 19.

[121] John Van Der Zee, *The Gate: The True Story of the Design and Construction of the Golden Gate Bridge* (New York: Simon & Schuster), 1986.

[122] *Purcell Pontifex: A Tribute* (San Francisco: "Privately Printed by His Friends," 1937).

[123] Donald C. Jackson, *Great American Bridges and Dams* (Washington, D.C.: Preservation Press, 1988).

[124] Kevin Starr, *Endangered Dreams,* 328.

[125] Petroski, *Engineers of Dreams,* 336.

This chapter will address the issue of how the Bay Bridge was designed. At the most basic level, it will attempt to set the record straight as to who was involved in the design process and attribute authorship for critical decisions, where it may be determined. In doing so, it will chronicle the daunting, almost frightening challenges posed by this huge and complicated structure and how the design engineers slowly and methodically made their way past them. At a somewhat more abstract level, it will seek to analyze the criteria that guided the engineers as they made the key decisions on the bridge. During the course of designing this bridge, the responsible engineers had at all times to pursue three fundamental objectives: structural integrity; economy; and aesthetics. The chapter will close with a discussion of how effectively the designers of this bridge handled their pursuit of these major goals. The Bay Bridge is such a long and complex structure that it is impossible to summarize how all aspects were designed. Instead, this chapter will focus on the design decisions that led to the three characteristics that are most distinctive and set it apart from other bridges: its unique back-to back suspension spans between San Francisco and Yerba Buena Island; the fact that it uses a variety of bridge types, from suspension to cantilever to through truss; and the fact that the piers of the East Bay Crossing were not taken to bedrock.

The first and most crucial fact about the design of this bridge is that it occurred in a great hurry. Although preliminary planning had begun as early as 1921 and the Hoover-Young Commission in 1931 had made important locational decisions, the Bay Bridge was effectively designed in a 24-month period, between early 1931 and early 1933. In early 1931, the Department of Public Works had yet to set up engineering offices of what would be called the Bay Bridge Division at 500 Sansome Street in San Francisco; little work had been accomplished other than the preliminary designs from the Hoover-Young Commission. By the early part of 1933, the bridge specifications were complete and the project was out to bid. During that remarkable two-year period, the state employees at Sansome Street and the private Board of Consulting Engineers, mostly working in offices in New York City, solved all of the outstanding problems associated with the bridge and brought the project to fruition. If mistakes were made along the way, the various state employees and consulting engineers deserve credit at least for their heroic efforts at designing the largest and most expensive bridge in the history of the world over the course of about two years.

7.1. The Establishment of the Bay Bridge Division in San Francisco

The design work for the Bay Bridge was controlled by the Bay Bridge Division of the California Department of Public Works, operating in offices at 500 Sansome Street in San Francisco. The Bay Bridge Division was a unique entity in state government. It was not formally part of the Division of Highways and was largely divorced from the California Toll Bridge Authority as well. The uniqueness of the Bay Bridge Division symbolizes the nature of its task, which was unlike anything the state had ever attempted.

In 1929, the California legislature established the California Toll Bridge Authority (CTBA), charging it with responsibility for designing and building the Bay Bridge. The decision for a separate state agency, while it ultimately appears to have been wise, created something of an orphan within the administrative structure of the state government. Since the early years of the

20th century, the design and maintenance of state highways and bridges had been accomplished through an established administrative structure. The Department of Public Works was an umbrella organization, roughly the equivalent of what is called an "agency" in the terminology of the state government today, i.e. a relatively small organization with broad control over several functional departments. The Department of Public Works had control over the Division of Highways as well as the Division of Engineering (the modern Department of Water Resources), the Division of Architecture (today's Division of the State Architect), and several smaller departments. The Division of Highways had direct responsibility for the design and maintenance of the state's highways and bridges and employed a large staff for that purpose.[126] Under normal circumstances, the Bay Bridge would have been the direct responsibility of the Division of Highways.

The Bay Bridge, however, was not designed by the Division of Highways. It was designed by the California Toll Bridge Authority and by the Bay Bridge Division of the Department of Public Works, or simply the Bay Bridge Division. The personnel of the Bay Bridge Division drew upon the staff of the Division of Highways. The relationship between the two is shown graphically in the organizational chart, attached as Appendix 2 to this report.

As shown in the organizational chart, the CTBA was a separate entity but was entirely dependent upon the Department of Public Works for staff support. Between its creation in 1929 and the opening of the bridge in late 1936, the work of the CTBA was accomplished by people associated with the Department of Public Works and Division of Highways. The Commission itself comprised elected and high-ranking appointive officials: the governor and lieutenant governor, director of the Department of Public Works, director of the Department of Finance, and chair of the California Highway Commission. After World War II, the CTBA was gradually incorporated into the Division of Highways, now called the California Department of Transportation.

In 1931, the legislature specifically authorized the CTBA to build a bridge from San Francisco to Alameda County and charged the Department of Public Works with building the bridge. The legislature also authorized an expenditure of $650,000 by the Department of Public Works to design the bridge, money that would ultimately be paid back to the state from the sale of revenue bonds. Thus, by legislative action, it was the Department of Public Works, not specifically the Division of Highways, that was charged with the task of designing and building the Bay Bridge.

The CTBA met briefly in 1929 and requested the Department of Public Works to develop an operational or administrative structure for designing and building the bridge. During 1929 and 1930, however, the key Division of Highways staff members, particularly the chief engineer, C.

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[126] The administrative history of the Department of Public Works and Division of Highways/Department of Transportation is summarized in Raymond Forsyth and Joseph Hagwood's *One Hundred Years of Progress: A Photographic Essay on the Development of the California Transportation System* (Sacramento: California Transportation Foundation, 1998). It is discussed in a broad context in: Gerald D. Nash, *State Government and Economic Development: A History of Administrative Policies in California, 1849-1933*. Berkeley: Institute of Governmental Studies, 1964. The Division of Highways was known as the California Highway Commission, the name of its policy body until 1923.

H. Purcell, and the chief bridge engineer, Charles Andrew, were actively involved in preparing the technical reports for the Hoover-Young Commission. Essentially all of the major studies for the Hoover-Young Commission report had been accomplished by Division of Highways civil service employees or consulting engineers and geologists, whose contracts were structured and administered by the division. Although the report was attributed to the Department of Public Works, it was the Division of Highways that actually prepared the technical studies. The CTBA, meanwhile, was essentially moribund in the two years, 1929-1930, when the Hoover-Young Commission was meeting. In 1931, however, the situation changed dramatically. With the completion of the Hoover-Young studies and passage of the 1931 legislation that specifically authorized the bridge and approved expenditure of $650,000, the Department of Public Works was forced to develop an administrative structure for this work.

Complicating matters somewhat, the year between completion of the Hoover-Young Commission Report in 1930 and authorization of the bridge in 1931 carried with it a change in administrations in Sacramento, between that of Governor C. C. Young and Governor James Rolph, who was inaugurated in 1931. Rolph had been mayor of San Francisco from 1911 through 1930 and was one of the most outspoken champions of the Bay Bridge. He would die in office in 1934, while the bridge was under construction, but not before presiding over all of the design efforts and the earliest stages of construction. It fell to Rolph's new Director of Public Works, Earl Lee Kelly, to develop a structure for designing the bridge.[127] Kelly, no doubt consulting with C. H. Purcell, elected to create an entirely new organization, called the San Francisco-Oakland Bay Bridge Division, or Bay Bridge Division, which had no formal ties with the Division of Highways. Rather, the new Bay Bridge Division reported directly to the Director of Public Works and to the CTBA.

The new Division, however, was hardly divorced from the Division of Highways. Kelly appointed C. H. Purcell to be the Chief Engineer for the Bay Bridge, without asking him to relinquish his larger role as State Highway Engineer. Kelly charged Purcell with the task of spending the $650,000 in the manner he judged best. Throughout the years, 1931 through 1936 (between creation of the Bay Bridge Division and the opening of the bridge), Purcell wore both hats as head of the Division of Highways and Chief Engineer of the Bay Bridge.

Purcell was a bridge engineer by training and inclination, although he spent the bulk of his career as an administrator. He was born in North Bend, Nebraska on July 27, 1883. He studied engineering at Stanford University for one year but returned to Nebraska after his father died. He graduated from the University of Nebraska in 1906.[128] Like many young civil engineers of the time, he first worked for the railroads and in mining. His work as a structural engineer for mining operations took him to the Far West, first to Ely, Nevada and later to Marysville, California. His primary interest throughout these early years, however, was in bridge construction. In 1910, he moved to Oregon and in 1912 accepted a position as bridge engineer with the new Oregon State Highway Department. With the Oregon highway department and

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[127] Kelly was preceded briefly by Walter Garrison as Director of Public Work in the Rolph administration.

[128] *Purcell Pontifex: A Tribute*, 1937.

Multnomah County, Purcell designed many of the well-known bridges for the Columbia River Highway. In 1917, he was hired as a bridge engineer by the U. S. Bureau of Public Roads (essentially the modern Federal Highway Administration). In 1919, he was appointed the district engineer for the Bureau in Portland.[129]

In 1928, Purcell accepted a position as Highway Engineer (agency head) for the California Division of Highways. He would remain as an administrator until shortly before his death in 1951. He was Highway Engineer for the Division of Highways through the mid-1940s and after that time was the Director of the Department of Public Works. In addition to his other accomplishments, Purcell appears to have surpassed all other candidates for the longest tenure as the head of the highway program in California. His remarkable career, either as head of the Division of Highways or Department of Public Works, extends from the real beginnings of the active State Highway Program in the 1920s through the beginnings of the freeway era in the early 1950s. Although historians may disagree about his role in designing the Bay Bridge, Purcell is a towering figure in the history of the highway system of the State of California.

Purcell further solidified the link between the Bay Bridge Division and the Division of Highways by appointing Charles Andrew as Bridge Engineer, essentially the chief assistant to the Chief Engineer. Andrew was loaned to the Bay Bridge Division on a full-time basis until the job was completed. Unlike Purcell, who was an administrator for more years than he was a bridge engineer, Charles Andrew was a bridge engineer for most of his career. He was born in Illinois and received a B. S. degree in civil engineering from the University of Illinois in 1906. He moved to the West Coast upon graduation and never left. Between 1906 and 1908, he worked on the great Portland and Seattle Railroad Bridge across the Willamette River at St. Johns, Oregon, serving under the engineer of design, Ralph Modjeski. That bridge was one of the earliest major commissions by Modjeski, whose career will be discussed in detail below. This early connection between Andrew and Modjeski may help explain why Purcell and Andrew turned almost immediately to Modjeski to serve as chair of the Board of Consulting Engineers for the Bay Bridge.

After that two-year stint in the private sector, Andrew went to work as a civil servant and would work in the public sector most of the rest of his life. He was appointed as city engineer of St. Johns, Oregon (where the railroad bridge was located) in 1908 and served there until 1913. He returned to private business in 1914, working on his own in 1914 and 1915 and then as a design engineer with Albina Engine and Machine Works between 1915 and 1917. Between 1918 and 1920, he was a bridge engineer with the U.S. Bureau of Public Roads in Portland, where he served under C. H. Purcell. Between 1920 and 1927, Andrew was the Bridge Engineer – the supervisor of the bridge department – for the State of Washington. In 1927, he was hired to head the Bridge Department of the California Division of Highways, a position he would maintain for

[129] The dates of career events in Purcell's life have been taken from an undated but painstakingly researched genealogical study of him, prepared by the California State Library, at some point around 1937. These dates are presented incorrectly in *Purcell Pontifex.*

many years.[130]

Although they had some minor experience in private sector work, Purcell and Andrew were long-term public servants. For a brief period in early 1931, Purcell and Andrew together comprised the entire staff of the new Bay Bridge Division, with Andrew being its only full-time staff member.

Although they were career civil servants, Purcell and Andrew were surprisingly reluctant to rely upon the civil service system to design the bridge. Instead, one of Andrew's first actions upon his appointment as Bridge Engineer was to request an exemption for the Bay Bridge Division from the civil service system. The reason for bypassing the civil service, as stated in a request prepared by Andrew, was that the job was highly specialized and temporary in nature. In a long memorandum to G. T. McCoy, Assistant Highway Engineer at the Division of Highways, Andrew explained:

> The following reasons are essential in dispensing with civil service regulations in the employ of men for the design and construction of the San Francisco-Oakland Bridge.
>
> 1st: Several men with special qualifications are not anticipated by civil service classifications, and who demand salaries higher than those allowed under civil service regulations, are required...
>
> 2nd. The services of a large part of the designers is of a temporary nature. We believe that it is not good policy to build the civil service personnel in structural work up to twice its present size and then, after the design work on the Bay Bridge is complete, to have to dispense with their services.
>
> 3rd. Past experience has shown that it would be a very heavy burden to give the necessary examinations...
>
> All men employed on the Bay Bridge should be of exceptional qualifications in their respective positions. Each appointment would be made by the Chief Engineer after a careful check of qualifications and expertise.[131]

One of the first steps taken by Purcell and Andrew was to hire Glenn Woodruff, then working with Ralph Modjeski in New York City. Woodruff had no standing in the California civil service system or any other such system; he had spent his career in the private sector, working with railroads and the most active consulting engineering firms in New York. Although he was technically the third-ranking member of the leadership (after Purcell and Andrew), Woodruff was paid the same as Andrew and more than Purcell, whose salary was that of the Highway Engineer for the Division of Highways. Woodruff was born in Pennsylvania in 1890 and graduated from Cornell University with a BS in civil engineering in 1910. Early in his career he worked for the

[130] Charles E. Andrew, "Professional Record," Engineers' Memoranda, 000.051, California State Archives.
[131] Andrew to McCoy, July 17, 1931, Engineers' Memoranda, 000.051, California State Archives.

American Bridge Company as well as various railroads, including the Northern Pacific and Lehigh Valley. He served one year in the military during World War I. After the war, he worked for the Southern Pacific Railroad and again for the Lehigh Valley Railroad, before landing a position with the prestigious consulting firm of Robinson and Steinman. Between 1923 and 1930, he worked as principal engineer for Ralph Modjeski. During those years, Woodruff worked on several high-visibility projects, including the Delaware River Bridge in Philadelphia and the Huey P. Long Bridge in New Orleans.

Purcell and Andrew hired Woodruff in 1931 to work as the engineer of design for the Bay Bridge, the person most directly in charge of design. He stayed at that position until the bridge was completed. During World War II, Woodruff worked with several large engineering firms with important government contracts, including the California firm of Barett & Hilp, the Utah-Pomeroy-Morrison Company and J. H. Pomeroy & Co. After the war, he established the partnership of Woodruff and Simpson, a firm that was a key component of the design teams for the Mackinac Straits Bridge in Michigan and the Richmond-San Rafael Bridge in California. Glenn Woodruff died in 1974.[132] Among his more notable achievements after leaving the Bay Bridge Division was his role as an analyst of the failure of the Tacoma Narrows Bridge disaster and his work with David Steinman in designing the Mackinac Straits Bridge.[133]

Within a few months of setting up the Bay Bridge Division, Purcell, Andrew, and Woodruff had assembled a team of more than 50 engineers along with allied specialists, including surveyors, draftsmen, and a clerical staff. It appears that the bulk of the staff came from Northern California, with most being young engineers. Some had previously worked for the state of California, including the Division of Highways, while many others had not. As noted, the early hires for the Bay Bridge were state employees but were not formally part of the state civil service. This condition prevailed until March 1932, when a ruling by the Division of Highways forced the Bay Bridge Division to transfer its positions to the civil service and make any further hires from the civil service lists.[134]

Many of the early hires by the Bay Bridge Division were transfers from the Bridge Department of the Division of Highways in Sacramento, including Norman Raab, Ralph Tudor, and Howard Wood. Ralph A. Tudor, educated in civil engineering at West Point, was first hired by the Bridge Department in 1929; two years later he transferred to the Bay Bridge Division in San Francisco. He stayed on with the design team through construction of the bridge and was put in charge of bridge maintenance in 1937. He continued to work for the Toll Bridge Authority until the outbreak of war, at which time he returned to the Army as an officer in the Corps of Engineers.

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[132] "Glenn Barton Woodruff, F. ASCE," *Transactions, ASCE* 139 (1974): 580.

[133] D. B. Steinman, "Engineering Report on Mackinac Straits Bridge, Mackinac Bridge Authority," 1953, with Glenn B. Woodruff.

[134] Letter dated March 6, 1932. The letter is a form letter to applicants for employment at the Bay Bridge Division, advising them that "For your information, recent orders from Sacramento require that all employees in this department be under Civil Service," and advising the applicants that "I suggest that if you are interested that you apply for these [civil service] examinations." Engineers' Memoranda, Charles Andrew, 000.051, California State Archives.

After the war, he worked briefly with the large contractor, Morrison-Knudsen (one of the major Bay Bridge contractors), before returning to work for the state as head of the Bay Toll Crossings, essentially the inheritor of the California Toll Bridge Authority. In 1953, he was appointed as the under-secretary of the Department of the Interior, in charge of water resource development, a post he held for 18 months. From 1954 until his death in 1963, he headed Tudor Engineering Company in San Francisco, one of the more active water resource development consulting firms.[135]

Howard C. Wood was born in 1900 in the Northern California town of Danville. He graduated from the University of California with a degree in civil engineering in 1923. Between 1923 and 1928, he was a draftsman, working with Charles Derleth and David Steinman on the design and construction of the Carquinez Bridge. In 1929, he was hired as a bridge engineer for the Bridge Department, Division of Highways. He transferred to the Bay Bridge Division in 1931 and stayed with the project until 1939. Between 1939 and 1941, he worked with the Bridge Department in Sacramento but returned to the Bay Toll Crossings in 1941 and stayed there for several decades.[136]

Norman Raab was born in Stockton, California and served in the Navy during World War I before receiving an MS in engineering at the University of California in 1922. He began working for the Bridge Department in 1923 and was apparently chiefly responsible for the design of the lovely Donner Summit Bridge on old U.S. 40, near Truckee, California. He was also given credit for much of the design work on the award-winning Bixby Creek Bridge near Big Sur, California during the late 1920s and early 1930s. In 1931, he transferred to the Bay Bridge Division in San Francisco and stayed with the Toll Bridge Authority-Bay Toll Crossings until he retired in the early 1960s. Raab is generally credited with the design of the reconstruction of the Bay Bridge, 1958-63, when interurban lines were removed.[137]

Transfers would also dominate in the years after 1933, as the project moved into construction phase, requiring a new set of employees with construction experience. I. O. Jahlstrom, for example, would serve as the resident engineer for the most troublesome of the state contracts, including both the foundation work and superstructure on the West Bay Crossing. Jahlstrom had started with the Division of Highways in 1927 and transferred to San Francisco in 1933. He stayed with the Division of Highways through 1965.[138]

Not all of the early hires, however, were transfers from Sacramento. We get a brief glimpse of how non-civil service employees were recruited in a February, 1932 memorandum from Charles Andrew to Glenn Woodruff, before the civil service exemption had been rescinded. Woodruff

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[135] "Ralph A. Tudor," *California Highways and Public Works* (January-February 1964): 58.

[136] Undated biography of Howard C. Woods, kept in Biographical Files, California Department of Transportation Library, Sacramento.

[137] Norman Raab kept a detailed work diary during the years, 1948 through the 1960s. These diaries are retained at the Bancroft Library of the University of California.

[138] "Highway Recollections of I. O. Jahlstrom," Oral History prepared for Caltrans on December 19, 1981, California Department of Transportation Library, Sacramento.

had submitted to Andrew a list of names of engineers he wanted to lay off from the Bay Bridge Division. One was an old acquaintance of Andrew, about whom Andrew wrote:

> [The named engineer] worked for me over a period of four years when I was Bridge Engineer of the State of Washington, and during that time I considered him to be one of the best men in the designing department, being intimately connected with and working on several major bridge projects including every kind of bridge foundation used on more than the average run of highway bridges... I feel that I am personally responsible for his leaving a permanent position with the State Highway Department in Washington, and moving his family down here... I cannot, however, help but feel that he is better fitted for foundation work, or structural steel work, than for approach layouts. For that reason, I greatly desire that you put him on foundation work for further trial before we take the final step of laying him off.[139]

Among the other employees slated for lay-off, one was a Bridge Department transfer, whom Andrew advised that he would "arrange for a transfer to Sacramento for him a little later on." As to the remaining employees, without civil service protection or support from the leadership, Andrew simply noted: "Notification to the other men listed are being given to you and you may use your discretion in the matter."

In 1932, as noted, the Bay Bridge Division was forced to return to the regular civil service fold. By that time, however, the bulk of the staff was in place and brought into the standard civil service classifications by taking normal examinations for the engineering and other classes, established by the Division of Highways. In time, many of these people would continue on with the Division of Highways; many others would not.

This crew of state employees would remain on the job from early 1931 through completion of the bridge in late 1936; many, as noted, would continue on much longer, to complete remaining elements of the bridge (particularly the interurban connections), to maintain the bridge and make improvements, or to work on new toll crossings, including the San Mateo and Richmond-San Rafael bridges. The great flurry of activity, however, occurred in the period, 1931-36, at least with respect to the Bay Bridge, with the design work accomplished between 1931 and 1933 and construction completed between 1933 and 1936.

Purcell and Andrew began assembling a Board of Consulting Engineers, however, even before the Sansome Street office had been fully staffed. This fact led to a symbiotic and generally harmonious relationship between a very talented but largely unknown group of state employees and a small but highly visible group of very famous bridge engineers, a relationship that stayed in place for nearly five years.

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[139] Charles E. Andrew to Glenn Woodruff, February 20, 1932, Engineers Memoranda, 000.051, California State Archives.

7.2. The Board of Consulting Engineers Established

No evidence has been found to explain exactly why Purcell and Andrew felt the need to have a Board of Consulting Engineers, although the reasons are explained indirectly by the participants and through a reading of the situation. The first and probably controlling explanation is that it was customary within the engineering profession to rely upon a board of distinguished colleagues to approve the design of very large bridges. Virtually every great bridge built between 1927 and 1937 was designed with the assistance of a consulting board. Indeed, many of the best-known engineers served on the boards for more than one of these long span bridge projects. The simplest explanation for the appointment of a consulting board, then, is that it followed a responsible and time-tested tradition within the profession.

A compatible explanation is that no one at the Bay Bridge Division, other than Woodruff, had any experience in designing or building a bridge of this magnitude. Purcell and Andrew collectively had dozens of years of bridge design experience but had never undertaken a project that approximated the scale of the Bay Bridge. It was for this reason, no doubt, that they hired Woodruff, who had far more experience in designing the type of bridge that would be called for at the San Francisco Bay crossing. The same reason also helps explain why they appointed a board of consulting engineers and relied heavily upon the judgement of board members.

Whatever the reason, Purcell and Andrew began discussing the Bay Bridge project in earnest with Ralph Modjeski before December 1930. Public Works Director Earl Lee Kelly announced his intention to appoint a consulting Board of Engineers in December 1930, and indicated that Ralph Modjeski would serve as chair and Daniel Moran as one of the board members.[140] Because of problems in getting the release of state funding, however, none of the Board of Consulting Engineers was under contract with the state until August 1931.

Purcell, Andrew, and Woodruff did not wait for the formality of the contract, however, to seek the advice of Modjeski and Moran, who had experience in the two areas that most vexed the early design work: designing long-span suspension bridges and constructing very deep foundations. In early February 1931, for example, Purcell wrote to Modjeski, saying "We are in receipt of your letter of January 22, to which was attached a proposed layout for the bridge across the west channel between San Francisco and Goat Island." Purcell then sent Modjeski four alternative alignments already worked out by his staff, with the notes "I should be very glad to have your comments on any of the subject matter of this letter."[141] Modjeski replied with a long letter to Purcell, then at his main office in Sacramento because the Sansome Street office had not been organized. This letter, discussed in detail below, gives a detailed critique of the four alternatives, offering detailed suggestions for improving those alternatives "from the standpoint of economy

[140] Charles Derleth, Jr. to C. H. Purcell, January 2, 1931, Board of Consulting Engineers, 200.5, California State Archives.

[141] Purcell to Modjeski, February 4, 1931, Board of Consulting Engineers, 200.5, California State Archives.

as well as aesthetics."[142] It is unlikely that Modjeski was paid for this advice, not immediately, at any rate; he would not be under contract with the state until August 1931. Similar correspondence exists for all of the months between January and August 1931. No similar correspondence exists between Purcell and the others who would join the board. It is for this reason that it is concluded that Purcell wanted Modjeski for the Consulting Board before any of the other members were under consideration.

Ralph Modjeski is one of the best-known bridge engineers to have practiced in the United States during the first half of the 20th century. He is known for his design of some of the largest as well as the most beautiful bridges in the world. As was observed in a 1931 tribute to him:

> It is that Ralph Modjeski was inherently an artist. He has not chosen oil, or dry point, or marble, or even music, in which he doubtless would have excelled, to express himself, but steel, and stone, and concrete. Using these as his chosen media, "by a pleasing simplicity of form and reliance upon the quiet dignity of the long spans whose members gracefully express function free from superfluities," he has made of bridge building a recognized art without in the least minimizing its importance as a science.[143]

He was born Rudolphe Modrzejewski in Cracow, Poland in 1861. His mother, Helena, was known as Madame Modjeska and was widely recognized as one of the great actresses of her time.[144] He traveled widely with his mother, including numerous visits to the United States. He settled with his mother in what is now Orange County, California in 1876 and remained in California through 1878. Between 1878 and 1881, he lived in Paris, France, in his words, "preparing for college."[145] He eventually enrolled at the L'ecole des Ponts et Cahaussees in Paris, where he studied civil engineering. He moved to the United States, where he worked briefly with George S. Morrison, then a pre-eminent American bridge designer. He worked with Morrison on the big Union Pacific Railroad Bridge across the Missouri River at Omaha (1887), and the great bridge across the Mississippi River at Memphis, Tennessee (1892). By 1893, however, he had moved to Chicago where he set up his own office and specialized in railroad bridge design.[146]

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[142] Ralph Modjeski to C. H. Purcell, February 17, 1931, Board of Consulting Engineers, 200.5, California State Archives.

[143] Quoted in Petroski, *Engineers of Dreams*, 172-173.

[144] Madame Modjeska, who lived between 1840 and 1909, had a considerable impact on the history of Southern California, in addition to her theatrical fame. She settled in an area that would become known as Modjeska Canyon, near Anaheim, in 1876 and founded a Utopian colony and continued to live there, even after the colony failed and she resumed her theatrical career. She lived her last years on Modjeska Island near Newport Beach. Ralph Modjeski (the difference in spelling appears to have been his decision) lived with his mother in California only for a brief period. He did attend public schools in Anaheim and San Francisco in 1876, 1877, and 1878 before leaving to study in Paris in 1878. Milton Kosberg, "The Polish Colony of California, 1876-1914," M. A. Thesis, University of Southern California, 1952. According to Kosberg, Ralph Modjeski was an accomplished pianist when he went to Paris and was torn between careers in music and engineering. Modjeski, for reasons not adequately explained in the historical record, asked to be buried in California when he died in 1940; his grave is in Inglewood, California.

[145] Ralph Modjeski, "Biographical Data," Board of Consulting Engineers, 200.501, California State Archives.

[146] Petroski, *Engineers of Dreams*, 171-172.

He continued to design railroad bridges throughout the late 19th and early 20th centuries, including another bridge over the Mississippi River at Thebes, Illinois in 1905 and a bridge across the Missouri River at Bismarck, North Dakota (also in 1905). Between 1905 and 1908, Modjeski designed several great bridges for the Spokane-Portland and Seattle Railway, including bridges across the Willamette and Columbia rivers. He achieved international repute for his decade-long role, 1908 to 1918, as a member of the board of consulting engineers for construction of the second Quebec Bridge, a monument in the history of bridge design, following the disastrous failure of the first bridge in 1907. Arguably his greatest success came with the Delaware River Bridge, generally called the Ben Franklin Bridge, between Philadelphia and New Jersey, completed in 1926, for which he was the Chief Engineer and Chairman of the Board of Engineers.

During the early decades of the 20th century, Modjeski would employ or work with many of the primary players in the Bay Bridge. As noted, he hired a young Charles Andrew in 1906. He worked closely with Leon Moisseiff, who served as Engineer of Design on the Delaware River Bridge. J. B. Strauss, the engineer of the Golden Gate Bridge, had worked as an assistant to Modjeski in the late 19th century. Glenn Woodruff, the Engineer of Design for the Bay Bridge, was working for Modjeski at the time he was hired by Purcell and Andrew. Modjeski had also been a participant in planning for the Bay Bridge since 1921, when he and J. Vipont Davies made an initial survey and minor borings for the bridge, using funds put forward by the San Francisco Motor-Car Association. He was hired by several private firms that submitted plans to the City of San Francisco, hoping for a franchise in the years between 1921 and 1926.

Daniel Moran, with his partner, Carlton Proctor, were arguably the best-known foundation engineers in the United States at the time the Bay Bridge was being designed and built. Moran was born in New Jersey in 1864 and was awarded a degree in civil engineering in 1884 from Columbia University. Like so many other young engineers of the era, Moran began his career in railroad work, specifically in laying out the Nevada-California-Oregon (NCO) narrow gauge track in western Nevada and northwestern California. In the early 1890s, however, he would turn to the specialized field of foundations engineering, a field that would occupy his talents until his death in 1937. Specializing in the design of pneumatic caissons, Moran would work on the foundations for dozens of very large buildings as well as many of the largest bridges built in the United States. He helped design the foundations for the Ben Franklin, Huey Long, Carquinez, George Washington, and Triborough bridges, before his work on the Bay Bridge, his last large commission before his death in 1937.[147]

Purcell had decided upon hiring Modjeski and Moran by late 1930 but was undecided nearly a year later about whom else to include. He wrote to Modjeski on July 25, 1931, enclosing a draft personal services contract. He pledged to Modjeski that any appointments would be made in consultation with him. "I can assure you, however, that all major appointments in the designing organization will be made in consultation with you and that efficiency and ability will be the

[147] Memoir, "Daniel Edward Moran," *Transactions, ASCE* 103 (1938): 1840-1844.

basis upon which such appointments will be made." He continued, "We have sent a similar contract to Moran and Proctor for their signature. The contract to them designates you as the Chairman of the Consulting Board. I cannot finally advise you of the complete personnel of the Consulting Board at this time for the reason I have not fully decided the matter. I am considering Mr. Moisseiff or Mr. Robinson and two local men. The appointment of Mr. Robinson is contingent upon your anticipated conference with him when you return to New York."[148]

The Mr. Robinson of whom Purcell spoke was Holton Robinson of the firm of Robinson and Steinman. Robinson was a very successful consulting engineer from New York with deep experience in suspension bridge cable design, having worked in that capacity on the Manhattan Bridge and the Ben Franklin Bridge.[149] Modjeski replied in August, 1931 that he much preferred Moisseiff: "If you remember, the question of another member of the Board of Consulting Engineers familiar with suspension bridges was being considered: one of them being Mr. Moisseiff and the other, Mr. Robinson. After serious consideration of the matter, I would recommend that Mr. Moisseiff be appointed rather than Mr. Robinson. One is, that Mr. Moisseiff worked under me for two or three years in connection with the Delaware River Bridge and I am very familiar with his qualifications. The second reason is, that it would be practically impossible to get Mr. Robinson to act on the Board without the cooperation of Mr. Steinman. Another reason for the above might be given, in that Mr. Moisseiff being employed on the Golden Gate Bridge would be spending a great deal of time on the Coast at any rate, and would therefore be able to devote more time to the Trans-Bay Bridge than would Mr. Robinson. I trust that you will approve of this recommendation and make suitable arrangements."[150] Moisseiff was appointed a few weeks later.

Leon Moisseiff was born in Latvia in 1872. He attended the Baltic Polytechnic Institute in Riga but emigrated with his family to the United States before he completed his studies. The family settled in New York City and Leon Moisseiff graduated from Columbia University in 1895, with a degree in civil engineering. He worked as a bridge designer for New York City for a number of years, where he met Gustav Lindenthal, with whom he would later be associated. He set up his own consulting engineering office in 1915 and was extremely active in bridge design, chiefly suspension bridge design, through the 1940s.[151] Moisseiff is credited with a major role in the design of the George Washington Bridge, Mackinac Bridge, and the ill-fated Tacoma Narrows Bridge (the so-called Galloping Gertie, which failed in 1940, shortly after it had been completed).[152]

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[148] Purcell to Modjeski, July 25, 1931, Board of Consulting Engineers, 200.50, California State Archives.

[149] Petroski, *Engineers of Dreams*, 331-332.

[150] Modjeski to Purcell, August 15, 1931, Board of Consulting Engineers, Ralph Modjeski, 200.50, California State Archives.

[151] Petroski, *Engineers of Dreams*, 293-295.

[152] Albert F. Gunns, "The First Tacoma Narrows Bridge: A Brief History of Galloping Gertie," *Pacific Northwest Quarterly* 72 (1981) 162-169; Lawrence A. Rubin, *Bridging the Straits: The Story of Mighty Mac* (Detroit: Wayne State University Press, 1984).

As to selection of the other two members, neither Modjeski nor Purcell seemed to have had strong opinions, except that they should be "local men." One such member campaigned for a position. Charles Derleth, Jr., who was on the Board of Consulting Engineers for the Golden Gate Bridge and was dean of the college of engineering at the University of California, asked the leadership of the Golden Gate Bridge and Highway District to intercede on his behalf. He wrote William Filmer of San Francisco, one of the directors of the district, noting that Modjeski and Moran had already been named as members and that "there should be at least one local western California engineer. I feel that I have the qualifications which deserve consideration if a local man is appointed; just as I am the local member of the Board of Consulting Engineers for the Golden Gate Bridge. A local man can do much to bring together amity and understanding the heterogeneous interests of central California. When occasion permits, I would appreciate if you would speak in my behalf to Governor Rolph."[153] Filmer wrote to Purcell rather than Governor Rolph, speaking highly of Derleth's work.[154] There is no clear indication as to why Purcell selected Henry Brunnier as the final member of the Board. Throughout the project, Purcell had been sensitive to the jealousies of cities on the two sides of the Bay. Derleth was an East Bay resident. Brunnier kept an office in San Francisco and may have been selected, in part, to balance the local team geographically.

The role of the Board of Consulting Engineers occurred at two levels: communication between the Bay Bridge Division and Modjeski and Moran, before and after the Board was formally convened; and the formal actions of the larger Board, which included Moran, Modjeski, Leon Moisseiff, Charles Derleth, and Henry Brunnier. The communication with Moran and Modjeski began in early 1931 and was anything but idle speculation. Indeed, the most interesting and telling correspondence between Purcell, Andrew, and Woodruff and the Board members are those of early 1931, when the biggest and most important decisions were still unmade. Once the Board of Consulting Engineers was in place, communications continued to pass through formal and informal channels. It appears that the three New York-based engineers – Modjeski, Moran, and Moisseiff – met frequently on Bay Bridge questions. A number of letters from them were signed by all three, and the three frequently referred to themselves as the "New York members of the Board of Consulting Engineers."

In addition, the three New York members were by far the highest paid of the five and were expected to produce more than a certification or stamp of approval. Time and again, Purcell, Andrew, and Woodruff would turn to the three New York members for specific design and calculation tasks. Moran essentially designed the caissons for the deep-water foundations. Moisseiff and his staff checked the calculations for the entire bridge. These design and calculation tasks were, in most cases, work orders that were reimbursed above and beyond the guaranteed payments to the Board members. Modjeski was rarely called on to perform specific design tasks but, as chairman of the board, was asked most frequently to pass judgment on design

[153] Derleth to William P. Filmer, January 2, 1931, Board of Consulting Engineers, 200.50, California State Archives.

[154] Filmer to Purcell, January 13, 1931, Board of Consulting Engineers, Charles Derleth, 200.50, California State Archives.

ideas, great and small, as these were developed by the staff in San Francisco.

The entire Board did meet formally as well; there were 16 formal sessions in San Francisco between early 1932 and late 1936. The Board would meet for several days in a row, usually during an entire week, in each session, discussing and formally acting on design issues that needed to be resolved at each juncture.[155]

The most fundamental choices are those discussed below, specifically: the bridge type for the West Crossing; how to sink the foundations, particularly for what would become Piers W-3 through W-6 and E-2 through E-6; and selecting a bridge type for the East Bay Crossing. (The major piers were numbered from west to east, with a separate set of numbers for the West Bay Crossing and for the East Bay Crossing. Thus, W-1 was the westerly pier for the West Bay Crossing, while E-1 as the westerly pier for the East Bay Crossing.) To a large extent, these decisions had been made before all of the Board of Consulting Engineers was in place, decided chiefly through communications between Purcell, Andrew, and Woodruff on the one hand and Modjeski and Moran on the other. This does not underestimate the role, however, of the large staff in San Francisco or the input of the other Board members, particularly Leon Moisseiff.

7.3. Solving the Problems of Bridge Types for the West Bay Crossing

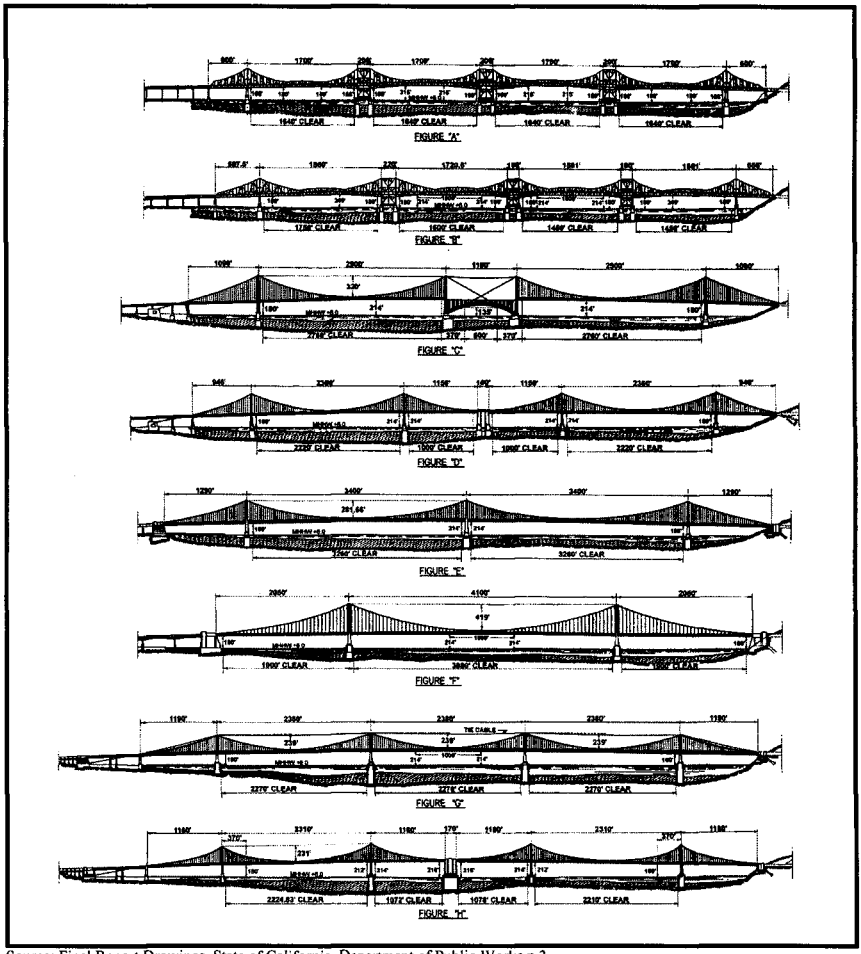
Seemingly, the most vexing problem facing the Bay Bridge Division and the Board of Consulting Engineers was how to span the two-mile distance between San Francisco and Yerba Buena Island. The problems of this crossing were natural as well as regulatory in nature. The natural facts were the length of the crossing and the depth to bedrock for its foundation. The regulatory problem was that of the War Department, which had made abundantly clear during the Hoover-Young Commission meetings its expectations regarding vertical and horizontal clearances at this important shipping and military channel. The essential problem was: how to span these two miles while maintaining the War Department-mandated vertical and horizontal clearances and at the same time minimizing the number of piers to reduce the extraordinarily expensive foundation work?

From the outset, the issues of mid-Bay foundations and the bridge type for the West Bay Crossing were intertwined. This fact accounts for Purcell's initial selection of both Modjeski and Moran to the Board of Consulting Engineers. Modjeski was known internationally for his design of very long-span bridges of various types, including both suspension and cantilever bridges, while Moran was the acknowledged leader in the design of very deep foundations. This fact also helps explain why Purcell and Andrew, and later Woodruff, corresponded often with Modjeski and Moran, even before they were under contract as consultants. No serious design work could proceed until the issues of the West Bay Crossing and the closely related issue of foundation

[155] The minutes of most of the sessions of the Board of Consulting Engineers were preserved by Charles Derleth and are stored with his papers in the Water Resource Center Archives at the University of California, Berkeley. Minutes from the 13th and 14th sessions are missing from that collection. The California Department of Transportation, District 4, Oakland, retained a full set of minutes as part of its archives from the Bay Toll Crossings group.

design had been resolved.

The essential choices for the West Bay Crossing were four: multiple cantilever spans; a double-suspension span with a center anchorage; a continuous suspension bridge with two anchorages but more than two towers; and a conventional suspension bridge with two anchorages and two towers. All were largely unprecedented, except for the cantilever spans. It was probably for this reason that the multiple cantilever design was the first to be given serious consideration. All planning for the Hoover-Young Commission had been based upon a cantilever design, including the rough cost estimates included in that report. The state's final application for a War Department permit as well as its application for funding from the Reconstruction Finance Corporation, had used a cantilever design for illustrative purposes.



Source: Final Report Drawings, State of California, Department of Public Works p.3
Location: California Department of Transportation Archives, District 4

West Bay Crossing Options

Purcell and Andrew began to abandon the cantilever design, however, almost as soon as the Hoover-Young Commission had been completed. In a series of *Engineering News-Record* articles in 1937, Purcell, Andrew, and Woodruff offer a terse explanation of when and why they began to consider a suspension bridge for the West Bay Crossing:

> The 1931 legislature appropriated $650,000 for preliminary surveys and designs. The bridge department of the division of highways immediately began more detailed design studies, particularly on the possibility of a suspension-bridge layout for the west channel. This resulted from the opinion of the [Hoover-Young] commission that wider horizontal clearances were desirable than could be provided by a cantilever design. The studies included a twin suspension span, including the use of a central anchorage and a continuous suspension-span layout.[156]

The suspension-bridge options were complicated by the fact that the West Bay Crossing was longer than any suspension bridge yet built. A conventional suspension bridge (two anchorages, two towers) would have required a main span of 4100', which was longer than the George Washington Bridge (at that time the longest suspension bridge in the world, with a main span of 3500') but about the same length as the main span of the Golden Gate Bridge (the main span is 4200'). Because the total length of the West Bay Crossing was greater than that of the Golden Gate, however, the side spans would have been exceptionally long, at about 2000' each, nearly twice as long as the side spans of the Golden Gate Bridge. [The long side spans were also needed to protect navigation in San Francisco harbor.] A conventional suspension bridge was, in short, a heroic challenge for the designers of this half of the Bay Bridge.

A continuous suspension bridge also posed enormous problems. The principal challenge was that no such bridge had ever been built and the engineers were quite concerned about how a bridge of this design would perform, particularly in light of the substantial winds and earthquake risks present at the crossing. The state would ultimately investigate two variations on a continuous span: one with three and one with four towers. With three towers, the bridge would have two main spans of 3400' each, and side spans of 1290'. With four towers, there would be three main spans of 2380' and side spans of 1140' each.

The double-suspension span shared with the continuous suspension bridge design the drawback that no such bridge had ever been built. Only one such design was studied: the design that was actually built. It was similar in some respects to the four-tower continuous suspension bridge except that a central anchorage was inserted at the midpoint of what would have been the center span for the four-tower design. The span lengths were comparable to those of the four-tower continuous design, with two main spans of 2310' each and four side spans of about 1160' each.

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[156] Purcell, Andrew, and Woodruff, "San Francisco-Oakland Bay Bridge, A Review of Preliminaries," *Engineering News-Record,* 373.

In 1937 articles in the *Engineering News-Record*, Purcell, Andrew, and Woodruff, no doubt shortening the narrative for the sake of brevity, explain how they arrived at a twin-suspension design:

> Designs were worked out for both of these types [twin suspension design and continuous span], and in June, 1931 professor G. E. Beggs, Princeton University, was retained to make models of these two designs in cooperation with Professor R. E. Davis at the University of California. The model study checked the design of the department, proving the superiority of the central anchorage type. This layout was also favored at early conferences with Ralph Modjeski, chairman of the consulting board, appointed Aug. 15.[157]

Elsewhere in the same piece, Purcell, Andrew and Woodruff expand somewhat on the decision-making process that led to the twin-suspension design. [The original text included lower case letters to refer to alternatives reproduced in that article. Text drawing No. 12 includes a similar set of alternatives but in a different order. The lower case letters below refer to the alternatives shown in text drawing No. 12 and are not the same letters used in the original text.]

> Even during the final steps of securing approval for the cantilever layout, the engineering thinking had turned to a suspension design as the more logical answer to the problem. The advantages included lower cost, fewer construction hazards and more pleasing appearance. The length of the crossing required consideration of the following alternatives: (1) conventional suspension type with 4,100-ft. main span (f); (2) multiple-span layout (d) and (g); and (3) central anchorage design (d and h). [NOTE: the center span shown in Alternative (f) is 3990 rather than 4100 feet.]
>
> The 4,100-ft. span presented strong temptations. It required fewer departures from past practice than any alternative layout, reduced the number of piers to be constructed and was a more monumental structure. On the other hand, it was open to the following objections;
>
> 1. The difficulties in building the San Francisco anchorage. An open cofferdam, 100-x 250-ft. in plan, constructed to -120 would have been required.
>
> 2. While investigations indicated that it would be possible to secure the necessary stiffness with a width of 72 ft. c. to c. [center to center] of trusses, a large amount of stiffening-truss material would have been required to resist wind stresses.
>
> 3. It did not provide as much clearance in the main steamship lane between the pier-head line and the first pier as does the adopted design.
>
> 4. The construction west of the anchorage involved the destruction of two harbor piers.

[157] Purcell, Andrew, and Woodruff, "San Francisco-Oakland Bay Bridge, A Review of Preliminaries," 373.

5. The construction cost was estimated at $3,000,000 higher than the adopted design.[158]

Purcell, Andrew, and Woodruff go on to say that the structural tests conducted by Professors Beggs and Davis raised serious concerns about the safety of that design, and the alternative was not studied in great detail. They note that in early 1932 "we presented these studies to the consulting board which had been appointed, and unanimous agreement was reached on the outline of the final design."

The narrative as presented by Purcell, Andrew, and Woodruff is correct as far as it goes; it is deficient in that it omits some of the most interesting debates that occurred between and among the various engineers. Correspondence of the key players suggests that Andrew, Purcell, and Modjeski had decided upon the advantages of a twin-suspension design very early in the process, but that Moran, Moisseiff, and Woodruff (who was supervised by Purcell and Andrew and was less open in expressing his feelings) leaned toward a simple suspension bridge with a massive main span.

As to the third option – a continuous suspension bridge with three or four towers – virtually everyone agreed at an early date that it was a bad idea. The referenced engineering model study showed that the towers, particularly the inside towers, were too flexible to handle most wind and earthquake stresses unless the towers were joined by horizontal cables, tied from the tops of the towers. In July 1931, Modjeski wrote to Purcell, expressing grave reservations about this design:

> If this latter type of Bridge is used [continuous suspension bridge], the most economical remedy for the elimination of the excessive deflections would be by use of tie-cables between the tops of the towers... The use of tie-cables might result in some savings in the weight of stiffening trusses and towers but would be objectionable from an aesthetic standpoint.[159]

Modjeski was even more blunt in a letter of December 22, 1931 to Glenn Woodruff:

> I suppose that you mean by "tie cables" is what are sometimes referred to as restraining cables. Personally I am very much opposed to the use of such cables as being in the nature of a makeshift. Aside from the difficulty in anchoring these tie cables there are other objections which I do not wish to discuss at the present time, but I shall express these objections at the next meeting of the Board. I am very sorry that any time at all is spent on this design.[160]

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[158] Purcell, Andrew, and Woodruff, "San Francisco-Oakland Bay Bridge, A Review of Preliminaries," 376.

[159] Modjeski to Purcell, July 10, 1931. Consulting Board of Engineers, Ralph Modjeski, 200.5, California State Archives.

[160] Modjeski to Woodruff, December 22, 1931, Consulting Board of Engineers, Ralph Modjeski, 200.5, California State Archives.

Leon Moisseiff expressed a negative view in a letter of November 7, 1931, stating that "in order to obtain the desirable rigidity would involve a cost much higher than the difference of $2,000,000 estimated by you for the single span bridge. I, therefore, recommend that your work be concentrated on a more complete study of the single and the twin spans."[161] He later wrote again to Woodruff, stating that "your figures have demonstrated the inapplicability of this type for the West Bay crossing."[162]

Thus, the continuous suspension design was rejected by consensus for reasons related chiefly to the use of tie cables, which were objectionable for cost and aesthetic considerations. The other option – a conventional bridge with a long main span and very long side spans -- was not so easily rejected and the decision not to build it was not unanimous.

It appears that Purcell and Modjeski had tentatively concluded that the twin-suspension design was superior to the conventional suspension bridge, perhaps as early as January 1931.[163] Scant evidence from correspondence between the two men indicates that Modjeski had either suggested the idea of a twin-suspension design to the state employees, or had arrived independently at that design. In a January 19, 1931 telegram to Purcell, Modjeski reported on meetings with War Department officials regarding changes to the War Department permit to accommodate a design other than a multiple cantilever. Modjeski had apparently met with these officials on behalf of the state, and proposed tentatively the idea of a double-suspension design. The telegram read: "Had interview with General Brown and Pillsbury. Stop. Both will gladly approve suspension design with central anchorage. Stop. Two shore spans 2200 feet clear and two center spans about 1050 feet clear each. Stop. Will await further instructions from you. Will send sketch from New York."[164]

In a February 4, 1931 letter to Modjeski, Purcell expressed support for the twin-suspension bridge design because it was cheaper and posed fewer problems with respect to the interruption of shipping in San Francisco -- the rationale given by Purcell, Andrew, and Woodruff in their 1937 articles.[165] Purcell acknowledged receiving a sketch from Modjeski and noted that it was "comparable" to a design developed by his staff. Modjeski responded, agreeing that the twin design was superior "from the standpoint of economy as well as aesthetics."[166] As noted, it is not

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[161] Moisseiff to Woodruff, November 7, 1931, Consulting Board of Engineers, Ralph Modjeski, 200.5, California State Archives.

[162] Moisseiff to Woodruff, December 29, 1931, Consulting Board of Engineers, Ralph Modjeski, 200.5, California State Archives.

[163] The available correspondence between the two in early 1931 refers to alternative bridge designs through reference to drawing numbers. The drawings, unfortunately, are not attached to the correspondence, making it possible to decipher the intent only by inference.

[164] Modjeski to Purcell, January 19, 1931, Board of Consulting Engineers, Ralph Modjeski, 200.5, California State Archives.

[165] Purcell to Modjeski, February 4, 1931, Board of Consulting Engineers, Ralph Modjeski, 200.5, California State Archives.

[166] Modjeski to Purcell, February 17, 1931, Board of Consulting Engineers, Ralph Modjeski, 200.5, California State Archives.

clear from this correspondence whether Modjeski had developed the design and suggested it to the engineers at the Division of Highways, or whether the two had independently arrived at the concept. The former explanation is more plausible, given the general lack of experience in suspension bridge design among the employees at the Division of Highways.

Moran and Moisseiff disagreed with the conclusion already reached by Modjeski and Purcell. Moisseiff, writing in November, 1931, urged Woodruff to continue to study the single suspension design, despite an estimated $2 million additional cost for it, versus the twin-suspension design: "The higher cost of 7 percent which the single span shows is in my mind well justified by the superior structure which will result. The absolute figure of $2,000,000 will probably be saved by your more detailed studies."[167] He wrote Woodruff again in December, arguing that Woodruff's calculated stresses on the stiffening trusses for the single suspension design may have overstated the problem, noting that "I still entertain hopes that the long span will prove the more practical."[168]

Moran and Proctor were brought to the team chiefly to deal with foundation issues and were rarely asked to comment on general bridge types or superstructure matters. Nonetheless, the firm in November 1931 expressed a strong preference for the single suspension design. In a letter signed by both partners, Moran and Proctor stated:

> We would further call the attention to the Board [of Consulting Engineers] to the greater advantages, to the cities of San Francisco and Oakland, of a single span design; first, because it would provide the best possible water way for shipping and; second, because it would undoubtedly create a bridge which architecturally and spectacularly would appeal to the civic pride of both Cities, and would attract and interest all of the surrounding districts. In my opinion such a bridge would attract so many visitors to the two Cities, that in the course of years the profit to the two Cities, from this source alone, would more than compensate for the relatively small difference in cost. It would be impossible to estimate how much the City of New York and Brooklyn profited by the spectacular achievement of the Brooklyn Bridge, or how much St. Louis benefited by the Eads Bridge. We feel sure that if you consider the value of the bridge to the two communities, there will be no hesitancy in giving a very considerable value to the difference between the cost of such a bridge as compared with a bridge which would place an extremely large pier in the center of the channel, which would place five piers in the channel instead of two, and which would also indicate that the design was one adopted for economical reasons rather than for reasons based on harbor requirements plus architectural requirements.[169]

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[167] Moisseiff to Woodruff, November 7, 1931, Board of Consulting Engineers, Leon Moisseiff, 200.504, California State Archives.

[168] Moisseiff to Woodruff, December 29, 1931, Board of Consulting Engineers, Leon Moisseiff, 200.5, California State Archives.

[169] Moran and Proctor to Woodruff, November 9, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

The Board of Consulting Engineers met in San Francisco in late January 1932 and, as noted by Purcell, Andrew, and Woodruff, unanimously approved the twin-suspension design. The board rejected the conventional suspension bridge option on January 26, "on account of the difficulties and hazards of pier construction on the rock slopes West of Yerba Buena" and "on account of cost."[170] The unanimous vote no doubt reflected confidence by Board members that the design was economical and safe. It did not, however, reflect consensus that such a design was the best solution to the problem. Moran and Moisseiff had lobbied as best they could for a single suspension design, with their most forceful appeals coming months before the January 1932 meeting of the Board.

In this critical design decision, it appears that Purcell and Andrew made their decision based upon economy and compatibility with existing land and water uses in San Francisco. They took into account the issue of aesthetics; they could hardly have done otherwise, given the strong appeals by Moisseiff and Moran on that basis. Modjeski, who regarded the twin-suspension bridge as an aesthetically pleasing form, supported Purcell and Andrew in their decision. In the end, this fundamental choice was made by Purcell and Andrew, who had to weigh the advantages and disadvantages of two alternatives, both of which were felt to be structurally sound and practical to build. The other Board members acceded to the wishes of Purcell and Andrew; the Board, ultimately, was advisory in nature and members recognized that the responsibility for making such tough decisions fell to the two responsible state employees.

7.4. Solving the Problem of Mid-Bay Foundations

The decision on a bridge type for the West Bay Crossing (and for the East Bay as well) influenced the number of deep-water piers as well as their placement. The state employees and Board of Consulting Engineers understood from the outset, however, that these piers would be problematic, no matter how many or where they would be put. While there were myriad smaller issues, the essential challenges posed by these piers were: How deep should they be placed? and How could this work be accomplished?

The answers to both questions hinged to a large extent upon the conditions of the Bay floor. Although a substantial number of borings had been made as part of the Hoover-Young Commission studies, a great deal was still unknown in 1931, as the design efforts were getting underway. This information could be gathered only through very expensive borings, work that could not proceed until state appropriations were released in August 1931.

Nonetheless, a great deal was known from the Hoover-Young Commission borings, enough to alert Andrew and Purcell to the key problem areas, particularly those in the East Bay Crossing. In January 1931, when the state's studies were just getting underway, Andrew and Purcell sought the advice of Modjeski and Moran on how to proceed with their early work on the East Bay. This

[170] Minutes, Fourth Meeting of the Second Session of the Board of Consulting Engineers, January 26, 1932. The Second Session lasted from January 25-30, 1932. Most of the major decisions about the design of the bridge were resolved at that session.

work was crucial to their early design work because it would affect their decisions about span length and placement of piers for the main shipping channel span on the East Bay side of Yerba Buena Island.

Andrew and Purcell were at that time considering three lengths for the East Bay main span: 800', which was less than specified by the War Department; 1400', the minimally acceptable length in the view of East Bay shipping interests (and the length that was ultimately built); and 1700', a length preferred by the War Department and East Bay interests. In December, 1930 or January, 1931, Andrew and Purcell forwarded to Modjeski and Moran the results of the limited boring program from the Hoover-Young studies, seeking their advice on the implications of foundations studies for the design of the East Bay span. Moran and Modjeski, who were not under contract with the state at the time, replied with a remarkably detailed preliminary analysis, in a letter of January 10, 1931. They concluded as follows:

> After careful study of the pertinent data, we beg to report as to the question of span lengths for the East Channel Section of the San Francisco Bay Bridge.
>
> 1. That irrespective of the determined length of the first span East of Goat Island, the foundation supports for this span should consist of heavily reinforced concrete, large area, piers to bed rock.
>
> 2. The results of sub-soil boring explorations indicate bed rock at approximately 250 ft. depth at the location of piers for the support of the easterly end of an 800 ft. span east of Goat Island, - at approximately 300 ft. depth for a 1400 ft. span; and at approximately 335 ft. depth for a 1700 ft. span. This data is of controlling importance because:
>
> A. Piers will be required for any of the three mentioned spans at considerably greater depths than any previously installed; the greatest depth heretofore involved in bridge pier installation being less than 200 ft.
>
> B. The maximum depth to which a bridge pier can be installed is a function of the skin friction, which will develop to resist sinking. The materials overlying rock at this site are of the type of stiff clay, which will produce the greatest frictional resistance to sinking. The design for these piers must depart from precedent to meet entirely unprecedented conditions, therefore it is impossible to definitely predict the maximum depth to which such piers can be installed; the decision as to the maximum depth to which a pier should be designed to be sunk being entirely a matter of judgment.
>
> C. The maximum possible resistance to earthquake stresses decreases rapidly with both the increase of depth of foundation piers and the increase of span. The weight on the piers under a 1700 ft. span will be twice that of the 1400 ft. span, with a moment arm increase of more than 10%.

> 3. It is our opinion that a type of foundation pier can be designed to be successfully installed to the required depth for the support of a 1400 ft. span, but that this is the maximum depth that should be attempted. To attempt a greater depth would be in defiance of the best engineering principles.
>
> 4. The conditions in the East Channel are not comparable to those in the West Channel due to the wide variation in foundation depths. In the West Channel with rock at considerably more reachable depths, the most economical design involves large spans, whereas in the East Channel the very considerable depth to bed rock requires minimum pier depth involving minimum span for maximum economy.
>
> 5. The increase in cost for a 1400 ft. span East of Goat Island over that of an 800 ft. span would amount to $4,000,000.00. The unprecedented depth of foundation required for a 1700 ft. span precludes the possibility of applying unit costs for such foundations.
>
> We therefore recommend that the maximum span East of Goat Island be 1400 ft. with a maximum vertical clearance of 185 ft. above M.H.H.W.[171]

As noted, this letter was intended to help Purcell and Andrew make preliminary decisions about the length of the span east of Yerba Buena Island. It necessarily focused on foundation work, however, because the depth to bedrock was known to be much greater on the East Bay Crossing than on the west. At this early date, Moran and Modjeski had drawn two key conclusions: that the first of the East Bay Crossing piers should be taken to bedrock; and that the main span should be no more than 1400'.

When money became available for more detailed geological studies, Purcell and Andrew again looked to Moran for advice on how to structure the borings program. As soon as the state money was released, Purcell and Andrew sent a telegram to Moran, asking his opinion on how the borings program should be structured to yield the most reliable data. On August 3, he replied with a four-page letter, detailing the specifications for every aspect of the work, from the type of cutting edge to the diameter of the sample to the methods for storing samples prior to inspection by engineers and geologists.[172]

It appears that Purcell and Andrew in late 1931 began to have misgivings about the practicality and economic feasibility of taking the East Bay Crossing piers to bedrock. On November 4, 1931, Purcell wrote to Moran:

> We are just starting borings on the east channel. You will recall that there has been some discussion in regard to the pier at the east end of the 1400-foot channel on account of the

[171] Modjeski and Moran to Purcell, January 10, 1931. Board of Consulting Engineers, Ralph Modjeski, 200.5, California State Archives.

[172] Moran to Purcell, August 3, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

> extreme depth (approximately 300 feet) to rock.
>
> From all reports, the clay in this section is extremely stiff and it does not seem to me that we should assume the necessity of carrying this pier to rock. For instance, it may turn out that this clay is as good as the clay on which the two bridges at Memphis are founded.[173]

Five days later, Moran expressed guarded agreement with the concept of stopping short of rock with Pier E-3. He wrote:

> In answer to your letter of November 4, I beg to say that in our opinion all main piers should be carried well below the level at which artesian water is found. If the substrata below the artesian water levels are determined by test to have a low compression change, we would agree with you that these piers could be safely designed to rest on very solid clay... In our opinion it is essential to make laboratory tests on the clay-like materials encountered by the borings, and to obtain careful samples to rock.[174]

In early January 1932, Moran wrote a more discouraging analysis to Purcell, having seen some initial analysis on the boring samples by Professor R. E. Davis. He wrote:

> The initial report of Prof. Davis confirms our preliminary diagnosis of the soil samples, in that the tests indicate that under moderate loads of less than six tons per square foot on the clay at the elevations from which the samples were obtained, a very considerable settlement results... Even if the sampling and testing of materials progresses rapidly it will undoubtedly be impossible for us to arrive at a decision as to the proper design of the piers for the eastern section of the bridge, or as to the unit loads which can be imposed on the material by February 10th.[175]

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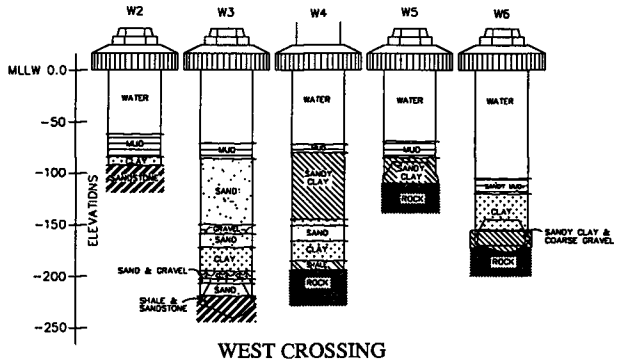
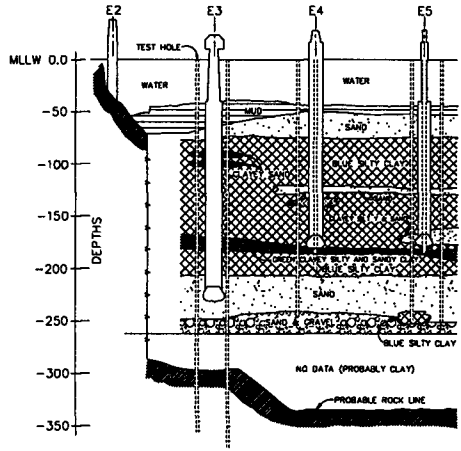
[173] Purcell to Moran, November 4, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives. As Purcell observed in his note to Moran, not all great bridges were built on bedrock; he cites two bridges in Memphis that were not. The Brooklyn Bridge in New York City includes a pier that does not reach bedrock.

[174] Moran to Purcell, November 9, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

[175] Moran to Purcell, January 7, 1932, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.



WEST CROSSING



EAST CROSSING

Source: Sixth Annual Report San Francisco-Oakland Bay Bridge p.103-104
Location: California Department of Transportation Archives, District 4

Geological Foundation

In May, 1932, Modjeski, Moran, Proctor, Moisseiff and members of their staff convened a series of meetings, calling themselves the "New York Members of the Consulting Board," to decide what could be done about the East Bay Crossing piers. By this time, all misgivings or doubts about the foundations on the east spans had disappeared. The meeting, rather than focusing on the required depth, centered on the methods through which such foundations could be built. The long letter report outlined the innovative floating caisson method of construction, which Moran had used previously on a number of bridges and for which he had a pending patent. Pier E-3, the most troublesome of all, was described "as a reinforced concrete crib sunk to elevation -230.0, with such dimensions that the resulting pressure does not exceed 2 1/2 tons per square foot in vertical loads only." Piers E-4 and E-5 were described in a similar manner but taken only to -180. The remaining East Bay piers were "to be designed as pile foundations," noting that "it is the intention that during construction careful observations should be made to determine if the piles are destroying the character of the soils through which they are being driven, and if necessary, at the time of construction, either the adoption of other methods for driving the piles or a redesign of foundations to avoid piles, be considered."[176] The letter, in short, discussed the methods for building the piers but did not discuss how deep the piers should be. The "New York Members" had by May 1932 agreed with Purcell and Andrew that it was impractical to attempt to reach bedrock on the eastern half of the bridge.

A change of heart had occurred between January and May 1932 on the part of Moran and Proctor with respect to the need to reach bedrock on the East Bay Crossing. To what may this be attributed? In the absence of additional internal memoranda, this point cannot be settled conclusively. The best available evidence suggests that geological studies helped change the opinions of the New York engineers. The final geological studies, conducted by Andrew Lawson of the University of California, were not reported until early June 1932, but the general results were available earlier to Moran and Proctor. Indeed, Lawson had presented his findings in person before the Board of Consulting Engineers when it met in San Francisco on April 18 and April 22, 1932.[177]

Lawson's report was not optimistic about the chances of taking foundations to bedrock but seemed confident with respect to construction on the clays above. At the crucial E-4, E-5, and E-6 sites, rock was encountered at -308.1 feet and -284.0 feet. Lawson noted:

> These figures indicate that the rock surface east of Yerba Buena Island is deeper than that between the island and San Francisco, and that therefore the ancient valley, which by subsidence became San Francisco Bay, had its main drainage on the east side of the island, then a hill in the valley. It is furthermore probable that the deepest part of the rock

[176] "Memorandum," May 27, 1932, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

[177] Minutes, Second Meeting of the Third Session of Consulting Board, April 18, 1932; Tenth Meeting of the Third Session, April 22, 1932. Lawson was also the consulting geologist for the Golden Gate Bridge, the foundations for which were nearly as vexing as those for the Bay Bridge.

surface is still further east, since a bore hole that was put down near Alvarado some years ago passed thru 730 feet of gravels, sands and clays before reaching bedrock.

[Lawson then notes that the rock is principally sandstone and shales, similar to the rock at Yerba Buena Island.] While these observations as to the cl aracter of the bedrock are interesting, the surface of the latter is too deep to be considered as a possible foundation for the piers necessary for the support of the bridge east of the island. It becomes, therefore, a matter of importance to ascertain the character, distribution and bearing strength of the bay bottom deposits which rest on the bedrock surface, since it is in these that foundations must be found for the succession of piers that will carry the bridge over this portion of San Francisco Bay...

[He notes that between -180 and -120 the sands are mixed with peat.] The clays and sandy clays are, however, rather plastic and it appears to be inadvisable to attempt to find a foundation for any of the piers above this depth. Below this there is, however, a persistent stratum of sand or very sandy clays about 30 feet thick, which in turn lies on sandy clays, clays and sands which are stiffer and much more unyielding than those above the 30 foot sand layer. It is my opinion that an adequate foundation will be found for the piers at the top of this 30 foot sand layer... [For Pier E-3] it may be advisable to sink to about -220' and place the foundation upon a lower, still more sandy and gravelly formation... [This material at -220'] will in my opinion afford a satisfactory foundation for pier E3.[178]

After May and June 1932, all discussions about the foundations turned from the depth to bedrock to the equally vexing issue of how to build the piers. The decision not to go to bedrock on the East Bay Crossing appears to have been decided by Purcell, drawing upon the best advice he could find: the confident approval of Professor Lawson and the somewhat more reluctant approval of Moran and Proctor. By June 1932, the project was already falling behind in its ambitious design schedule. Once the decision was made, neither the state employees nor the consulting engineers ever seemed to have looked back on it.

The methods for sinking the piers appears to have been entirely the work of Moran and Proctor, whose reputation in this regard was the chief reason they were selected for the board. The previously cited memorandum from Modjeski, Moran, and Moisseiff in May 1932, laid out the basic approach, one that was followed without major deviation. Before that May meeting, the state had issued a separate contract through the firm of Moran and Proctor to "advise this department as to what types of caissons and piers should be used."[179] This work, which lasted three months, formed the basis of the May meeting of the New York members of the board, resulting in adoption of pier-by-pier caisson specifications.

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[178] Andrew C. Lawson, Letter report to C. H. Purcell, June 4, 1932, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

[179] Purcell to Moran, February 3, 1932, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

The manner in which the caissons were erected and the piers built is one of the most heroic aspects of the construction of the Bay Bridge. Briefly, Moran and Proctor recommended use of a "flotation cylinders" caisson, a method of construction for which Moran, as noted, had developed a patent application. As soon as the state expressed interest in using the method, Moran wrote to Purcell, insisting that he was "anxious to have the State of California have free use of this invention for this bridge," and announcing that he had asked his attorneys as to how this could be done.[180] In the Autumn of 1932, the state engineers in San Francisco worked out the drawings for the caissons and sent these to Moran for his comments, which were voluminous, and his ultimate approval.

In conclusion with regard to the mid-Bay piers, there was no early consensus except that the West Bay Crossing piers needed and could be taken to bedrock. The various parties – state engineers, consulting engineers, geologists, and others – struggled with the problem for a year before arriving somewhat reluctantly at a less-than-bedrock solution. This decision changed all elements of the bridge type selection for the East Bay Crossing, which had to be designed with the less-than-bedrock foundations in mind.

7.5. Designing the East Bay Crossing Superstructure

A persistent myth about the Bay Bridge is that the East Bay, which was less powerful politically than San Francisco, was somehow slighted in the design of the bridge, with San Francisco getting the view of a more elegant suspension span and the East Bay a more utilitarian cantilever bridge. As suggested in the discussion of foundations, however, the bridge types for the East Bay Crossing were governed to a large degree by the foundation considerations there. The choice of a bridge type for the East Bay Crossing involved a series of compromises involving issues of aesthetics, cost, and safety.

When the state made its first attempt to portray a bridge across San Francisco Bay, it presented a structure built entirely of cantilever spans, on the West Bay as well as the East Bay Crossings. The decision to move to a suspension bridge on the West Bay Crossing was influenced by many considerations, chief among which was the need to preserve shipping channels in the area. In addition, all early indications were that bay floor at the West Bay Crossing would support the large and heavy foundations for very long span structures, including the huge center anchorage. By contrast, early indications were that the East Bay would not support the foundations for any long-span bridge; indeed, the more the subject was investigated, the worse the situation appeared to be.

Thus, there is no indication that at any time the state or its consulting engineers seriously considered a suspension bridge for the East Bay Crossing. Purcell asked Moran and Modjeski in late 1930 or early 1931 to consider the length of span for the main East Bay Crossing; they

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[180] Moran to Purcell, June 29, 1932, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

argued against anything greater than 1400' because of fears about the foundation.

In the absence of a great span, the choices of bridge types were more limited. In a 1931 speech, Charles Andrew spoke as if the design of the East Bay Crossing had already been decided. Andrew outlined in great detail the on-going debate over twin-, single-, or continuous-suspension spans for the West Crossing. As to the major structure on the East Bay, however, he simply stated: "Present superstructure plans east of the island contemplate a 1400' cantilever just off the shore, followed by three or four 500' spans and a long stretch of fixed spans of shorter length to the east shore."[181]

In a speech given to an unnamed group in early January 1932, Glenn Woodruff professed that the selection of a bridge type had not yet been made. He stated:

> In crossing from Yerba Buena Island to the Key Route Mole, our span layouts are made quite definite by the War Department permit which requires a 1400 foot span east of Yerba Buena then 3- 500 foot spans. For the remainder of this crossing the lengths of the spans will be such as to keep the cost to the minimum. Our principal design problem is, then, to find the most economical solution of the 1400 foot span and at the same time give due consideration to the question of appearance.
>
> We have considered three possibilities as follows:- 1. A self anchored suspension. 2. Cantilever. 3. Continuous. Our studies have not reached such a point as to enable us to give a definite conclusion.[182]

In their 1937 series of article for *Engineering News-Record*, Purcell, Andrew, and Woodruff include illustrations of the alternatives listed by Andrew, along with a through arch, on the model of the great Hell's Gate Bridge in New York. In their text, however, the three make no mention of why the cantilever design was selected; this is in contrast with the extensive discussion of alternatives on the West Bay Crossing. They speak only of the controlling factors of the unstable abutments and of the need to reduce the weight of the structure. They speak as well of the need to use steel columns rather than masonry columns, again to reduce dead load (i.e. the weight of the bridge itself), as well as the long distances between expansion joints.

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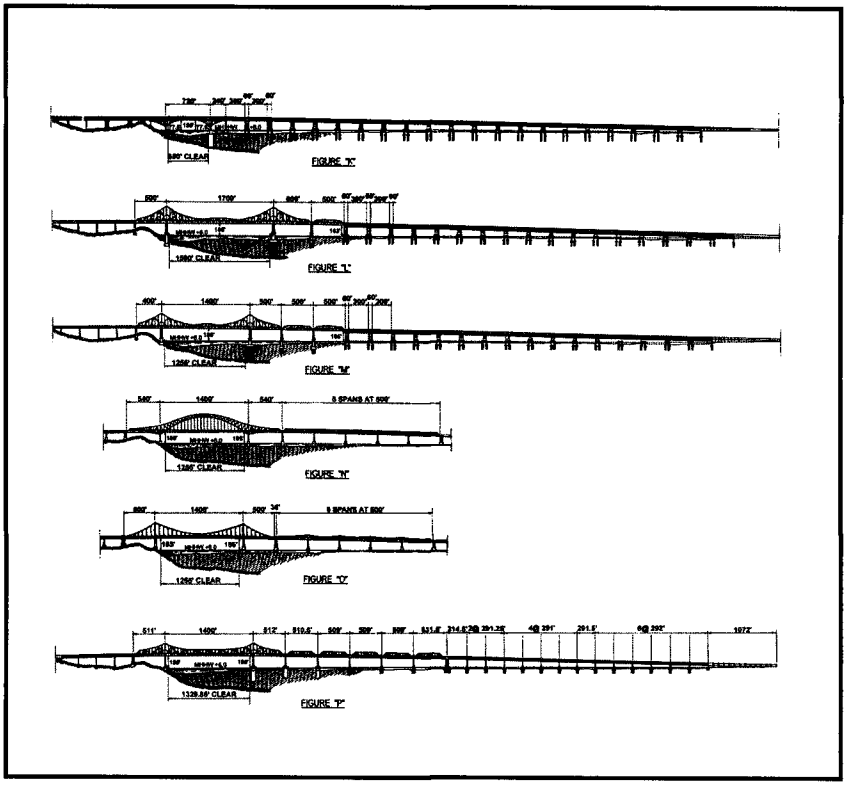
[181] Undated speech, "Preliminary Foundation Studies and Main Span Design, San Francisco Bay Bridge," in Andrew's memoranda. The provenance in the file suggests it be given in early 1931.

[182] "The Design of the San Francisco-Oakland Bay Bridge," Memoranda of the Engineers, Glenn Woodruff, 000.052, California State Archives.



Source: Final Report Drawings, State of California, Department of Public Works p.3
Location: California Department of Transportation Archives, District 4

East Bay Crossing Options

The minutes of the formal meetings of the Board of Consulting Engineers offer some insight on how and why the cantilever design was selected over that of the tied arch. On January 25, 1932, the Bay Bridge division prepared a report on design considerations for the shipping channel of the East Bay Crossing. In this document, various cantilever designs were outlined. The report continues: "None of the cantilever designs were satisfactory from the standpoint of appearance. The tied arch design.. was developed as presenting a better appearance... The estimates indicate that it compares favorably in cost with the cantilever design."[183] The board apparently agreed. The minutes for the board meeting of January 27 note that: "The different alternative designs for the East Bay Crossing were submitted to the Board. After discussion, it was decided that if not materially more expensive, the arch design should be adopted."[184]

The board reconsidered the issue at its next session in April 1932. The Bay Bridge Division again summarized the design considerations that had gone into planning for the 1400' span, but this time with a different conclusion. In a report dated March 18, the state engineers recapitulated the prior design work on this span. This included the following summary: "We have made several layouts in an effort to develop a structure more pleasing in appearance than a conventional cantilever. Among our early studies we developed a design for a self-anchored suspension bridge. The appearance of the resulting structure was not satisfactory and its cost was excessive. Our next effort was the tied arch design."[185]

With respect to the tied arch, the author of the report (probably Woodruff) noted that the tied arch was feasible although difficult to erect without intermediate falsework, which the state hoped to avoid. The author then compared the estimated cost of the tied arch and cantilever 1400' spans, with an estimate of $3,608,500 for the arch and $3,239,000 for the cantilever. He concludes: "It should be noted that the same unit prices have been used in both the arch and cantilever design. It is our opinion that not less than $240,000 should be added for more expensive fabrication and more difficult erection of the arch span. This gives a differential of $600,000 in favor of the cantilever layout. We recommend that one of the cantilever layouts be chosen for the final design and that further study of the arch layout be discontinued."[186]

In short, available documentation suggests the cantilever and tied-arch designs were both given serious considered for this crossing. The continuous truss and self-anchored suspension designs were considered, at least to the degree that drawings were made of them. The self-anchored suspension design was studied in greater detail but was rejected as unattractive. The tied-arch was given the more in-depth consideration, chiefly because engineers were concerned about the

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[183] California Department of Public Works, "East Bay Crossing," January 25, 1932, stored with the Minutes of the Board of Consulting Engineers, Second Session, in the papers of Charles Derleth, Water Resources Center Archives, U. C. Berkeley.

[184] Minutes of the Board of Consulting Engineers, Sixth Meeting of the Second Session, January 27, 1932, in the papers of Charles Derleth, Water Resources Center Archives, U. C. Berkeley.

[185] "The East Bay Crossing," March 18, 1932, report submitted to the Third Session of Consulting Board, April 18-22, 1932, 2.

[186] "The East Bay Crossing," March 18, 1932, report submitted to the Third Session of Consulting Board, April 18-22, 1932, 3-4.

aesthetics of the cantilever design. The tied-arch was ultimately rejected, however, because it was estimated to cost $600,000 more than the cantilever, or about 18 percent more. It appears that this cost differential, combined with the increased difficulty in erecting the tied arch (which was reflected in the cost), was the reason for rejecting the tied arch design.

7.6. Conclusions regarding how the Key Elements of the Bay Bridge Were Designed

The Bay Bridge was designed by a large team; if there is any conclusion that can be derived from its history, it is that no one individual can lay claim to the primary responsibility for this spectacular structure. Some of the great minds of 20th century American engineering participated, along with dozens of dedicated state employees and the employees of the offices of the consulting engineers.

One historian, Kevin Starr, has concluded that the bridge was designed by Glenn Woodruff and other "straightforward civil servants."[187] That contention is only partially supported by the facts. First, Woodruff's role was more that of a consultant than a civil servant; he was hired away from private practice for a few years and returned to the private sector as soon as the bridge had been completed. Purcell, Andrew, and the employees at 500 Sansome Street surely were civil servants but whether they were straightforward is a matter of interpretation.

The notion that the bridge was exclusively, or even primarily, designed by the state employees, however, is not supported by the facts. The three key elements highlighted in this study, for example, were essentially designed by the consulting engineers: Modjeski apparently devised the twin-suspension bridge, Moran the treatment of the foundations, and Modjeski and others the multiple bridge type concept. These plans had to be approved by Purcell and taken to final design by the state employees. But it is a misreading of the situation to underestimate the role of the consulting engineers in the key decisions on the bridge.

A second issue of authorship concerns the contemporary attribution by many to C. H. Purcell. As has been stated, it is misleading to give any one individual credit for any substantial part of the design of this or any other great bridge; it was a team effort. A more focused question is whether Purcell served as the "mastermind," as Petroski uses the term, the individual whose vision led to the creation of the bridge. The press coverage upon completion of the bridge was effusive in its praise of Purcell, dubbed *Purcell Pontifex*, and left no doubt that his vision was responsible for this great achievement. Former President Herbert Hoover said as much in dedicating the bridge: "Charley, some day people will erect a monument to you for building the San Francisco-Oakland Bay Bridge!"[188] The San Francisco *Recorder* addressed the issue of how to assign authorship to a structure so grand:

> To our untutored mind the San Francisco-Oakland Bay Bridge has been flung across our waters by a kind of white magic. Call it engineering magic, by all means, but the science

[187] Kevin Starr, *Endangered Dream*, 328

[188] *Purcell Pontifex*, 73.

> of strains and stresses, etc., etc., when applied to an undertaking as huge as this, seems to us to transcend the resources of the human brain. When we look at the bridge we are all humility, and we salute a miracle.
>
> Many laymen must feel as we do. There is the bridge before our eyes. How did it get there?
>
> We have a strong suspicion that it got there because an engineer by the name of Charles H. Purcell has been on the job.[189]

The importance of Purcell's role in designing the bridge may seem very large or less significant, depending upon the elements of the design process that are taken into account. Purcell excelled in two areas: as an administrator and as a responsible decision-maker. He assembled the team that designed the bridge and ensured that the dozens of individuals worked effectively and toward a singular goal. The breakneck speed with which the major decisions were made and the plans assembled is an accomplishment of tremendous significance and it is to Purcell that the principal credit should be given. Any high-ranking state administrator must also be a politician, and Purcell was skilled at balancing the many interests not treated in this chapter: the state politicians; the Reconstruction Finance Corporation, which held the purse strings; Congress; San Francisco, Oakland, and other concerned cities. Purcell kept the team together, and for that he deserves credit. He was also a tough decision-maker. When his team arrived at conflicting conclusions, as was the case with the West Bay Crossing superstructure, Purcell was ready to step in and decide, based upon his perception of the public interest.

If responsibility for the Bay Bridge is measured in terms of vision – the creative "mastermind" vision of which Petroski speaks – the importance of Purcell is diminished. If one person were to be credited with the engineering vision for the bridge, the ability to envision the bridge in its entirety taking into account cost, safety, and aesthetics, that person would likely be Ralph Modjeski. Modjeski offered calm counsel to the state employees in San Francisco and provided new ideas whenever the design process began to founder. This observation does not diminish but rather focuses the role of C. H. Purcell in designing the bridge. Neither Purcell nor any other state employee had ever worked on a bridge of such complexity and magnitude. It is to Purcell's credit that he selected an engineer of the artistic and practical sensibilities of Modjeski to serve as his chief advisor. Modjeski offered sound advice and left many of the details to Purcell and his employees. Glenn Woodruff, who studied under Modjeski, was the state employee most directly responsible for making design decisions; if credit for a vision of the bridge must be given to one of the state employees, that credit belongs to Woodruff.

As noted, the design process for the Bay Bridge required that the team be able to focus simultaneously on three factors: cost, safety, and aesthetics. All three considerations had powerful impacts on how the bridge was designed.

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[189] *Purcell Pontifex,* 51.

Of these, economy was particularly important because the state had only so much money to spend. It is difficult to understate the importance the Great Depression had on the decision-making process for Purcell and the others in San Francisco. When planning began for the Bay Bridge, all hoped to sell bonds to private investors, bonds that would be backed by the toll-generating capacity of the bridge and secondarily by the good faith and credit of the State of California. The conditions in private bond markets and the desperate condition of state financing left Purcell with no choice but to rely upon the funds available from the Reconstruction Finance Corporation (RFC). Only the RFC was prepared to invest in the project. The RFC in turn had limited its participation to the amount that economic forecasts had indicated the bridge could support on a self-liquidating basis. Purcell knew that he had $70 million to spend and not a penny more. There were no alternative sources of funds; if the bridge could not be built for $70 million, it could not be built. Economy, in short, was not a desirable goal, it was a barrier that could not be crossed.

The need to economize affected all aspects of Purcell's decision-making. The selection of the twin-suspension span appears to have been chiefly an economic choice, as was the decision not to take the East Bay Crossing piers to bedrock. The decision of a cantilever East Bay main span over a tied-arch design appears to have been made exclusively on the basis of cost. In 1933, when Purcell appointed a Board of Consulting Architects to work on the approaches and other design details, he would fall back on economy as the principal reason for rejecting much of what the architects put forward.

Safety and structural integrity were also unavoidable considerations. The first rule of bridge engineering is to construct structures that will be safe and stable. All of those involved, from the well-known consulting engineers to the new hires at 500 Sansome Street, understood this basic rule and all of their decisions took it into account. The overriding concern for safety and structural integrity, however, did not mean that the responsible parties were not prepared to take risks. Indeed, the entire enterprise was something of a risk because of the large number of untried methods and technologies involved. This was particularly the case with the West Bay Crossing and the foundation work. The twin-suspension bridge design had never been built before. While models showed it was stable, all parties adopted it with the understanding that there were aspects of its performance that could not be predicted. Similarly, the incredibly deep foundations on both crossing were designed with the understanding that unresolved questions remained. The West Bay piers posed hazards for the workers and long-term questions about whether they could even be built. The decision not to take the East Bay piers to bedrock was also a calculated risk, balancing economy and technical feasibility on the one hand against the understanding that any major pier would perform best if taken to bedrock. The reluctance with which the major designers agreed to this approach, particularly Moran and Proctor, underscores the difficulty of this decision.

Aesthetics was the third part of the equation and was considered at every juncture of the design process. As discussed in the following chapter, some historians have criticized the design of the Bay Bridge because it was not planned to a significant degree with the input of an architectural board. While there was a Board of Consulting Architects for the Bay Bridge, the influence of the

architects was probably not as great as was the case with the Golden Gate Bridge.

It is wrong to conclude, however, that aesthetics was not a consideration in the design of the bridge, because architects were uninvolved or ignored. The fact is that the bridge engineers were themselves quite concerned with the aesthetics of the design. Nearly all of the engineers, from Purcell to Andrew to Modjeski to Moisseiff, had developed reputations for designing handsome structures. In a previously quoted testimonial, Modjeski was described as "inherently an artist. He has not chosen oil, or dry point, or marble, or even music, in which he doubtless would have excelled, to express himself, but steel, and stone, and concrete."[190] Andrew in his years as head of the bridge department of the Division of Highways earned national acclaim for the beauty of bridges, particularly concrete arches, built by the state. In his best-known discussion of the role of the highway bridge as a monument, Andrew wrote "that no objects in America more greatly mar the landscape than the bridges, and none in Europe are more attractive." The failure of American bridges in this respect he attributed to "lack of artistic training in engineers, limited resources, competition and haste in construction, undesirable or unsymmetrical location, inadequate materials, absence of state or municipal supervision." He exhorted his own staff to "higher ideals in bridge designing," concluding "it is the hope of the bridge engineer that the finished structure will be durable, pleasing in appearance, conform to the canyon or stream; so that the layman and engineer will gain the impression that bridge construction is being kept abreast with building of modern highways."[191] Even Moisseiff and Moran, whose specialties were calculations and foundations, respectively, pleaded passionately for consideration of aesthetics, particularly with respect to the West Bay Crossing. Reasonable people may disagree over the success with which these engineers pursued a pleasing bridge design. It is incorrect, however, to suggest that Purcell, Modjeski, and the others did not include aesthetics in their consideration of design alternatives.

Aesthetics, however, was but one of the three major criteria and was sometimes compromised for the sake of economy or structural integrity. The East Bay Crossing may be interpreted in this regard. The cantilever span, as noted, was the preferred bridge type for the entire structure during the early planning. It appears that the design team gave little consideration to alternative designs, although a tied-arch was considered at least briefly. The decision to build a cantilever at this major crossing – one of two shipping channels – may be attributed to concern over both economy and structural integrity. Although there were several ill-fated cantilever projects in North America early in the 20th century, the cantilever form was arguably the best-understood long-span bridge form available to the design team. The East Bay Crossing was particularly problematic, owing to the fact that the foundations would not be taken to bedrock, a decision that required drastic reduction in the dead load. The decision to stay with a well-understood bridge form at this crossing appears to reflect concerns over structural integrity and, to a lesser degree, for economy. Given the great challenges at this crossing, Purcell stayed with what he knew best. The design team did address the aesthetics of the cantilever and studied the tied arch in detail because it "presented a better appearance" than the cantilever designs. Initially thought to be

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[190] Petroski, *Engineers of Dreams*, 172-173.

[191] C. E. Andrew, "Bridges on California State Highways," *California Highways and Public Works* (July-August 1928): 2, 14.

comparable in cost, the tied arch was ultimately rejected because it cost about 18 percent more than the cantilever. It should be observed, however, that a cantilever bridge is not by its nature an ugly structure. The great Firth of Forth Bridge, the beginning of modern cantilever design, was alternately called a monstrosity or a majestic piece of engineering. Modjeski, who prided himself in aesthetic design, initially made his reputation designing cantilevers, particularly the great second Quebec Bridge. The beauty (or lack of it) of the East Bay Crossing is subject to interpretation, depending upon one's perception of the cantilever as a bridge form.

In the end, the design process that led to the Bay Bridge represents the best solution that a very talented and experienced group of engineers could arrive at over the course of two years to one of the most demanding challenges ever faced by structural engineers. They only had so much money to build the longest bridge with the deepest piers ever attempted and only so much time to design it. Despite the collapse of a 50' section during the Loma Prieta earthquake, the bridge has generally proved to be safe and sound. It was brought in under budget and ahead of time. It stands as a fascinatingly complex structure that is beautiful to many but pedestrian to others. Balancing competing interests of economy, safety, and aesthetics, these engineers – Purcell, Andrew, Woodruff, Modjeski, Moran, Moisseiff, and the others – devised a highly complex series of structures, with each element performing a specific solution to a specific problem. If it lacks a single, coherent vision, it is because the crossing was too long and the footings too deep to allow for a unified structure. The bridge in its many forms reflects the many compromises made by this group of engineers on the way to solving the thousands of problems, great and small, posed by this crossing.

8. THE BOARD OF CONSULTING ARCHITECTS AND CONSIDERATION OF AESTHETICS IN THE DESIGN OF THE BAY BRIDGE

Unavoidably, the Bay Bridge has been compared with the Golden Gate Bridge and for obvious reasons: both were under construction at the same time and in the same city, with San Francisco anchorages about three miles apart. The literature about these bridges typically emphasizes the great superlatives of the Bay Bridge – longest, deepest, most expensive, and so forth. The Golden Gate Bridge, while an awesome suspension span built in treacherous waters, is more often spoken of with respect to its great beauty. Such is rarely the case with the Bay Bridge.

Generations of writers have compared the aesthetics of the Bay Bridge and Golden Gate Bridge, with a near-consensus that the Golden Gate Bridge is a work of art while the Bay Bridge is a largely utilitarian structure. Richard Dillon, who wrote a book-length study of the two bridges, calls the Golden Gate Bridge the "largest work of art in history, dwarfing such an example of combined art-and-engineering as the Eiffel Tower, it is the greatest sculpture ever dreamed,"[192] He admires the Bay Bridge for its engineering superlatives but laments the absence of adoration for the Bay Bridge, relative to that for the Golden Gate. "What more could a bridge ask?" Dillon continues. "Except to be loved, like the Golden Gate Bridge."[193]

Kevin Starr addresses this issue as well in his history of California during the 1930s, *Endangered Dreams: The Great Depression in California.* Starr provides greater detail than most writers about the manner in which each bridge was designed, specifically regarding the role of consulting architects. Regarding the Bay Bridge, Starr writes:

> "San Francisco architect Timothy Pflueger was invited to chair a committee of consulting architects, but one strains to see any element of Pflueger's styling genius in even the suspension half of the structure, which he did work on as a designer. As straightforward civil servants, responsible to the Department of Public Works in Sacramento, neither design engineer [Glenn] Woodruff nor chief engineer Charles Henry Purcell had either the budget or the inclination to commission Pflueger to stylize the four 518-feet-high suspension towers as Gordon Kaufman was asked to stylize Hoover Dam. In terms of design and style, the San Francisco-Oakland Bay Bridge bespoke the engineering aesthetic of public works and the Toll Bridge Authority rather than the aesthetic proclivities of San Francisco."[194]

Starr points to a much larger and successful role for Irving Morrow, the architect of the Golden Gate Bridge, whom he credits with being able to "coax a great work of engineering into its fullest expression as art."[195]

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[192] Dillon, *High Steel*, 5.
[193] Dillon, *High Steel*, 29.
[194] Starr, *Endangered Dreams*, 328.
[195] Starr, *Endangered Dreams*, 334.

Documentary evidence both supports and refutes the position taken by Dillon, Starr, and others. The designers of the Bay Bridge were obsessed with its great engineering challenges, chiefly its unprecedented deep piers, two-mile suspension span, and the tricky business of joining several different bridge types on the East Bay Crossing. The architectural details of the bridge were considered only after those staggering engineering problems had been worked out. Because the technical design of the bridge took place in a span of less than two years, greater attention was given to these vexing engineering problems than to architectural detail.

On the other hand, it would be a misinterpretation of the facts to conclude that architectural design was not considered, before or after a Board of Consulting Architects was appointed. Starr is generally correct in downplaying the importance of the architect's role, at least in relation to that of the state's engineers, or the role of the consulting engineers, especially Ralph Modjeski, whose input rivaled that of any of the state employees. But Starr is not correct to conclude that no traces may be found of the influence of Timothy Pflueger, the other consulting architects, and in-house designers for the state. The relationship between the engineers and architects was often contentious but design considerations may clearly be seen in the finished product. This chapter explores that relationship chronologically and concludes with comments regarding the probable impact of the architectural board as well as the in-house architectural team of the state on the final design of the bridge.

It is an established fact that the Bay Bridge was designed, at least to some degree, with the assistance of a Board of Consulting Architects. The members of the Board were Timothy L. Pflueger, Arthur Brown, Jr. and John J. Donovan, with Pflueger serving as the chair. At the time they were appointed, all three had established careers in Bay Area architecture, although Pflueger and Brown had far more substantial commissions in their resumes than did Donovan. The *Architect and Engineer* summarized their accomplishments and styles in an article of March 1934:

> Mr. Pflueger is an exponent of the modern, with his Four-Fifty Sutter Street, San Francisco Stock Exchange, and Telephone Building as outstanding examples.
>
> Mr. Brown is an exponent of the classic, with the everlasting beauty of San Francisco City Hall and Coit Memorial Tower on Telegraph Hill, numbered among his recent works.
>
> Between the two, with a mixture of both, stands John J. Donovan whose Oakland Auditorium and many California school structures, rounded out the Consulting Board with regard to architectural background.[196]

The board met between April 1933 and completion of most of the construction contracts in November 1936, although the bulk of its work on the bridge proper occurred in 1933 and early 1934. After 1934, the board worked on appurtenant buildings, including the tollbooths, the Transbay Terminal Building, and a garage on Yerba Buena Island, some of which were not

[196] Frederick W. Jones, "Architectural Treatment of the Bay Bridge," *The Architect and Engineer* (March 1934): 49.

completed until 1938. Members of the board were not merely advisory; they were paid retainers and reimbursed for hours spent working on plans.

The crucial fact about the Board of Consulting Architects is that it was appointed very late in the design process for the bridge, after most important decisions had been made. Whatever influence the board may have had was restricted to the details of a bridge form that was firmly established before it ever met. The Bay Bridge Division of the Department of Public Works was established in 1931, although the key personnel, including Chief Engineer C. H. Purcell and Bridge Engineer Charles Andrew, had worked on the bridge design since 1929. The Board of Consulting Engineers, whose contribution to bridge design was very great, was established in mid-1931, although Purcell and Andrew had communicated with some members of the board as early as December of 1930. By the time the Board of Consulting Architects was appointed in April 1933, the plans and specifications had been completed and the project was out to bid; most of the major construction contracts were awarded in late April 1933. Thus, the architects were asked to design a bridge that was already under construction! Any input from them necessarily took the form of a change order to the construction contracts. That fact alone explains why the architectural input was less than it might have been and explains as well the sometimes contentious relationship with the bridge engineers.

8.1. How and Why the Board of Consulting Architects was Appointed

One wonders why the state appointed an architectural board at all, given the late date in which the appointments were made. C. H. Purcell had in his employ some of the most famous bridge engineers in the world, including Ralph Modjeski, Leon Moisseiff, and Daniel Moran. All had designed very beautiful bridges in the past and all had strong opinions about the aesthetic of bridge design. Indeed, the long debate about a bridge type for the West Bay Crossing, between San Francisco and Yerba Buena Island, centered on aesthetics, in addition to the daunting problem of bridge foundations.

No documentation has been found to record why and exactly when C. H. Purcell initially considered hiring an outside architect to work on the bridge. He had a design professional on staff at the Bay Bridge Division – Carlos Nuese – who probably did as much as the Board of Consulting Architects to develop the aesthetics of the bridge, in that he was with the Bay Bridge Division from the outset.[197] The decision to appoint a consulting board appears to have related

[197] Very little information has been uncovered about Nuese. A 1921 notice of his marriage in San Francisco notes that he was 42 years old at the time, had been trained as an architect at the Ecole de Beaux Arts, and had worked on the design of the French Building at the Panama-Pacific International Exposition. There is some doubt, however, as to whether Nuese was licensed as an architect; he left no record with the San Francisco American Institute of Architects or the California Board of Architectural Examiners. In San Francisco city directories, he listed his profession as "delineator." When the Board of Consulting Architects was appointed, Nuese was re-assigned, first to the office of Arthur Brown, Jr. and later to Timothy Pflueger. *San Francisco Chronicle*, August 17, 1921, p. 3, records his marriage. A *San Francisco Chronicle* article of December 7, 1937, 9, mentions that he was living in Hollywood. Among his most notable achievements, Nuese was responsible for the fine architectural renderings that appear in the Annual Reports for the bridge.

more to political pressure, from the American Institute of Architects (AIA), from civic arts organizations, and others, than to a perceived need on Purcell's part for additional architectural advice.

The impetus for appointment of a formal consulting board came from outside groups, who mounted a spirited campaign for such a board in late 1932 and early 1933. The first significant step in this campaign came from the Art Commission of San Francisco, the architectural sub-committee of which included many respected members of the architectural community: Lewis P. Hobart, John Bakewell, Jr. and other prominent San Francisco architects. In a letter of August 1932, the Art Commission of the City and County of San Francisco wrote to C. H. Purcell, stating as follows:

> In accordance with the new Charter of the City and County of San Francisco the design or model of any bridge, viaduct, elevated ways, or approaches that extend upon the property of the City and County of San Francisco must receive the approval of the Art Commission.
>
> In order to expedite matters the Art Commission of the City and County of San Francisco respectfully requests that the California Toll Bridge Authority submit their design or model for that part or section of the San Francisco side of the bridge which is to be erected over or upon property of the City and County of San Francisco.[198]

Two days later, Purcell wrote to Charles Andrew, instructing him to "reply to the communication of the Art Commission, and forward to them the necessary plans." Andrew penciled a note on this letter: "This is important. We should get started on this."[199]

Andrew's note was made in September 1932; the Board of Consulting Architects would not be appointed for another six months. In the interim, it appears that the word was out within the architectural community of the Bay Area that the state might be hiring architects for design work on some part of the bridge. This is documented in a letter from Timothy Pflueger to C. H. Purcell in October, 1932, stating: "We desire to respectfully submit our names for consideration in selecting the architects for the San Francisco-Oakland Bay Bridge."[200]

Purcell began serious consideration of appointing an architectural board in October or November 1932. A brief glimpse into his decision-making is offered in a memorandum, dated November 1, 1932, which states (in full): "Consulting Architects for Consideration in connection with Approaches: George Kelham, Frederick Meyer, Pflueger (Miller and Pflueger)."[201] However

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[198] Joseph H. Dyer, Jr. Secretary, Art Commission to C. H. Purcell, August 29, 1932, External Design, 200.640, California State Archives.

[199] C. H. Purcell to Charles E. Andrew, September 1, 1932, Archives Architects and Architectural Design, 200.660, California State Archives.

[200] T. L. Pflueger to C. H. Purcell, October 24, 1932, Architects and Architectural Design, 200.660, California State Archives.

[201] C. H. Purcell, "Memorandum," 11-1-32, 000.050, Folder 1, California State Archives.

brief, this memorandum establishes several key points. First, no decision had been made by November of 1932. Second, Purcell had contemplated hiring an architect, even before the AIA petitioned him to do so; as discussed below, the AIA petition came in January 1933. Third, he was considering established San Francisco architects: Kelham, Meyer, and Pflueger all had offices in San Francisco and were active in the design of notable buildings there, chiefly commercial buildings. Of this group, however, only Pflueger would actually be hired to work on the bridge. Fourth, the phrase "consulting architects for consideration in connection with approaches" indicates that Purcell saw a limited role for the architect, dealing only with the approaches.

The American Institute of Architects formally joined the effort for employment of architects in January 1933. On January 31, the Northern California Chapter of the American Institute of Architects issued a strong recommendation that the bridge be designed with architectural design in mind. The long resolution included the following:

> That it is imperatively necessary for the future interests of San Francisco, Oakland, the Metropolitan Area and the entire State of California for the new San Francisco Bay Bridge to have the benefit of competent architectural services in the study and carrying out of its design. Such service can only be rendered by an architect or architects of recognized ability and standing.
>
> In this connection, certain vital facts must be considered:
>
> 1) That the California Toll Bridge Authority for the people of California is proceeding to carry into actual construction the greatest bridge project ever attempted in the history of man;
> 2) That the structure will not only affect the physical appearance of the finest harbor in the world, but will establish the first impression of the two major cities facing each other on the shores of San Francisco Bay;
> 3) That the entire Metropolitan Area has by various acts and efforts of its citizens definitely gone on record for the development of beauty in its public works, both utilitarian and monumental;
> 4) That the entire State of California has the greatest pride in the quality and design of its public edifices, as in its far-famed scenery and natural heritage;
> 5) That New York City has by her farsighted policy permanently established her fame ... by linking her metropolitan areas with great bridge structures...
>
> Those in charge of the Golden Gate Bridge have shown their understanding of this principle by engaging the able services of architects Morrow and Morrow to mould this gigantic structure into forms of beauty...
>
> In view of these facts, we urge that the authorities who have responsible charge of this great project give their earnest consideration to this important phase of the undertaking and give to the public at an early date assurance that the architectural design and

appearance of the bridge will be adequately safeguarded.[202]

Other civic groups in San Francisco and the East Bay joined the AIA and San Francisco Art Commission in calling for creation of an architectural board. In a long letter of March 15, 1933, Charles Derleth, Jr. wrote to Purcell, warning him of mounting agitation among the architects and civic groups for the appointment of some type of architectural advisory board. Derleth's comments hint at some suspicion on his part as to the ability of architects and civic groups to understand all of the design issues associated with the bridge. He wrote:

> The advocates of the employment of Architects are very active. They think the architects and an architectural commission should be appointed now but are not clear for just what purpose; some are thinking of artistic and imposing terminals; others are thinking about the outline of the bridge proper; doubtless some would change the shape of nature's catenary. One group thinks there should now be arranged an architectural competition for the monumental features of the bridge; the successful competitor to be doubtless employed. One group is active in San Francisco; there is also an eastbay group, very active, who are anxious to see that the east bay receives equal art treatment with San Francisco.
>
> The ladies are very active. Two prominent eastbay women whom I have known for thirty years telephoned me Monday morning and wanted me to speak before some art society in the eastbay on Tuesday afternoon... They were the ones who spoke of an architectural competition. They want a planning commission in the east bay similar to the Art and Planning Commission of San Francisco. They want these things now. It was clear from their statements that they object to our cantilever bridge east of Goat Island. They think an architect could improve its outline. Doubtless the architects are influencing them. These ladies have interviewed Mr. Andrew and Mr. Nuese. They have seen Mr. Nuese's drawings at 500 Sansome St. They want to know why similar drawings are not being prepared for the Oakland terminal. They would build heavy architectural structures as a portal, terminal and toll house on the soft ground 1000 ft. west of the Oakland shoreline; in fact they so stated. Of course they know nothing of the foundation condition.
>
> In San Francisco a Mrs. Chapman is active. This morning Dr. von Adelung, President of the Oakland Forum, telephoned to me. He is informed that these ladies both from San Francisco and from the east bay, had solicited him and the backing of the Oakland Forum to advocate the appointment of architects, competitions, etc. I think I convinced Dr. von Adelung that this was no time to discuss these subjects, which if the intent is to build portals at terminals, may safely be left for a year or two.[203]

Derleth's comments were made in mid-March; the actual appointments to a Board of Consulting

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[202] *Architect and Engineer,* March 1933.

[203] Charles Derleth, Jr. to C. H. Purcell, March 15, 1933, Board of Consulting Engineers, 200.503, California State Archives.

Architects were made in early April 1933. The April, 1933 *Architect and Engineer*, a publication chiefly geared to architects, reported on the appointment, noting that the "appointments had the approval of Governor Rolph and were made as a result of conferences between the San Francisco Art Commission, Director [Earl Lee] Kelly [Director of Public Works] and Chief Engineer C. H. Purcell."[204]

The agreement arising from the referenced conference in San Francisco resulted in two important concessions by state engineers: the appointment of a Board of Consulting Architects and an agreement by the state to submit its plans for work in San Francisco for review by the Art Commission. It is likely that the concession to San Francisco was helped along by Governor James Rolph, who had been mayor of San Francisco for several decades before being elected governor in 1932.

No specific record has been found to document why or how Purcell decided to appoint Pflueger, Brown, and Donovan. Pflueger and Brown had enviable records in the design of important buildings in San Francisco; Donovan was an East Bay architect and may have been selected on that basis. As noted, Pflueger had lobbied on his own behalf for appointment to the board nearly six months before his appointment. It is significant, however, that other architects made similar pleas but were rejected. Purcell seems to have decided upon Pflueger for chair of the board at an early date and added the other names as something of an afterthought.

Whatever the basis for their selection, the architects were actively working on the bridge in April 1933. This fact is established by their invoices to the state; a small invoice was submitted in April and much larger invoices in subsequent months. The architects were apparently paid a retainer, plus office labor. Between April and September 1933, the three invoiced for more than $20,000.[205]

Most of the major construction contracts for the bridge were awarded in April 1933. Thus, any input the architects might have necessarily took the form of change-orders in the appropriate contracts. This situation was fraught with danger for all parties -- the architects, Purcell and the bridge engineers, and the contractors. Conflict could easily have been predicted under these circumstances, particularly regarding any recommendation by the architects that would have raised the cost. The situation was further complicated by the involvement of the Art Commission of San Francisco, which had been given review authority over work in the city, which included the bulk of work undertaken by the architects, as both the San Francisco approaches and all of the work at Yerba Buena Island would occur within the boundaries of San Francisco. The Board of Consulting Architects, the Art Commission, and the Bay Bridge Division spent months locked in conflict before settling down to developing design compromises. The somewhat argumentative relationship among these parties is detailed below.

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[204] "Bridge Architects Named," *The Architect and Engineer* (April 1933): 52.

[205] Thomas Cox, Inter-Office Memorandum to Charles Andrew, October 6, 1933, Engineers Memoranda, 000.053, California State Archives. This translates to about $232,000 in 1997 dollars, or $13,000 per firm per month.

8.2. Relations between the Board of Consulting Architects and the Engineers of the Bay Bridge Division

Purcell attempted to limit input from the architects, even before he appointed them. On April 11, 1933, he transmitted copies of letters he had prepared to Director of Public Works, Earl Lee Kelly, to be sent to the three members of the Consulting Board of Architects, announcing their appointments. He noted in his transmittal that "I believe this [scope of duties] keeps sufficient control in our hands to assure satisfactory results in the relation between engineering design, contractors, and our department." The letter, which was signed by Kelly but written by Purcell, spelled out what was and was not wanted from the architects:

> The structural features of the bridge and its structural form have been determined, and plans available for your use. It is my desire that you study the general elevations of the massive piers and anchorages, together with the necessary approach structures, and make any suggestions as to the architectural treatment which will, in your opinion, beautify or make more impressive and pleasing the general appearance of the several parts of these structures. It is hoped that you will not find it necessary to make changes which will affect the general structural form.[206]

The three-member board met later in April and on May 1, 1933 wrote a memorandum, giving its tentative thoughts about the project. The scope of these suggestions must have come as a surprise to Purcell because it went far beyond architectural treatment of the piers, anchorage, and approaches. The board delivered preliminary thoughts on five subjects, as summarized below:

> Super-Structure. The West Bay Crossing super-structure as a whole seems to us highly harmonious and imposing. On the other hand the East Bay Crossing seem to be less harmonious and a striking departure in conception and design.
>
> Island Crossing. If it is not too late, we offer for consideration an open cut instead of a tunnel with bridges spanning the cut to take care of the island traffic... [or] carrying the roadway around the face of the island...
>
> Pedestrian Traffic. We believe that suitable sidewalks should be provided for practical needs and could serve as scenic promenades...
>
> Suspension Towers. Pursuant to your request we have devoted our attention to the appearance of the steel suspension towers. We believe that some revision might be made which would improve their appearance...
>
> San Francisco Approaches. It appears that the study of the San Francisco approaches should start inland from "pier No. 1" which is an important location on the Embarcadero.

[206] Earl Lee Kelly to Timothy L. Pflueger, April 10, 1933; C. H. Purcell to Earl Lee Kelly, April 11, 1933, Architects and Architectural Design, 200.660, California State Archives.

> In other words, the approach study should encompass all of the land structures. The main approach from Fifth Street should be ample in size, impressive in design and suitable as a link in a boulevard which will later be tied in with the City's boulevard system.[207]

Two weeks later, Glenn Woodruff and Charles Andrew wrote a concerned memorandum to Purcell, copied to the members of the board, insisting that the scope of investigation be limited. Regarding the superstructure, they wrote: "We do not consider any material changes in the East Bay Crossing possible." Regarding the island crossing, they wrote: "Both the open cut and road around the Island were discussed with and vetoed by the Government [U.S. Navy] officials. There is no useful end in reopening these discussions." Regarding sidewalks, they wrote: "The question of pedestrian traffic has repeatedly been considered and as often turned down." Regarding the towers, Woodruff and Andrew were more accommodating: "The changes in the towers are now under consideration. A compromise on the design must be reached immediately." Regarding the San Francisco approaches: "The location of the main approach between the Embarcadero and Fifth Street, as shown by the drawings sent the Architects, must be considered unchanged."[208]

Despite the insistence of Woodruff and Andrew, the board immediately began consideration of major changes to the San Francisco approaches, including the width and alignment of the approach as well as its major structural elements. The board recommended a range of options for the concrete viaduct between the Embarcadero and Fifth Street. One option would have included a 450' closed arch span immediately west of the anchorage. Another would have built the viaduct with spandrel walls, creating a solid structure between the anchorage and the Fifth Street Plaza. On June 8, 1933, Woodruff wrote to Purcell, adamantly objecting to both suggestions. Regarding the arch, he wrote that geologic conditions were unstable in that area, noting: "Such being the case, this is an unfortunate location for an arch, especially one of the 450-foot span proposed." He estimated the need for a foundation for the western pier of the arch to elevation of -153' at a cost approximating that of one of the water piers. The suggestion for solid walls on the viaduct, Woodruff observed, "it would be practically a case of adding fake spandrel walls throughout the length of the Bridge. These walls would complicate our expense problems and would be very difficult, if not impossible, to reinforce so that they would not be subject to unsightly cracking from shrinkage." He went on to object to both ideas from an aesthetic standpoint:

> It may be out of the writer's province to comment on architectural features. On the other hand, this proposal to build a Chinese Wall through San Francisco is so radical that it does not seem to me that it should go unchallenged from this office. It has been a fundamental rule in all previous suspension bridge designs that the cable anchorage should be designated, and should express, by their architectural form, their purpose. This is entirely lacking in the proposed design. The arch just west of the suspension bridge ... will be so

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[207] Memorandum, Board of Consulting Architects, May 1, 1933, Architects and Architectural Design, 200.660, California State Archives.

[208] Memorandum, Andrew and Woodruff to Purcell, May 18, 1933, Architects and Architectural Design, 200.660, California State Archives.

> massive as to detract from the comparatively light stiffening truss, and to a certain degree will be a case of the tail wagging the dog. [209]

In June, the board submitted preliminary recommendation for the center anchorage, built around a pyramidal form with a heavily battered profile. Late in June, Purcell wrote to Pflueger, insisting that any design work on the three anchorages should be coordinated. He wrote about the center anchorage and the proposal for an arch or series of arches west of the anchorage:

> Referring first to the San Francisco anchorage: I believe that before adopting any design for this anchorage the outlines of the Center Anchorage and the Yerba Buena Anchorage should be studied, in order that there may be harmony between the design of the three. For example, the space requirements at the roadway level of the Center Anchorage and the space available at the base of this anchorage would make it impractical to adopt a pyramidal form with anything approaching the batters, of the design you showed yesterday. Referring to the Roman arches just west of the Anchorage: In general this type of arch is suited to arches where there is considerable amount of earthfill.[210]

By late August 1933, relations between the design engineers and the architects had begun to fray. In a memorandum of August 24, Glenn Woodruff wrote to Purcell, hinting of a crisis in scheduling as well as in interpersonal relations. He wrote:

> Below is a memorandum, possibly superfluous, on the lack of progress made by the Architects and the design department on changes to be made to the San Francisco Anchorage and the viaduct west thereof. The Architects have been working on the design of these elements for over four months. The latest study, received at this office on Monday, is so impossible, from a structural standpoint, that I have not done any work on it in the drawing room. I am making no statement as to how much it is my fault, but to date I have been unable to give any suggestions to Mr. Pflueger as to essential structural details, especially in regard to expansion points, etc. The result is that there is absolutely no coordination between the Architects and this office.[211]

In October, the Board of Consulting Architects submitted a finished set of plans for the San Francisco approaches to the Art Commission of San Francisco. The Board of Consulting Architects, the Art Commission, and representatives of the Bay Bridge Division met in early November 1933, along with staff from the public works section of the city. Purcell recorded the results of this meeting in a long memorandum of November 6, 1933. The memorandum recorded the meeting but also served as a policy statement by Purcell. Purcell sought the support of the Financial Advisory Committee for the bridge and the California Toll Bridge Authority in his

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[209] Memorandum, Woodruff to Purcell, June 8, 1933, Architects and Architectural Design, 200.660, California State Archives.

[210] Purcell to Pflueger, June 30, 1933, Architects and Architectural Design, 200.660, California State Archives.

[211] Memorandum, Woodruff to Purcell, August 24, 1933, Architects and Architectural Design, 200.660, California State Archives.

position that "no sum should be expended for beautification beyond the limits of the financial set-up at the present time. Any extra funds now available should be conserved to provide for unseen conditions that may arise affecting the engineering integrity of the structure, and that this contingency should have the first call on the entire capital available for this project." [212]

To make his point, Purcell recounted various instances in which the architectural board had proposed designs that would have required major cost overruns. He recalled the options that had been considered for treatment of the San Francisco anchorage, one of the key buildings or structures on the bridge, at least in terms of public visibility. At the time of his writing, Purcell noted that the anchorage was "now under construction in the excavation below Rincon Hill." He noted:

> The Architects for some four months have been working on a design for this matter. Repeatedly, the discussion has come up regarding the confining of their design efforts to the amount available for construction of the particular unit under consideration. We now have a plan, submitted by the Architects, which involves approximately $150,000 more than is available for this unit of the Bridge. The design increases the viaduct approach connecting the anchorages with Rincon Hill by an increased cost of 75%. The exact amount on the anchors has not been calculated to the [cent?] The carrying out of this plan would involve the seeking of further funds under the Bond arrangement with the Reconstruction Finance Corporation, and a modification of our contract with Healy-Tibbetts Construction Company.
>
> We have now a design of anchorage that comes within the funds available for this unit, which was agreed to by one of the Architects - Mr. Brown. It is proposed to submit to the Art Commission the two designs, stating that we desire approval of both from the Art Commission's standpoint, but can only build the one within the limits of our finances.
>
> It is proposed, by the producers of clay products and a number of their business associates, that a study be requested by the Architects, as to covering the concrete faces with tile to add to their beauty.
>
> Approximate estimates by the Architects are around a million to a million and a half for this work... Claim is put forward that this will enhance the beauty of the structure. To our

[212] C. H. Purcell, "Memorandum Report of Projects and Ideas Affecting the Finance of Bridge and Approaches, Presented by Civic Bodies or Groups," November 6, 1933, Engineers Memoranda, 000.050, Folder 1, California State Archives. The Financial Advisory Committee, comprising influential leaders in San Francisco and the East Bay, had no apparent formal approval role, but their influence over the political leaders of the California Toll Bridge Authority was considerable. The Financial Advisory Committee met on November 14, 1933 to consider Purcell's proposed policy. The group adopted as policy: "That the cost of the bridge must be kept within the plans and specifications and costs already submitted to the Reconstruction Finance Corporation, and that in so far as the bridge can be further beautified we are heartily in favor of such beautification." The minutes of this advisory committee have been retained by Caltrans, District 4, Central Records, Box 421.

> knowledge, such an engineering structure has never been treated in this way before.

Purcell also hinted at disagreements over the design of the portals to the Yerba Buena Island tunnel:

> Proposals have been made for the elaboration of design of tunnel portals and walls on the Island. These studies by the Architect indicated costs of some $700,000 additional, and the Architects have been informed that such expenditure cannot be made on this project. They seem to feel, however, that an effort should be made to obtain further funds for this.

Purcell's tough stance appears to have had an effect on the work habits of the members of the Board of Consulting Architects. After this meeting, relations between the architects and engineers appear to have improved considerably. Between December 1933 and March 1934, the Board of Consulting Architects submitted to Purcell a flurry of plans for discrete elements of the bridge: Pier W-1 on December 14; the column and beam design of the concrete viaduct in San Francisco on January 4, 1933; the steel shroud on the center anchorage on January 29; the concrete on the center anchorage on February 8 and again on February 19; the tunnel portals on Yerba Buena Island on February 21; revised plans for the steel shroud on the center anchorage on March 17 and again on March 24.[213] After March, 1934, the correspondence between the board and Purcell diminished markedly, indicating that the design of major elements had been resolved.

The board continued to meet for several years after March 1934. Areas of consideration, however, were limited to appurtenant structures, including the headquarters building near the tollbooths, the tollbooths, and minor structures such as the garage on Yerba Buena Island. The board would also be involved with the late design issues regarding the bridge proper, ranging from minor considerations, such as the light standards, to major issues, including the paint color. The key considerations, however, were necessarily decided by the spring of 1934, as construction proceeded at a very fast pace.

8.3. Design Changes Attributable to the Recommendations of the Board of Consulting Architects

The question remains: what did the architects actually propose for the design of the bridge, and where was their advice followed? In answering this question, a careful distinction must be made between the bridge itself and appurtenant buildings, such as the Transbay Terminal, the tollbooths, administration building, and so forth. The consulting architects designed all of these appurtenant buildings, mostly under separate contracts after the bridge had been completed. They were also called in to design the substations that were built as part of the railway system on the bridge. Their work on the bridge itself (including the tunnel and the viaducts on the island and in San Francisco) was compressed into a period of less than two years, while those elements were

[213] Memorandum, Timothy L. Pflueger to C. H. Purcell, Dec. 14, 1933, Jan. 4, 1934, Jan. 29, 1934, Feb. 8, 1934, Feb. 19, 1934, Feb. 21, 1934, Mar. 17, 1934, Mar. 24, 1934, Architects and Architectural Design, 200.660, California State Archives.

under construction.

In a March 1934 article in *The Architect and Engineer*, "Architectural Treatment of the Bay Bridge," Frederick W. Jones attempts to summarize that contribution. Although he does not quote any of the architects involved, it is highly likely that he interviewed some or all of the board members to gain his insights. Jones gives little information about the process of design and negotiations with Purcell and his staff, noting simply that "Frequent conferences were held at which the three architects submitted designs and discussed them with Chief Engineer Purcell, Bridge Engineer Chas. A. Andrew, and Engineer of Design Glenn B. Woodruff."[214]

Jones enumerates four areas in which the recommendations of the architectural board were followed: the bracing on the suspension towers; the massing of concrete on the three anchorages (San Francisco, Yerba Buena Island, and Pier W-4, or center anchorage); the steel shroud for the center anchorage; and the design of the portals to the Yerba Buena Island tunnel. Jones' analysis provides a useful starting point in assessing the contributions of the architectural board to the design of the Bay Bridge.

Tower Design

Regarding the bracing for the towers, Jones notes:

> The first suggestion of the architects to be approved by the engineers and placed in the bridge was the increasing of the angles of the diagonal cross bracing between the legs of each tower of the suspension bridge. This, according to the architects, would increase the appearance of height and majesty of these structural steel edifices which rise to the height of a 45-story building above the bay surface.[215]

Corroborating evidence supports Jones' contention that bracing on the towers was changed in response to recommendations of the architectural board. Indeed, this was one of the greater successes for the Board of Consulting Architects; the architects made a recommendation to the engineers, their recommendation was accepted, and this massive element of the bridge design was changed to reflect the thinking of the board.

As might be expected, the board submitted multiple alternatives for tower design. On May 2, 1933, only a few weeks after it had been appointed, the board submitted four alternative tower designs, identified as Schemes 1, 1A, 2, and 3. Scheme 1 relied upon thick, enclosed horizontal struts, not unlike those built for the Golden Gate Bridge.[216] The major difference from the Golden Gate design was the inclusion of a huge circular shape in the thick strut below the deck level.

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[214] Jones, "Architectural Treatment of the Bay Bridge," 50.

[215] Jones, "Architectural Treatment of the Bay Bridge," 50.

[216] These drawings are retained in the archives of the California Department of Transportation, District 4, Oakland. Unfortunately, the transmittal letters for these drawings are retained at the California State Archives, Sacramento, while the drawings are in Oakland. These tower alternatives were transmitted by Pflueger to Purcell, May 3, 1933.

Scheme 1A used a combination of enclosed and open horizontal struts. Most struts were arranged in a series of X-braces. Scheme 2 had a round-headed arched opening, similar in some respects to the towers for the St. John's Bridge in Oregon (the St. John's arch is Gothic), or to the towers of the George Washington Bridge. Scheme 3 was essentially what was built: broad diagonal bracing with no horizontal struts. The diagonal braces are more boldly scaled than was necessary from an engineering standpoint.

Photograph 401 in this HAER documentation is a reproduction of the Board of Consulting Architects' elevations for Scheme 1A. Scheme 1A is similar to the final design, although the arrangement of X-bracing was substantially different. Photograph 402 is a reproduction of the Board's elevations for Scheme 3, which featured an arched portal. Photographs 403 and 404 illustrate the details for the tops of the towers; these are quite similar to the final plans for these details.

The process by which Scheme 3 was adopted may be inferred from what happened after May 2. On May 18, 1933, the board submitted Scheme 7, which was a variation on Scheme 3, with minor changes to the bracing system, eliminated one horizontal strut above the upper deck. [It is presumed that there were also Schemes 4, 5, and 6, but no record has been found for them.] On June 1, the board submitted several detail sheets for Scheme 7 and on July 7, it submitted a very detailed perspective view of a tower for Scheme 7. The July 7 perspective drawing appears to be identical to what was built. This record suggests that the state engineers selected the Scheme 3/Scheme 7 design within a week or two of its submittal and asked the architects to work out the details on that alternative alone.

The state engineers had planned for suspension towers that were substantially similar to the Scheme3/Scheme 7 plan. In January 1932 (more than a year before the consulting architects first met), the Bay Bridge Division had submitted a conceptual design for the suspension tower for consideration by the Board of Consulting Engineers.[217] That tower design involved diagonal braces in the manner of the Scheme 3/7 design. It differed, however, in that fewer braces were used. The Scheme 3/7 design included two panels of diagonals below the deck and three panels above. The 1932 drawing showed one panel below the deck and two above, indicating the panels were nearly twice as large as what was built. There is no way to know whether Purcell, Woodruff, or Andrew approved of this design. It is clear, however, that the basic form of the tower, built around diagonal cross-bracing, had been considered by the state before it was proposed by the architects.

The reception for Scheme 3/7 was not entirely unanimous among the engineers. On May 15, 1933, Glenn Woodruff wrote a memorandum to Purcell, agreeing somewhat reluctantly to the thicker steel diagonal members called for in Scheme 3. He wrote to report on a "conference with the architects re proposed changes to the towers." He estimated the changes would cost about

[217] A small number of conceptual plans are retained by the California State Archives, in file F3780. Most of these drawings are original pencil sketches. The drawings were prepared for consideration by the Board of Consulting Engineers. Most are very conceptual in nature, with architectural details deliberately left blank.

$230,000, counting materials, change order charges from the contractor, and interest. The changes, in Woodruff's estimation, would add marginally to the stresses in the towers and on the piers. He concluded: "In case you feel the change is desirable, I believe it would be wise to recognize it as an architectural appendage and build it of light metal framed out from the column proper." He left the decision to Purcell, noting, however, that "it is my opinion that, from a structural standpoint, the resulting structure will be inferior to the present design."[218]

Purcell and Woodruff acknowledged that the diagonal bracing was modified to improve the appearance of the towers in a brief statement in an article in the *Engineering News-Record*: "Diagonal bracing, without horizontal cross-struts, was chosen in preference to a rectangular system. For the same weight of metal, it results in a higher degree of rigidity. In the opinion of the authors, it gives a better expression of this rigidity and the resistance of lateral forces. For the sake of appearance, the widths of the bracing members were increased beyond those required by stress considerations."[219] The role of the architects in the tower bracing was also confirmed in an article in the *California Highways and Public Works* magazine, an in-house publication of the Department of Public Works, where it was noted that "we [the Department] incorporated their suggestions in the angles of the tower bracing in order to embody aesthetic principles in these large structures."[220] Arguably, the most significant contribution of the Board of Consulting Architects was, as Jones notes, the elegant bracing on the suspension towers, and that contribution was made within weeks of the appointment of the board. This, however, was also the only recommendation that was accepted with so little controversy. The absence of controversy may be explained in part, however, by the fact that the architect's design paralleled a design developed earlier by the Bay Bridge Division engineers.

Yerba Buena Tunnel Portal

All of the remaining elements were so intertwined from the design standpoint that it was nearly impossible to resolve one issue without also resolving the others. This fact no doubt slowed the work of the architects and increased the possibilities for disagreement with the engineers. For example, the portals to the Yerba Buena tunnel are ostensibly discrete architectural elements. The west portal, however, is located very near the Yerba Buena anchorage and the architects hoped to coordinate the design of the portals and the anchorage. They hoped as well to coordinate the design of all three anchorages with one another. To achieve any continuity, it was necessary to resolve the design of all of the major concrete elements, including the portals, all of the anchorages, as well as the concrete viaducts.

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[218] Glenn Woodruff to C. H. Purcell, "Proposed Changes to Tower," May 15, 1933, Engineer's Memoranda, Folder 2. 000.052, California State Archives.

[219] C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Batter-Leg Towers for San Francisco Bay Bridge," *Engineering-News Record* (June 20, 1935): 865.

[220] "First Annual Report on Bay Bridge Reveals Construction Up to Schedule," *California Highways and Public Works* (January 1934): 26.

The Yerba Buena tunnel portal was the first element for which agreement was reached. Regarding these portals, Jones writes:

> The portal to the tunnel, visible from the upper deck of the bridge, carries out the general simplicity of the concrete face. No adornment is given to it other than three separate planes of broad arches over the crown of the tunnel portal and a raising of the portal by concrete blocks pyramided up to the necessary height.[221]

The essential elements of this tunnel were proposed in a plan of July 24, 1933. The tunnel portal in that drawing includes the three segmental arches that dominate the final design. The drawing, however, also calls for a broad retaining wall of scored concrete, extending far beyond the requirements for the tunnel itself. This additional wall may have been the cause in the long delay in approving the portal design by the Bay Bridge Division.

As he was leaving for a trip to the East Coast in September 1933, Glenn Woodruff left instructions to his assistants on how to deal with remaining design issues. Regarding the tunnel as well as the Yerba Buena Island anchorage, Woodruff observed: "The Architects will deliver to this office plans of the Island Anchorage and tunnel portals. Mr. Green will confer with Mr. Andrew regarding these drawings, and take such action as Mr. Andrew may direct." [222] This issue was still very much unresolved more than a month later. In the previously quoted memorandum of November 6, 1933, Purcell observed: "Proposals have been made for the elaboration of design of tunnel portals and walls on the Island. These studies by the Architect indicated costs of some $700,000 additional, and the Architects have been informed that such expenditure cannot be made on this project." Purcell's mention of "tunnel portals and walls on the Island" seem to indicate that the elaborated walls around the portals were the cause in the delay. By February 1934, however, the architects and Purcell had reached agreement. In transmitting a drawing for these portals, Pflueger reminds Purcell that the "drawing conforms to the perspective of the scheme that you favored which we handed to you yesterday."[223]

San Francisco Anchorage and Viaduct

The San Francisco anchorage was arguably the most divisive single element of the bridge design because it was so closely linked to architectural proposals for the concrete viaduct to the west of it. The engineers and architects haggled for months over both issues but particularly over how to treat the viaduct. Because the two were linked, physically and in a design sense, one issue could not be resolved without the other.

State engineers had not finally resolved how to treat the San Francisco anchorage and viaduct,

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[221] Jones, 1934, p. 53.

[222] Glenn B. Woodruff to Employees of the Design Department, September 23, 1933, Engineer's Memoranda, 000.052, Folder 2, California State Archives.

[223] Pflueger to Purcell, February 21, 1934, Architects and Architectural Design, 200.660, California State Archives.

prior to hiring the architectural board. In conceptual plans of April 1932, state engineers had drawn a two-level anchorage, with a broad base (the actual anchorage) and a top level (the support for the deck) that was half the width of the base. The top level was a zigzag pattern, with vertical setbacks. In addition, the lower level was not a solid piece but rather was broken into two sections, one for the anchorage for each cable.[224] Again, there is no indication of support for this conceptual plan by the state engineers; these were prepared for consideration by the Board of Consulting Engineers early in the design process.

During May, June, and July, 1933, the architectural board submitted a series of different alternatives for the anchorage and viaduct designs. There were five basic alternatives. The major difference between the alternatives had to do with the treatment of the viaduct. The anchorage structure differed as well, it being coordinated with the design of the viaduct. The five essential approaches were labeled Sheets 10, 12, 23, 26, and 33. As their numbers suggest, these alternatives were submitted in sequence, although it is likely that the architects were offering multiple alternatives for consideration by the engineers, as they had done with the tower design.[225]

Two of these were discussed earlier. In sheet 10, the viaduct was a solid wall from Pier W-1 to the 5th Street Plaza, with only tunnel openings to allow surface streets to pass underneath. This was the proposal that Woodruff called the "Chinese Wall" of San Francisco. A second alternative (shown on Sheet 26) would have included a huge concrete arch east of the anchorage, with a 450' span.[226] Purcell objected to this alternative because of the engineering problems it posed; Woodruff objected to it on aesthetic grounds. A third alternative, shown as Sheet 12, involved a viaduct with a series of small round-headed arches, similar to a Roman aqueduct. The fourth alternative, shown as Sheet 23, would have used four smaller segmental arches to carry the bulk of the length of the viaduct. Photograph 407 in this HAER documentation is a reproduction of "Sheet 26" by the Board of Consulting Architects, showing the one large arch west of the anchorage.

By October, 1933, the Board of Consulting Architects had apparently settled on a fifth design for the viaduct and anchorage, one that the board carried to a greater level of detail than any of the others. The essential outline of this design was shown in Sheet 33. This design was somewhat similar to that shown in Sheet 12 but with substantial variations. First, the viaduct was carried on three rather than four arches. Second, those arches were open spandrel spans, i.e. carried on concrete arch ribs, with openings in the spandrel area between the ribs and the deck. The deck itself would have been open-walled as well. Photograph 408 in this HAER documentation is a reproduction of "Sheet 33" by the Board of Consulting Architects. It shows three round-headed arches west of the anchorage.

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[224] Stored with conceptual plans, retained by the California State Archives, in file F3780:150.

[225] Sheets 10 and 12 were submitted on July 11, Sheet 23 on August 19, Sheet 26 was not dated, and Sheet 33 on October 25, revised on November 3.

[226] A 450' span would have been a record-breaking concrete span at that time. For reference, the great Bixby Creek Arch in Monterey County, built a few years before the Bay Bridge, was among the longest concrete bridges at the time with a 360' span.

Also of interest was the use of cast concrete decorative elements on several of these alternatives. On Sheets 12 and 23, the anchorage structure was decorated with cast eagle forms, one at each corner of the top of the structure. On Sheet 33, the alternative studied in the greatest detail by the board, the plan included a large concrete panel to be cast on either side of the anchorage structure, at the deck level. While the panel seems small in relation to the building, the panels are shown as being as tall as the deck, or about 32' and about 48' wide. The panel, in a stylized Art Deco manner, appears to show a giant figure of Mercury, walking over water, carrying lightning bolts in one hand and a vehicle in the other hand. On one panel, that vehicle was an automobile (a large mid-1930s sedan); on the other panel, the vehicle was an interurban train car. In a later correspondence, Pflueger emphasized how important it was, in his opinion, to include some type of artwork on the sides of the anchorage. As to a motif, he noted, "It may typify automotive and electric transportation."[227] Photograph 410 in this HAER documentation reproduces details for the San Francisco anchorage, as designed by the Board of Consulting Architects. The Mercury figure panel may be seen at the top center of that photograph.

The Bay Bridge Division engineers objected to both the anchorage and viaduct design but were particularly concerned about the viaduct because of major financial and engineering considerations. The issue of the treatment for the concrete viaduct remained unresolved throughout most of 1933, as it was considered on several occasions by the state and by the Board of Consulting Engineers. By mid-1933, the Board of Consulting Engineers met infrequently because the bulk of the engineering design was completed and the work was under construction. Purcell did convene the engineering board from time to time, however, to monitor construction and to offer advice on remaining design issues, including the proposals from the architects. The consulting engineers were asked to consider the viaduct design on two occasions: on August 10 and November 8, 1933.

It appears that by August, 1933, Purcell and Woodruff had rejected any consideration of a solid wall viaduct as well as the giant 450' arch. Gone as well was the proposal for a series of small arches, as shown in Sheet 12. The engineering board was apparently asked to select between two options: a proposal by the architectural board that included four arches in the viaduct and a plan for a haunched girder viaduct, apparently prepared by the Division of Highways. The four-arch proposal was that of Sheet 33. The haunched girder proposal was the design that was ultimately built.

Photographs 406 and 409 are reproductions of the final two designs submitted for approval by the Board of Consulting Engineers. Photograph 385 shows the haunched girder design, the plan that was built. Photograph 386 shows the four round-headed arch design. Although these alternatives were developed by the Board of Consulting Architects and they are so credited in the legend for the drawings, it appears that these renderings were actually made by Carlos Nuese, who drew all of the renderings that appeared in annual reports and other documents for public consumption.

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[227] Pflueger to Purcell, October 30, 1933. Architects and Architectural Design, 200.660, California State Archives.

The origin of the haunched girder proposal may be inferred from correspondence on the subject as well as the design traditions of the Division of Highways. In November, 1933, Purcell transmitted to the City of San Francisco two plans for the viaduct and anchorage. These were labeled "Perspective A: Original Design" and "Perspective B: Revised Design." The drawing shown as "Perspective A," therefore, may be presumed to be the "original design," i.e. the contract design developed by the Bay Bridge Division. This reading is consistent with the design tradition of the Division of Highways. The California Division of Highways built many bridges and viaducts during the 1930s with similar haunched girders; that girder design, indeed, is a diagnostic element of 1930s bridge design in California.

In its August 1933 meeting, the Board of Consulting Engineers and the state engineers were initially favorably disposed toward the arched viaduct, voting that "the principle of the four arches in the approaches west of the Anchorage block, be approved."[228] A few months later, however, the consulting engineers had a change of heart, for reasons not satisfactorily explained in the record. The minutes of the board's meeting of November 8 note that: "The feeling of the Board Members was decidedly against the arches in the viaduct. It was, further, the general opinion that the original plan was preferable, from an artistic viewpoint, to any that had been subsequently proposed."[229] The "original plan" as noted almost certainly was developed by the Bay Bridge Division, and that plan was ultimately built. With respect to the viaduct, then, it appears that the recommendations of the architectural board were overruled altogether.

These disagreements over the viaduct and approaches delayed consideration of what to do with the San Francisco anchorage, to an extent that serious potential problems loomed for on-time and in-budget completion of the Healy-Tibbetts contract for the San Francisco anchorage and viaduct. This problem prompted the aforementioned meeting on November 6, 1933, convened by Purcell, of the Art Commission and Board of Consulting Architects, in which Purcell established as policy that no proposals would be entertained that could not be funded within the original budget for the item of work. After the CTBA adopted Purcell's policy, the architects appear to have moved expeditiously to complete their suggestions for the San Francisco anchorage.

After their viaduct plan was rejected, the architects apparently accepted the original design of the anchorage as well; the form shown in the "original design" is roughly what was built. Rather than push for an entirely new form, the architects pressed for some way to improve the design developed by the Bay Bridge Division. In this respect, the architects proposed different but not necessarily contradictory approaches: to mold the concrete into clean sculptural forms; and to decorate the sides of the anchorage with cast concrete shapes. As noted, the architects had proposed some type of panels on the San Francisco anchorage from the outset. In November, 1933, Pflueger continued to insist on the importance of some type of cast concrete work on the anchorage. Pflueger described the design concept for the panels, noting that "the panels will be

[228] "Minutes of the Board of Consulting Engineers," Seventh Session, Sixth Meeting, August 10, 1933, "Derleth Papers," Water Resources Center Archives, U. C. Berkeley.

[229] "Minutes of the Board of Consulting Engineers," Eighth Session, Sixth Meeting, November 8, 1933, "Derleth Papers," Water Resources Center Archives, U. C. Berkeley.

of different designs although similar in character."[230] The panels were to be modeled in plaster negatives "which shall be set in place by the general contractor who will pour the concrete against same." There is no record of Purcell's reaction to this proposal except that he had apparently decided against statues or panels by December 14. On that day, Pflueger submitted a plan that met Purcell's wishes, and spoke of a "simple massive character" for the building.[231]

The final plan for the anchorage and viaduct appears to have been developed cooperatively by the consulting architects as well as the Bay Bridge Division engineers, but not until the Bay Bridge Division had established its preference for simple, clean structural forms. The design of the viaduct was almost certainly developed by the Bay Bridge Division. The anchorage building was designed along lines suggested by Pflueger, in a plan that included vertical and horizontal setbacks in the concrete planes. This was a plan that was ultimately developed by the board of consulting architects but only after at least two other alternatives had been rejected.

[Missing from Jones' analysis is an attribution to the architectural board of the design of Pier W-1, which is architecturally compatible with the San Francisco anchorage. This pier design appears to have been closely coordinated with the architectural board. In mid-December, 1933, Pflueger sent to Purcell a revised plan for Pier W-1, a modification of the Bay Bridge Division plan "to bring it into harmony with the final design of the San Francisco anchorage."[232]]

Yerba Buena Anchorage

The design for the Yerba Buena anchorage was not approved until early 1934, several months after the San Francisco anchorage design had been approved. That delay reflects an order of delivery established by Purcell and does not suggest a high level of disagreement between the architects and engineers.[233] Indeed, it appears that there was relatively little disagreement over the design of this element. In July 1933, the architectural board submitted to Purcell a design that was similar to what was actually built, at least with respect to the form of the concrete. It differed, however, in that it included giant concrete eagle forms, perched above the roadway at the entrance to the roadway section of the anchorage. It will be recalled that the architects had also proposed an eagle form as one alternative for the San Francisco anchorage; these eagles were no doubt seen as complementing that alternative for the San Francisco structure.

No correspondence has been found to document Purcell's reaction to the design but it apparently was not favorable. On January 3, 1934, the architectural board submitted a much-simplified plan,

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[230] Pflueger to Purcell, November 11, 1933, Architects and Architectural Design, 200.660, California State Archives.

[231] Pflueger to Purcell, December 14, 1933, Architects and Architectural Design, 200.660, California State Archives.

[232] Pflueger to Purcell, December 14, 1933, Architects and Architectural Design, 200.660, California State Archives.

[233] Following the aforementioned major meeting on November 8, 1933, Pflueger wrote to Purcell, asking that he prioritize design work in order of need. Pflueger to Purcell, December 12, 1933. No reply has been located but Purcell's copy of the letter has draft due date penciled on it. The priority established by Purcell moved from west to east, with San Francisco work having top priority, followed by Yerba Buena, followed by work at the Oakland tollbooth.

a plan that was approved by the Board of Consulting Engineers in February 1934.[234] While no documentation has been found regarding the change of heart by the consulting architects, it may be that they decided on their own to simplify the Yerba Buena anchorage, to make it conform to the sparse design of the San Francisco anchorage, which had been approved three months earlier.

Center Anchorage

The architect-engineer debate over the center anchorage rivaled that over the San Francisco anchorage in terms of the depth of disagreement and length of time before resolution. In discussing this design, two separate issues must be treated: the form of the concrete anchorage, and the form of the metal shroud at the cap of the structure. It appears that the architects sought to make their boldest statement with the center anchorage, proposing massive sculptural forms that towered several hundred feet from the water to the deck level. Unfortunately, this is the one element of design for which no original drawings have been located, although the general character of the design may be inferred some correspondence regarding the proposal.

It should be noted that during the summer of 1933, the board of consulting architects had devised a general scheme or program for all of the concrete elements, one that included very large concrete statues or panels near the deck level of each of the major concrete structures. In San Francisco, at least two motifs were proposed: eagles and a panel that spoke of motion. Pflueger said of that panel: "It may typify automotive and electric transportation."[235] At Yerba Buena Island, the only known proposal was that for eagles, although it is likely that the architects proposed coordinated statues for the two end anchorages. For the center anchorage, the board of architects (apparently over the objection of Arthur Brown, Jr.) proposed truly heroic statues, located at either side of the concrete structure.

The first known reference to the center anchorage statues is that found in an August 1933 letter from Ralph Modjeski to Purcell, in which Modjeski expresses grave concerns about the plan. He wrote:

> I have been thinking considerable about the plans which the architects are preparing for the centre and end anchorage piers. In my opinion no satisfactory design has been proposed by them. The gigantic figure which is proposed for the centre anchorage is out of place for a structure of this kind and would not harmonize with the end anchorage.
>
> The designs prepared by Mr. Carlos Nuese in your office, seem to me very much more logical and harmonize well with the general character of the structure. It seems to me that they are much superior to anything that the architects have presented, to the present time.

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[234] "Minutes of the Board of Consulting Engineers," Tenth Session, Second Meeting, May 9, 1934. "Derleth Papers," Water Resources Center Archives, U. C. Berkeley.

[235] Pflueger to Purcell, October 30, 1933.

> I should like to have you take this matter into serious consideration.[236]

The "gigantic figure" was described in greater detail in minutes from the Board of Consulting Engineers in August 1933. The minutes from the second meeting of the seventh session of the engineering board describe the center anchorage in greater detail:

> The Architects submitted the model study of the center anchorage, which consisted of a block with practically the same dimensions as those shown by the Contract Drawings. The relief was furnished by gigantic statues extending from the top of the fender to the top of the anchorage, a matter of over 200 feet. Mr. Brown stated that he did not approve of this design, and the architects were requested to furnish other sketches.[237]

In the verbal accounts, three conclusions may be drawn. First, the architectural board had submitted a plan for at least two massive concrete statues, presumably of concrete, to be built as part of the central anchorage, extending from the fender level (about 25 feet above the water) to the tops of the anchorage. No drawings have been located but is presumed that the figures were to be in relief, in the manner of the proposed figures for the San Francisco anchorage. Second, this proposal was not unanimous; Arthur Brown, Jr. is reported as having objected to the idea. Third, of course, the idea was not implemented; the nearly unanimous opposition from the state and consulting engineers killed the idea and it was not discussed again.

By early 1934, the architectural board had apparently abandoned its plan for sculptural work on any of the anchorage structures. The sound defeat of the center anchorage plan in August 1933 no doubt hastened that decision, although the reaction to the San Francisco anchorage proposal had not been well received either. After January 1934, the architectural board did not discuss the use of statues on the center anchorage. Rather, their design efforts concentrated on the form of the structure.

The second round of proposals by the Board of Consulting Architects in early 1934 concerned establishing a pyramidal form, in which the area of the top of the concrete anchorage tower be much smaller than the area at the bottom, resulting in a battered or tapered shape. Purcell insisted that the structural and operational requirements at both the top and bottom of the anchorage did not permit such a difference in area. The board reluctantly accepted this analysis and submitted final plans for the concrete tower in February, 1934, noting: "There is scarcely enough difference between the required width at the top and the width at the base to provide for as much batter and as heavy offsets as we would like. We have employed the available difference to get the best vertical breaks and the largest horizontal offsets and batters possible under the circumstances."[238] The ultimate design took advantage of the batter that was feasible, providing relief through

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[236] Ralph Modjeski to C. H. Purcell, August 17, 1933, Board of Consulting Engineer, 200.501, folder 2, California State Archives.

[237] "Minutes of the Board of Consulting Engineers," Seventh Session, Second Meeting, August 7, 1933, "Derleth Papers," Water Resources Center Archives, U. C. Berkeley.

[238] Pflueger to Purcell, February 19, 1934, Architects and Architectural Design, 200.660, California State Archives.

"horizontal offsets and batters."

Shroud for Center Anchorage

The final design accomplishment listed in the Jones article is the metal shroud atop the center anchorage. The shroud was a metal cap atop the concrete form of the center anchorage. It enclosed the structure that actually held the ends of the cable, called an A-frame. Jones said of this design:

> The concrete center anchorage, midway between San Francisco and the Island, with a plate steel section at its top along the side of the bridge roadway, will carry the bridge through and not break the twin suspension bridges into separate parts. It is believed by both the architects and the engineers that this steel treatment of the upper 30 feet of the concrete center anchorage will unify the suspension bridge crossing. A panorama of the West Bay crossing, with its steel-topped concrete center anchorage, will make the bridge appear to have three main spans rather than two main spans with two side spans in the center joined together by a concrete monument.
>
> The steel top of the monument lessens its monumental appearance and subjects this unit to the sweep and cohesion of the two great cables with their naturally artistic lines.[239]

It appears that the consulting architects and state engineers discussed the design of the steel shroud for many months before arriving at an acceptable design. In December 1933, the architects requested that the entire area of the center anchorage above the lower deck be made of steel, to which Purcell replied simply that "such a proposition could not be entertained, since the concrete housing of this steel work was such an essential element of the structural design. The plan is not structurally feasible."[240] The architectural board sent at least three revised plans for the steel shroud, with the last dated March 24, 1934. The transmittals for these plans emphasize the need to make the steel hoods conform to the batters and vertical offsets of the concrete on the center anchorage, a fact that helps explain the delays in completing these plans, as these offsets could not be calculated until the design of the anchorage itself had been finished.[241]

8. 4. Conclusions Regarding the Role of the Board of Consulting Architects in the Design of the Bay Bridge

It appears that the Board of Consulting Architects should be credited with an influence in the design of the four major elements pointed out by Frederick Jones – the shape of the braces in the suspension towers, the portals to the tunnel, the design of the three anchorages, and the shape of the steel shroud for the center anchorage. Jones' article was written in March 1934, at about the time that the last of these major decisions was being made. The architects also designed Pier W-

[239] Jones, "Architectural Treatment of the Bay Bridge," 50, 53.
[240] Purcell to Pflueger, December 29, 1933, Architects and Architectural Design, 200.660, California State Archives.
[241] Pflueger to Purcell, March 24, 1934, Architects and Architectural Design, 200.660, California State Archives.

1, an element not mentioned in Jones' article. Correspondence between the architects and engineers suggest that the Board of Consulting Architects also helped design some elements of the concrete piers on the east side of Yerba Buena Island as well as the concrete viaduct on the east side of the island.

Jones' analysis is misleading, however, in that it fails to mention the many different design iterations that were required before agreement was reached. It is also somewhat misleading in that it suggests that the clean lines used in the final design of these elements represented the first choice of the architects. In several instances, Jones emphasizes these clean lines. In discussing the portal design, for example, he noted that "no adornment is given to it other than three separate planes of broad arches over the crown of the tunnel portal." Speaking of the San Francisco anchorage, Jones emphasizes that the great concrete mass "will make an imposing monument of simple lines," and will "give this bridge a majestic bigness which in itself is a form of beauty." The steel shroud was praised for the fact that it conforms with the catenary of the cables and "subjects this unit to the sweep and cohesion of the two great cables with their naturally artistic lines."

The record, shows, however, that Pflueger, Donovan, and Brown had a more elaborate design in mind and fell back to the clean motif only after their original suggestions were rejected. Their architectural program may be described as combining neo-classical elements with a general Art Deco or Streamline Moderne style. The neo-classical influence may be seen in the push for arched bridge forms in the San Francisco viaduct and in the use of decorative statues or panels, although the artistry of the statues and panels was decidedly that of the 1930s. The Moderne influence may be seen in the underlying sculptural shapes of the concrete. It was not uncommon for architects of the 1930s to combine classical and Moderne elements. This mix, which was unique to architecture in the United States during the Great Depression, was used so commonly in the design of federal buildings that Lois Craig, in her study of federal architecture, coined the term, "starved classicism," to refer to the style.[242] It was not the original intent of the Board of Consulting Architects to design a bridge with clean line, devoid of architectural embellishments. Indeed, it would be difficult to find any proposed embellishments on any building or structure in the history of California that rivaled those proposed for the Bay Bridge. They abandoned those ideas only after they had been rejected repeatedly by Purcell and the other engineers in charge of the program.

Once the state engineers had made clear their preferences, the architectural board made the best of the situation and designed the best-looking structures that were possible within the predetermined budget. In Jones' opinion, they did a very good job in that regard, carrying the simple, clean lines to all of the structural elements. The bridge elements are coordinated according to a well-defined architectural program, as observed by Jones. That program, however, was not the first choice of the architectural board.

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[242] Lois Craig, *The Federal Presence: Architecture, Politics, and National Design*, Cambridge, MA: MIT Press, 1984.

The Board of Consulting Architects continued to meet after Jones wrote his article in March 1934, although most of the major architectural decisions had been made by that time. In March 1935, for example, the board designed the light standards, revising plans submitted by Westinghouse.[243] The board also was responsible, as a board or as individual firms, for designing all of the buildings associated with the Bay Bridge, including the Transbay Terminal, Headquarters Building, tollbooth, and garage on Yerba Buena Island. This work continued for several years after the bridge had opened.

Perhaps the key late issue was that of the color of the bridge. The manner in which the color for the bridge was selected was typical of the give-and-take between the architects and engineers throughout this project. The discussion of bridge color began early during design considerations but, for various reasons, was not concluded until mid-1935. The Board of Consulting Engineers had discussed the issue and the Bay Bridge Division had given careful consideration to it as well. State engineers clearly preferred black. C. H. Purcell himself expressed his preference in two newspaper interviews. At that time, civic groups in San Francisco had taken up the issue and were lobbying against the use of black paint. B. R. Funston of the San Francisco Chamber of Commerce referred to the use of black paint as "draping the span in mourning," adding that "from the standpoint of sightliness, black appeared to be the worst color."[244] Purcell countered that black paint would highlight the structural complexity of the bridge: "Black paint will make every part of the bridge a clean-cut line of structural beauty."[245] In another interview, Purcell observed that "The spider web of open-work construction of a bridge almost requires black, so that its structural work will be visible."[246]

Through internal discussions at the Bay Bridge Division, the decision on color was reduced to two choices: black or aluminum, with black being the preferred. As major elements of the steelwork neared completion in early 1935, the decision could be delayed no longer. The Bay Bridge Division took two steps to seek resolution: it asked for the advice of the Board of Consulting Architects; and it sent Glenn Woodruff to the East Coast to inspect personally the paint schemes of several bridges, and to confer with officials of the American Bridge Company.

The Board of Consulting Architects submitted its report on May 14, 1935, while Woodruff reported on his East Coast trip in March. Nonetheless, it appears that Woodruff was aware of the wishes of the board, because he inspected bridges with three colors: the black and aluminum favored by the Bay Bridge Division, and a gray color, favored by the board. Woodruff conducted part of his field inspection with Leon Moisseiff, who drove him around the bridges of New York City. He was particularly interested in the George Washington Bridge, which was painted gray on its towers and aluminum on its cables. The paint was only three years old at the time. The gray paint, he reported, "is beginning to break in places and will require considerable spot painting." The aluminum paint, however, "seems to be in good condition." Woodruff also

[243] Pflueger to Purcell, March 6, 1935, Architects and Architectural Design, 200.660, California State Archives.
[244] *San Francisco News*, April 25, 1935. Clipping in collection of Oakland Public Library, History Room.
[245] *San Francisco Chronicle*, April 25, 1935.
[246] *San Francisco News*, April 25, 1935.

inspected several bridges in Pittsburgh, several of which were painted aluminum. The aluminum paint coats were generally in good condition after more than five years. Nonetheless, Woodruff was still in favor of black: "I haven't seen anything yet which makes me think we should change our ideas about paint unless we have to. If a change was necessary I would then recommend aluminum as a close second in lasting qualities, with white lead and zinc (gray) as a very poor third – to be avoided."[247]

The final report from the Board of Consulting Architects was delivered in May 1935. The board had been asked to make "a recommendation between black and aluminum." In the typically freethinking manner of the board, however, the architects would not make a choice between black and aluminum without also considering other colors, particularly gray. The board began by issuing a series of criteria that "the ideal color" should meet: it should "harmonize the bridge with the landscape"; it should "express structural strength"; it should "harmonize the steel and concrete elements of the bridge"; it should be "pleasing and harmonizing" in relation to buildings in San Francisco and Oakland; it should be "pleasing to look at in driving over the bridge"; and it should eliminate "flicker."

Having stated these criteria or principles, the board reiterated its view that gray was the best color. It continued: "Realizing that you may not consider it feasible to use gray, your Board has given full consideration to a selection between black and aluminum." The board had the least to say about black: "We realize that black has excellent structural qualities and that in conformity with the thoughts of some schools of design it would be the frankest treatment of a bridge structure. However, we do not feel that this consideration overcomes the failure to meet the requirements for the ideal color which are listed above."

Regarding aluminum, the board was hardly more favorable in its estimation. "We do not feel that aluminum is by any means an entirely satisfactory color. It lacks structural quality and when new is decidedly thin and sheet-metal-like in appearance. Its shiny appearance is objectionable." Nonetheless, the board seemed to recognize that the only real choice available was between aluminum and black and it grudgingly weighed in favor of aluminum, noting that "based upon the local observations we have been able to make, [we] decide in favor of aluminum if limited to a selection between black and aluminum. However, we reiterate our preference for gray."[248]

The compromise reached on a color for the bridge illustrates the constraints under which the Board of Consulting Architects had worked from the outset. Brought into the process after the bridge had essentially been designed, the board was given a small canvas upon which to paint its vision of the bridge. Board members saw several major statements that could have been made, particularly on the approaches between Fifth Street and the anchorage in San Francisco and in the center anchorage. The most dramatic statements, proposed by the architects and rejected by the engineers, were, of course, those for concrete statues at the three anchorages. The engineers rejected these architectural statements, chiefly on the basis of cost but also because they worked

[247] Woodruff to Purcell, March 10, 1935, Engineer's Memoranda.

[248] Pflueger to Purcell, May 14, 1935, Architects and Architectural Design, 200.660, California State Archives.

against the engineers' sense of how the structural elements of a bridge should be expressed. The great statues at the center anchorage, for example, were rejected exclusively on the basis of aesthetics. The conflict between the engineers and architects was as often a disagreement between competing aesthetic visions as it was a conflict over cost or structural integrity.

The architects, then, were restricted to the details of the structural elements themselves and to a design program that emphasized the "clean-cut line of structural beauty," in Purcell's phrase. The architects finally conceded these constraints and designed the details of the structural elements in a coordinated manner. Their designs for these elements – the San Francisco anchorage, Pier W-1, the Yerba Buena Tunnel portals, and especially the center anchorage tower and shroud – work to accentuate structural function and are certainly not separate architectural statements. Nonetheless, these large elements are among the most handsome features of the bridge and are consistent with the steel elements; to use the favorite phrase of the board, the large concrete elements, along with the steel shroud of the center anchorage, "harmonize" with the bridge's other structural elements. The board was also responsible for installation of oversized diagonal bracing on the suspension bridge towers which, while unnecessary structurally (at least in the opinion of Glenn Woodruff), worked to give more pleasing proportions to the towers.

However limited it may have been, the role of the Board of Consulting Architects in the design of the Bay Bridge should not be minimized. The towers, three anchorages, and tunnel portals, after all, are huge structures and among the most accessible of the elements of the bridge. The clean lines, battered profile, and stepped appearance of these elements are the work of the consulting architects and their most important contribution to the design of the bridge. These elements harmonize with the rest of the bridge because they frankly express their functions, in much the same manner as the steel elements. These elements, however, are the only parts of the bridge for which details were designed specifically for the purpose of creating a more pleasing appearance. The success of these elements may be attributed, at least in part, to the fact that the architects were given little leeway and could work only within carefully constrained parameters. They were forced to adopt the "clean-line" vision through which the engineers had designed the bridge as a whole and the total bridge may be seen as more cohesive because of that fact. As Milton Pflueger, Timothy Pflueger's brother, observed many years later with regard to the input of the firm: "Proportion, scale, and character – the elements which, if right, produce good engineering and good architecture (they are one and the same) – were studied to the greatest degree possible, given the mandates."[249]

[249] Milton T. Pflueger, *Time and Tim Remembered: A Tradition of Bay Area Architecture* (San Francisco: Pflueger Architects, 1985), 27.

9. HISTORY OF CONSTRUCTION OF THE BRIDGE

The Bay Bridge was designed in about two years and built in a little more than three. The great haste in both instances may be explained only in the context of the Great Depression and the long campaign for the Bay Bridge during the 1920s. The primary incentives for rapid construction, as cited by leaders of the Bay Bridge Division, were to put men to work, avoid crushing interest costs on the federal loan, and deliver on promises made to Bay Area political and civic leaders. The state engineers pushed hard on themselves and their contractors to keep the job on schedule, to deliver on their many assurances and to bring in bridge toll revenues as soon as possible.

The plans and specifications for most of the bridge elements were completed in early 1933, although as noted a great number of details were still being worked out even while construction was underway. It was necessary to delay opening of bids until the Reconstruction Finance Corporation loan was virtually assured. Bids were solicited on February 28; the paperwork for the loans was completed on April 28, and the bids were opened the same day. The grand opening ceremony, marking the initiation of construction, occurred on July 10, 1933, with a customary ceremonial turning of the earth by former president Herbert Hoover, and a more dramatic and unusual remotely controlled dynamite blast on Yerba Buena Island, set off by President Franklin Roosevelt.[250] The bridge was dedicated and opened to vehicular traffic on November 12, 1936; the railroad-related elements of the bridge were not completed until January 1939.

The major elements of construction were divided into seven contracts, numbered 2 through 8. For the seven major contracts, the contract number, element of work, contractor, and dollar amounts are summarized below:

No.	Work	Contractor	Cost (in thousands)
2	West Bay Substructure	Transbay Construction Co.	6,957
3	SF Anchorage, Approaches	Healy-Tibbetts	1,049
4	East Bay Substructure	Bridge Builders, Inc.	2,697
5	Yerba Buena Island Tunnel, Anchorage	Clinton Construction	1,821
6	West Bay Superstructure	Columbia Steel Co.	9,566
7	East Bay Superstructure	Columbia Steel Co.	8,798
8	Oakland Approaches	Clinton Construction	254

Contract 1 was for borings into the Bay floor during design work; that contract was completed in 1932. Numerous other contracts were let after Contract 8. Most were either minor in nature, such as a small lighting contract, or were completed after the bridge was opened in November 1936. Major contracts for the interurban railway system, for example, were not completed until 1939. In the discussion below, the background of the contractors is summarized, followed by a brief description of the work involved with the major elements of work.

[250] *San Francisco Chronicle*, July 10, 1933, 1.

9.1. The Contractors

Not surprisingly, this huge project captured the attention of the American construction industry. The fact that the bridge was built in a little more than two years is a testament to the careful planning by the state and its consultants, but is a tribute as well to the professionalism and experience of the companies that won the construction contracts.

The contractors for the seven major elements of construction may be seen as comprising three groups. One group, with responsibility for all of the major steel work (Contracts 6 and 7), comprised subsidiaries of the U.S. Steel Corporation, the major steel manufacturer as well as the major fabricator of steel bridges. Another group, with responsibility for the substructure (Contracts 2 and 4), comprised companies affiliated with the "Six Companies," which built Hoover Dam and numerous other large construction jobs during the 1930s and 1940s. In an unexpected turn of events, different members of the "Six Companies" were affiliated with the Transbay Construction Company and the Bridge Buildings, Inc., and competed with one another for Contracts 2 and 4, with one group winning Contract 2 and the other group winning Contract 4. A third group comprised strictly local Bay Area contractors – these local contractors had responsibility for Contracts 3, 5, and 8.

9.1.1. The U.S. Steel-Related Companies

U.S. Steel Corporation was organized in 1901 as an assemblage of numerous large steel manufacturers, as well as the American Bridge Company, which was in turn an amalgam of numerous metal bridge fabricators. By 1933, the U. S. Steel Corporation could amass such a formidable group of steel-making subsidiaries that it won many of the major bridge superstructure contracts in the United States. In the Bay Bridge work, the prime contractor was Columbia Steel Company, a U. S. Steel subsidiary with a branch office in San Francisco. The American Bridge Company, however, conducted the bulk of the work. The steel fabrication was farmed out to various U. S. Steel plants, including its major plants in Gary, Indiana and Ambridge, Pennsylvania.

U. S. Steel did subcontract most of the East Bay superstructure to McClintic-Marshall. McClintic-Marshall, a subsidiary of Bethlehem Steel, rivaled the American Bridge Company as a builder of great bridges. It had fabricated and erected the superstructures for the Ambassador Bridge in Michigan, the George Washington Bridge in New York-New Jersey, and would build the towers and suspenders for the Golden Gate Bridge.[251]

9.1.2. The Six Companies-Related Consortiums

The Transbay Construction Company and the Bridge Builders, Inc. were consortiums, assembled specifically to bid on the Bay Bridge contracts. (Bridge Builders, Inc. was initially assembled to

[251] The company is profiled in Van der Zee, *The Gate*, 141.

bid on work on the Golden Gate Bridge, with a slightly different group of affiliated companies.) The Transbay Construction Company comprised: General Construction Company, Seattle; Morrison-Knudsen Company, Boise; McDonald and Kahn, San Francisco; Pacific Bridge Company, Portland; and J. F. Shea Company, Portland. The Bridge Builders, Inc. comprised: Missouri Valley Bridge and Iron Company, Kansas City; Raymond Concrete Pile Company, New York; Dravo Construction Company, Pittsburgh; Bechtel-Kaiser-Warren Company, San Francisco; and the Utah Construction Company, San Francisco.[252]

All of the above-named firms were independent operations, i.e. not subsidiaries of larger corporations. Many had worked in cooperation with one another, however, on major construction projects throughout the United States and abroad. A substantial proportion had been involved with a long-lived consortium called the "Six Companies," which had, among its other accomplishments, built Hoover Dam, which was under construction at the same time as the Bay Bridge. For this reason, this category of contractors is called "Six Companies-Related," although not all participants in the two consortiums were part of the Six Companies.

The "Six Companies" was organized in 1931 to bid on Hoover Dam; there were actually eight companies, owing to late additions. Each of the eight companies was associated with one or the other of the substructure contractors: Utah Construction Company (Bridge Builders, Inc.); Morrison-Knudsen (Transbay Construction Company); Pacific Bridge Company (Transbay); J. F. Shea (Transbay); McDonald and Kahn (Transbay); Bechtel Company (Bridge Builders); Henry J. Kaiser Company (Bridge Builders); and Warren Brothers Company (Bridge Builders). Thus, the eight members of the Six Companies were aligned evenly, with four in each of the major consortiums on the substructure work for the Bay Bridge.[253]

The fact that these companies bid against one another in this project illustrates the transient nature of these project-specific arrangements. When Bridge Builders, Inc. was organized in 1931 it bid on substructure and approach work for the Golden Gate Bridge, bidding against the Pacific Bridge Company; Pacific Bridge won the substructure contract and Bridge Builders the approach work.[254] The Transbay Construction Company was similar to the group that won the substructure work for the Golden Gate Bridge, headed by the Pacific Bridge Company and Morrison-Knudsen.

9.1.3. The Local Contractors

The contracts awarded to local contractors were the smallest of the seven major elements. Clinton Construction Company won two (Contracts 5 and 8) while Healy-Tibbetts won Contract 2. Both Healy Tibbetts and Clinton had been in business in San Francisco for many years before

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[252] California Department of Public Works, "First Annual Progress Report, San Francisco Oakland Bay Bridge," July 1, 1934, 32, 45.

[253] Donald E. Wolf, *Big Dams and Other Dreams: The Six Companies Story* (Norman: University of Oklahoma Press, 1996).

[254] Wolf, *Big Dams and Other Dreams*, 43-44.

1933. Both Healy-Tibbetts and Clinton subcontracted much of the work on these two large contracts, far more than was the case with the major contractors. On Contract 5 on Yerba Buena Island, for example, sub-contractors handled the bulk of construction, including the difficult excavation for the anchorage and vehicular tunnels.

9.2. Substructure, West Bay Crossing

Contract 2 was arguably the most complex and challenging of the seven major Bay Bridge contracts in that it involved the highest degree of unproven technologies. Contract 2 covered all of the water piers between San Francisco and Yerba Buena Island. The piers were identified by number, from west to east, with the western piers preceded by "W" and the east piers by "E." Thus, the pier closest to San Francisco was W-1, while the western pier for the East Bay Crossing was E-1. Contract No. 2 concerned Piers W-2 through W-6. Pier W-1 was a land pier and was built as part of Contract No. 3.

The resident engineer for this contract was I. O. Jahlstrom. The general contractor was the Transbay Construction Company, and the constituent companies of that consortium did most of the work. Charles P. Dunn, the chief engineer for the Transbay Construction Company, supervised the work.[255] The major subcontractor was the Moore Dry Dock Company, which fabricated the caissons. Other local subcontractors included the Judson Pacific Company and Western Pipe and Steel Company, which fabricated the steel for the cylinders in the caissons.[256] The workforce on this contract peaked at 968 in March 1934 and remained at a force of about 800 through January of 1935. It appears that the General Construction Company took the lead for five-company consortium.

The essential task of Contract No. 2 was to implement the caisson plan, developed conceptually by Moran and Proctor and finalized by the engineers of the Bay Bridge Division. Pier W-2 was built using an open cofferdam method. Piers W-3 through W-6 were built using Moran's patented flotation system.

Pier W-2, the most conventional pier of the group, was located at the outer edge of an historic steamship dock, leading east from the Embarcadero. Construction of this pier was carried out from the steamship dock, Harbor Pier No. 24. The pier site was first excavated through open trenching. A timber frame was towed to the pier site and sunk by weighting it down. Sheet pilings were driven into the sides of this frame to bedrock, 80 feet below the surface on the south end and 104 feet on the north end. The sheet pilings then formed a steel box, or cofferdam, to the desired shape of the pier. This "box" was excavated to bedrock. Concrete was poured in the cofferdam by buckets. As the pour reached to nine feet from the water level, the cofferdam was

[255] C. P. Dunn, "Building the West Bay Piers for San Francisco-Oakland Bridge," *Western Construction News*, (August 1934): 255-258. Dunn had been a construction engineer with Alcoa and the Portland Electric Power Co. before going to work for Transbay.

[256] I.O. Jahlstrom, "General Construction Report for Foundations Piers 2, 3, 4, 5, 6, and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, California Department of Transportation Library, Sacramento.

de-watered and the concrete poured dry. The concrete pour continued to a height of 40 feet above water level, forming the base for the suspension tower, Pier W-2, which is a solid concrete pier. The American Dredging Company performed the dredging on this sub-unit of Contract 2. The Moore Dry Dock Company fabricated the timber crib, while the Bethlehem Steel Company built the steel sheet pilings.[257] The contract work was accepted in November 1933. Thus, this was the first element of the Bay Bridge to be successfully completed.

Piers W-3, W-4, W-5, and W-6 were the most difficult and structurally complicated, owing to the great depth in the shipping channel and the fact that they were carried to bedrock at depths never before achieved. The system for this construction was so novel and specific to this project that it has been treated at great length in numerous civil engineering journals, including two long articles written by Carlton Proctor, partner to Daniel Moran, as well as an extensive article by Purcell, Woodruff, and Andrew.[258]

The pier construction process was built around what Proctor called a "domed coffer dam with pneumatic false bottom." The terms, domed, pneumatic, and false bottom, refer to the ingenious caisson that Moran developed and attempted to patent as a means of controlling the process of sinking very deep foundations. The process was built around a rectangular frame that surrounded a series of cylinders, each of which was domed on the top. Each cylinder on each pier was 15' in diameter. Because the piers were of different sizes, they included different numbers of cylinders. The construction caissons for Piers W-3 and W-6 comprised 28 steel cylinders, held in place in a rectangular wooden frame with steel struts. Thus, the caisson included 28 cylinders (set in four rows of seven), with a series of spandrel shapes, created by the voids between the rectangular grid and the cylinders. Pier W-5, the smallest of the four, is built around 21 cylinders, with three rows of cylinders set in groups of seven. Pier W-4, the double anchorage, is simply a much larger version of the same cellular design; it comprises 55 15' diameter cylinders, set in five rows of eleven.

Each caisson was built on shore at the plant of the Moore Dry Dock Company in San Francisco and towed into place. The caisson was secured in place through a combination of two structures: a series of reinforced concrete anchors that secured cables with block and tackle systems; and floating wooden fenders, held in place by anchors in deeper water or by timber piles in shallower water. Once the caisson was at the site, hemispherical domes were welded to the tops of the cylinders. Air was pumped into the cylinders to force the caissons to float, even as the weight of the concrete was poured around them.

Concrete was then poured into the voids outside the cylinders. The added weight caused the caisson to sink but at a rate controlled by the forced air. As the caisson sank, new sidewalls were

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[257] I.O. Jahlstrom, "Construction Report for Pier No. 2, Contract No.2 of the West Bay Crossing for the San Francisco-Oakland Bay Bridge, November 1933.

[258] Carlton S. Proctor, "Foundation Design for Trans-Bay Bridge," *Civil Engineering* 4:12 (December 1934): 617-621; and "Constructing Foundations of Trans-Bay Bridge," *Civil Engineering* 5:2 (February 1935): 91-95; C. H. Purcell, Charles A. Andrew, and Glenn B. Woodruff, "Bay Bridge Foundations Built with Unique Domed Caissons," *Engineering News-Record* (April 5, 1934): 431-436.

built to keep the top of caisson above water. New lengths were added to the cylinders as well by sawing off four domes at a time and adding new lengths to each cylinder before the dome was welded back in place. This process was repeated until the caisson reached the mud floor of the bay. At this point, the caisson was said to have "landed."

As Proctor emphasized, the landing "required great care and delicacy of handling," owing to tidal currents and the need to adjust all of the anchor lines to allow the caisson to move without listing.[259] By releasing air from the domes, the caisson was allowed to sink rapidly by gravity into the mud. At this point, some of the domes were removed but others left in place to provide a means of stabilizing the caisson. Many of the domes were left in place until the caisson had sunk to a stable level, typically on sandy clay below the mud. When it was determined that the caisson was stable, all of the domes were removed. The cylinders were then re-used as "dredging wells." Cranes, secured to the temporary fenders around the caisson, sank clamshell buckets through the cylinders to excavate the underlying material, allowing the caisson to sink further. The process of raising the sides of the caisson was then repeated, with additional concrete poured into the voids, new sidewalls built up, and the cylinders extended. This process was continued until the caisson sank to bedrock. Forced water jets were often required to cut through the last layers of firm sands, forcing debris out of the way. When the caisson was firmly on bedrock, the tops of the cylinders were sealed in concrete and the pier was completed.

The depth of these piers reflects the distance to bedrock, not necessarily the depth of water at the location. Pier W-3, for example, was built in a water depth of 50' but is the deepest of the piers, reaching bedrock at 220'. Pier W-4 reaches bedrock at about 180'. Pier W-5 reaches bedrock at only 105', and Pier W-6 at about the same depth. The water depth was greatest at Pier W-6, near Yerba Buena Island. When the pier reached bedrock, crews began construction of the base for the steel towers, which rise above the water on Piers W-2, W-3, W-5, and W-6; the central anchorage, Pier W-4 was built of concrete above the water level and includes no tower. Immediately above the water level, each pier includes a fender. A fender is a concrete arm, cantilevered from the bulk of the pier, finished in timber. Visually, this fender seems to exaggerate the mass of the pier, but it is actually a slender element projecting out from the edges of the pier. The base for the steel tower is only about one-half the area of the base of the pier. The caissons were sunk in the following order: Pier-W-6, Pier W-4, Pier W-3, and Pier W-5.

Caisson 6 was the first to be sunk and caused the greatest degree of anxiety. Pier W-6 is located about 1160 feet west of Yerba Buena Island. While not the deepest to bedrock (that distinction fell to Pier W-3), Pier W-6 was in the deepest water, with a water depth more than 30' deeper than any other pier. Pier W-6 serves as the foundation for the eastern tower of the eastern half of the suspension bridge. The caisson was towed to the site in June, 1933, blocked into place, and the painstaking process of sinking it began shortly thereafter: filling the outer chambers, raising the domes, and so forth. The pier "landed" (reached the level of bay floor mud) on December 11, 1933.[260] (All of the other water piers were also under construction by the time Caisson 6 landed.)

[259] Proctor, "Constructing Foundations," 92.

[260] Jahlstrom, Sheet 6 in Appendix.

On December 19, the company began dredging through the open cavities and all seemed well. Moran, who followed construction closely from his office in New York, sent a telegram to Charles Andrew: "Congratulations to you and Glenn for fine position and penetration of Six. Extend congratulations for me to Contractor. How are you for level?"[261]

By January 14, 1934, the caisson was 30 feet below the mud surface, or about 135 feet below the water level. The caisson suddenly dropped to the east, tilting such that its eastern side was about seven feet lower than the west. There ensued the single greatest crisis in the entire history of the construction of the bridge. The tilting occurred because the caisson had landed on a stiff stratum that overlay a softer one. The top layer was able to support the entire caisson and the softer layer was reached only by dredging. When the dredging broke through the stiff overburden and the caisson encountered the softer layer, the structure listed.[262]

The emergency was solved through close coordination by the Bay Bridge Division leadership, Daniel Moran (who came to San Francisco to supervise the work), and the contractor. As noted, the caisson tipped on January 14; it was not brought back to level until March 3. The essential strategy for righting the caisson was to remove material on the west side (the higher side). To avoid any sudden movement in that direction, however, some of the domes were re-installed on the cylinders, the forced air acting as a brake on movement in the other direction. The east-west tip was nearly resolved when the caisson on February 23 suddenly fell five feet to the north. The corrective measures were then applied on a north-south basis until the caisson was finally leveled in early March.

The other caissons were sunk with relative ease. Caisson W-4, the foundation for the huge center anchorage, also tipped in early February. The corrective measures for righting the caisson were complicated by the fact that the cylinders were plugged with mud, rendering the forced air in the domes ineffective.[263] The problem was solved by dredging away from the tilt. Caissons W-3 and W-5 presented no extraordinary problems, despite the fact that W-3 was the deepest of the piers. The piers were completed to about 25' above water level, except for Pier W-4, the central anchorage, which was taken to an elevation of some 225' above water level. The work on Contract 2 literally established the foundation for Contract 6, the West Bay superstructure work of the American Bridge Company.

9.3. Substructure, East Bay Crossing

Contract 4 was awarded to the Bridge Builders, Inc. Carl P. Jansen was the superintendent for

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[261] Moran to Andrew, December 12, 1933, Board of Consulting Engineers, 200.5, California State Archives. This letter reprinted the text of the telegram of the day before.

[262] The problems with Caisson 6 are detailed in C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Difficult Problems Overcome in Sinking Deep Caissons - I," *Engineering News-Record* (February 14, 1935): 239-242.

[263] C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Difficult Problems Overcome in Sinking Deep Caissons - II," *Engineering News-Record* (February 21, 1935): 278-281.

Bridge Builders, Inc.[264] V. A. Endersby was the resident engineer for the state. Although Henry J. Kaiser was the president of Bridge Builders, the general superintendent came from the Dravo Construction Company and the managing engineer from the Missouri Valley Bridge & Iron Company. The bulk of the work was completed by Bridge Builders, Inc. Subcontracts were awarded to Kaiser Construction for barge rentals and concrete mixing (Kaiser, of course, was part of the Bridge Builders team), Moore Dry Dock for construction of the caissons, Pacific Coast Steel for steel fabrication, and Duncanson and Harrelson, for test borings.[265] Employment on this contract peaked at 796 men; typically, the workforce was under 600.

Contract 4 was essentially the East Bay Crossing equivalent of Contract 2, to construct the foundation work for the East Bay Crossing. The methods were similar but execution differed in crucial ways, owing to the fact that the East Bay Crossing Piers were not taken to bedrock and many were built on piles. There are three distinctive aspects of the piers on the East Bay Crossing: there are many of them, relative to the West Bay Crossing Piers (22 versus six); none of the piers reaches bedrock; and the piers are of different sizes and configuration, owing to the different types of bridges on the East Bay Crossing and the different bearing requirements for the different bridge types.

The essential character of the piers may be summarized consisely. Pier E-1 (the piers are numbered west to east, from the island to Oakland) is a solid concrete pier on natural land; this pier was built as part of Contract 5. It anchors a viaduct span, connecting the Yerba Buena Island Tunnel with the beginning of the over-water bridge. It also serves as the western anchor for one of the side spans of the cantilever bridge. Piers E-2 and E-3 are the tallest of the East Bay Crossing piers; these support the cantilever bridge. Pier E-4 serves as an anchor for the eastern end of the cantilever span as well as the western support for the first of the through truss spans. Piers E-5 through E-9 support the truss spans; Pier E-9 also serves the western end of the deck truss spans. The rest of the East Bay Crossing piers support the deck truss spans. The first seven consist of steel towers on concrete bases; the remaining piers are solid concrete. These piers get shorter and shorter as the bridge descends toward the Oakland Mole. The deck truss piers are also very close to one another, compared with those for the cantilever or through truss spans.

The piers range in height according to the grade of the roadway. The piers also differ in width, according to the different roles they play in supporting this structurally complex crossing. For example, Piers E-2 and E-3 bear the weight of the cantilever bridge and thus carry the heaviest dead load of any East Bay Crossing piers. Piers E-I and E-4, by contrast, serve as "anchors" for the ends of the cantilever span, and therefore bear a great tension load and are larger than any piers, other than E-2 and E-3.

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[264] C. B. Jansen, "Eastbay Piers for $78,000,000 San Francisco-Oakland Bridge," *Western Construction News* (July 1934): 215-223. Connor was on loan from the Missouri Valley Bridge & Iron Company, where he was chief engineer and Jensen was on loan from Dravo Construction, where he was a supervising engineer.

[265] A two-box set of records for Contract 4 may be found at the California State Archives, with an accession number of F2517:176. These records include the weekly reports from the Resident Engineer for the Department of Public Works.

Of this group, Piers E-3, E-4 and E-5 were by far the most difficult to design and construct. Pier E-2 was built just east of the land's end and was easily taken to bedrock, which was about 45 feet below the water level. It is a solid concrete pier, poured into an open cofferdam. Like the middle piers on the West Bay Crossing, Piers E-3, 4, and 5 were sunk to great depths using a cellular caisson. The three major East Bay Crossing piers differ from the West Bay Crossing piers in three respects. First, as noted, they do not reach bedrock. Second, the cells are built from rectangular excavation chambers. Third, a conscious effort was made to reduce the weight of the piers themselves, recognizing that they would not be founded on bedrock.

The caissons for the three major East Bay Crossing piers were similar but of different sizes. Each was a steel rectangle with rectangular chambers. Construction proceeded in much the same manner as the West Bay Crossing piers. Concrete was poured into the columns, or voids outside the chambers, until the caisson reached the mud level, building new levels on top as necessary to keep the top of the caisson above water. Mud and other strata were excavated through the rectangular chambers until the caisson sunk to a previously agreed-upon level.[266] When that level was reached, an additional 15 feet was excavated and concrete poured through the excavation chambers, creating a concrete base below the edges of the caisson.

Although not reaching bedrock, those levels were spectacular. Pier E-3, sunk to a level of -235 feet, was the deepest of all of the piers. That, combined with an additional 15 feet below the caisson, gave a total depth of 250 feet, much deeper than the 220 foot Pier W-3, the deepest on the West Bay Crossing. Pier E-3 also had the largest area of the East Bay Crossing piers. The caisson for it measured 80 feet by 134.5 feet and included 28 rectangular chambers. The caissons for Piers E-4 and E-5 were both 60 feet by 90.5 feet. Each was taken to a depth of 180 feet, in addition to the extra 15 feet scouring below the caisson.

The only major surprise on Contract 4 occurred during the sinking of Pier E-3. State engineers and the contractor had assumed that the caisson would be difficult to sink, owing to "skin friction," or the resistance of the caisson's material to the mud. This skin friction, in the words of the resident engineer, "had been overestimated by both State and Contractor's forces." When the caisson had reached the desired depth, the contractor began to jet below it to create a cavity for pouring additional concrete. The caisson, however, continued to sink into this cavity; as the resident engineer noted, "the real problem was, not to cause the caissons to sink, but to stop them as desired."[267] The caisson was at the desired depth of –223.5 when the jets were turned on. The caisson continued to sink, finally coming to rest more than 10 feet lower. Thus, Pier E-3 accidentally earned the record of being the deepest pier in the world.

The remaining piers – Piers E-6 through E-23 – were built using an entirely different method.

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[266] The terminal levels for these piers had been established on the basis of borings, at a level in which the pier would "reach a suitable stratum" to bear the loads for the particular pier in question. Proctor, "Constructing Foundations," 94.

[267] V. A. Endersby, "Final Construction Report of the Substructure, East Bay Crossing of the San Francisco-Oakland Bay Bridge, Contract 4 and 4a," July 28, 1937, California Dept. of Transportation, Oakland, 33.

Piers E-6 through E-8 were called "intermediate pile piers," with steel-sided cofferdams founded on piles. Pier E-9 was unique among the Bay Bridge piers in that it was built to support a double tower, or square, four-column tower. The purpose of the tower was described in the contract completion report: "[it] acts as longitudinal bracing for the spans approaching the cantilever and stabilizes the curve in the bridge at this point."[268] It was built in the same manner as Piers E-6 through E-8 but was regarded as "the largest known pile foundation pier" at the time it was built. This pier is also distinctive in that the deck collapsed at Pier E-9 during the 1989 Loma Prieta Earthquake. Piers E-10 through E-22 were also built in the same manner as E-6 through E-8.

9.4. West Bay Superstructure

Contract 6 was the most famous and closely watched of the various construction contracts, for several reasons. It was the last contract to be completed and was highly visible, particularly to observers in San Francisco. It was also the most complex contract that could be seen; a case could be made for Contract 2 being more complex but the work took place almost entirely below the surface. Contract 6 was also the most photogenic of the contract jobs in that it involved hundreds of workmen, suspended high above the Bay.

Contract 6 was almost entirely the work of subsidiaries of the U.S. Steel Corporation. It was formally awarded to the Columbia Steel Company, which was a U.S. Steel subsidiary with an office in San Francisco. The bulk of the value of the contract, however, went to the American Bridge Company, which fabricated and erected the steel towers and spun the cables.[269] American Steel and Wire Company, also a U. S. Steel subsidiary, provided most of the wire for the cables. There were a few non-U.S. Steel subcontractors: the Pacific Bridge Company, which did the field-coat painting, Judson Pacific of San Francisco, which fabricated light structural elements, and the Moore Dry Dock Company, which fabricated some elements of the central anchorage.[270]

The work on Contract 6 was obviously dependent upon completion of other contracts – Contract 2, which was for the West Bay substructure, Contract 3, which included the San Francisco anchorage, and Contract 5, which included the Yerba Buena Island anchorage. As a result, Contract 6 was the last to be completed. The work on Contract 6, by far the most expensive of the Bay Bridge contracts, involved three basic steps: building towers on Piers W-2, W-3, W-5, and W-6; spinning cables from the San Francisco anchorage to Pier W-4 and to Yerba Buena Island; and installing the stiffening trusses from the cables. These steps are described separately below.

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[268] V. A. Endersby, "Final Construction Report of the Substructure, East Bay Crossing of the San Francisco-Oakland Bay Bridge, Contract 4 and 4a," July 28, 1937, California Dept. of Transportation, Oakland, 6.

[269] United States Steel, "San Francisco Oakland Bay Bridge," 1936, California Dept. of Transportation Library, Sacramento. This book is one of the most concise and factual accounts of all aspects of construction, with particular attention paid to Contracts 6 and 7, which were built by the U.S. Steel and its subsidiaries.

[270] I. O. Jahlstrom, "General Construction Report, Superstructure for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," Contracts No. 6 and 6A, May 1, 1937, California Dept. of Transportation Library, Sacramento.

9.4.1. Building the Towers of the West Bay Crossing

The suspension bridge towers on the West Bay Crossing are built on Piers W-2, W-3, W-5, and W-6. [Contract 6 also included steel bents A and B in San Francisco but did not include the concrete anchorage or concrete Pier W-1.] Although there are minor variations (minor in terms of the grand scale of these structures), the four suspension towers are nearly identical. The steel bottom, or base plate, for each tower begins 40 feet above low water level for the bay.[271] The outside towers (on Piers W-2 and W-6) are 414 feet high above their base plates. Towers on 3 and 4 (closest to the center anchorage) are 458 feet high above their base plates; the increased height relates to the fact that the center anchorage is higher than the deck level anywhere else on the bridge.

The towers comprise two thick vertical members, called columns, with horizontal and diagonal bracing, tying the two together. A distinctive element of these towers is the fact that the columns are hollow, attributable to the unusual manner in which the towers were erected. Each leg is in the form of a cross with a hollow center.[272] The columns were built of a series of steel cells, or rectangles that vary in size; the largest are 3' 6" by 4'. There are six cells at the top and bottom and four cells on each side, surrounding a hollow core of 7' x 8'. The columns taper toward the top. At the bottom, or base plate level, each leg is about 30' by 20', with the larger measurement being east-west oriented, in the direction of the cable. The two columns are about 83' apart. The steel that encloses these cells varies in width from nearly three inches to less than one inch in thickness.

The hollow core of the leg was included to serve as a base for a hammerhead derrick, which was built inside the lower parts of the tower and used to crane additional tower parts into place. As the tower rose, the derrick was raised and new parts of the tower were craned into place until the tower columns had been completed. As the columns were being raised and erected, the diagonal and horizontal bracing was installed as well. Each tower is built around a thick horizontal member, or strut, at the base, with two sets of heavy, crossing diagonal members between the base and the deck level, two additional horizontal struts to support the decks, with three sets of crossing members above the deck, terminating in another horizontal strut at the top. Towers of this nature exist above Piers W-2, W-3, W-5, and W-6.

At the base of each steel tower (the concrete top of the pier), the steel columns are bolted down with huge bolts on plates set into the concrete. The lowest strut is located a very short distance above the base plate, and the crossing diagonal pieces begin immediately above the horizontal member. All members other than the tower columns are latticed members, i.e. comprising thousands of crossing steel members, which appear to be solid because of solid steel plates placed

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[271] The technical specifications for the towers and other parts of the West Bay superstructure are taken from United States Steel, *San Francisco Oakland Bay Bridge*, 1936.

[272] The hollow core of the towers was an innovation suggested by the American Bridge Company, after the contract had been awarded to Columbia Steel.

on the outside. As noted, there are two sets of crossing steel members between the bottom horizontal member and the deck supports. The horizontal deck struts are located a little less than half-height in the towers. Three sets of crossing members exist above the deck levels; these too are latticed members. The towers terminate in a horizontal member, with minor members above each leg to accept the cable saddles.

The towers were arguably the least difficult elements of construction under Contract 6 in that the towers had been carefully fabricated by the American Bridge Company and construction involved assembling these pre-fabricated pieces. The towers were built one at a time to allow the hammerhead derricks to be reused. Tower construction began at Pier 2 on February 26, 1934 and the last tower construction item, the hood for the center anchorage, was completed on September 3, 1936.[273] The towers were essentially built in June, 1935, when the cable spinning operation began. The towers include almost 35 thousand tons of steel and more than 505,000 field rivets. The entirety of the steel used on the Bay Bridge (East Bay and West Bay Crossings), represented one-eighth of the steel production of the United States during the years in which the Bay Bridge was under construction.

9.4.2. Spinning the Cables

Judging from coverage in popular journals and books, the cable spinning operation was inherently the most interesting aspect of building the Bay Bridge. It was also arguably the least unusual aspect of the job. The substructure and tower design, for example, involved highly ingenious innovations. The cable spinning operation was, for the most part, a predictable job for experienced bridge builders, not unlike the equivalent operation on any other major suspension bridge.

While it may have followed predictable processes, this operation was also among the most technically challenging, requiring the services of skilled workmen at nearly every juncture and subjecting the workmen to the greatest danger. Seven men died on this contract, all from falling, representing one-quarter of all deaths from bridge construction.[274] Simplifying the process considerably, the spinning may be seen as involving four steps: building a footbridge; "spinning" wire from one anchorage over two tower saddles to the other anchorage; cable compacting; and cable banding.

Footbridge construction was a relatively minor item in terms of cost but was essential because it provided a platform for workmen and materials. The footbridges on the Bay Bridge were ten feet wide supported by 2 ½-inch diameter wire ropes, with a mesh floor between. The footbridge included wire rope handrails with posts between the wire handrails and the floor. One catwalk was built for each of the final cables.

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[273] I. O. Jahlstrom, "General Construction Report, Superstructure for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," May 1, 1937, 28-29.

[274] As discussed in Chapter 10, there is some disagreement as to the number of deaths, ranging from 23 to 28. Jahlstrom gives the number of dead on this contract as seven.

The actual cable spinning operation involved carrying wire from one anchorage to the next, over the tops of the towers. A "spinning machine" was winched from one anchorage to the next, carrying wire at the top and bottom. Thus, two wires were spun in a single pass of the machine. The wire was held in place by "shoes," or steel spools that attached to eyebars in each anchorage; the center anchorage includes two sets of eyebars, one facing either direction. The eyebars are embedded in the concrete at each of the four anchorage points: in San Francisco; two anchorage points at Pier W-4; and an anchorage at the island. The wire used in the bridge was round steel wire that measures about .19 inches in diameter (five such wires laid side by side would measure about an inch). "Spinning" the cable involved dragging wire from big reels constructed on land (in San Francisco and Yerba Buena Island). Ultimately, 472 wires were wrapped around each shoe, with 236 on either side of it. These 472 wires would be bound into a strand. Ultimately, 37 strands would be bound together to form a cable. The one innovation associated with the Bay Bridge cable spinning operation concerned the "saddle" on top of the towers. Typically, the strands were spun outside the saddle and lifted into the saddle when the strand was completed. At the Bay Bridge, the spinning was conducted inside the saddle, to avoid the task of lifting the strand into the saddle.[275]

The many strands were bound together to form a distinct strand. The only major mishap in Contract 6 involved this step, binding a strand once it had been spun. On the night of September 18, 1935, a strand shoe on Pier W-4 (the center anchorage) popped open. This strand extended from San Francisco to the center anchorage on the south side. Perhaps affected by contraction in the nighttime temperature, the wire pulled away from the shoe, destroying the entire strand. The strand was re-spun, at a net loss of 14 days in the schedule.[276] As a final step, the 37 strands were bound together, compacted, and wrapped in bands. For this purpose, a seven and one-half ton compressed air jack was wrapped around the strands and used to compact them into a nearly perfect circle.

9.4.3. Building the Suspended Roadway

This element of the construction job -- hanging the roadway from the completed cables -- was among the trickiest parts of the job, owing to the very long total length of the West Bay Crossing. The greatest worry was that the addition of the weight of the stiffening truss would unbalance the towers or put too great a strain on the anchorages. To avoid any such problems, the state engineers and the contractor built a scale model of the bridge in San Francisco and hung to-scale

[275] C. H. Purcell, Chas. A. Andrew, and Glenn B. Woodruff, "Cable Spinning on the Bay Bridge," *Engineering News-Record* (May 7, 1936): 657.

[276] C. H. Purcell, Chas. A. Andrew, and Glenn B. Woodruff, "Cable Spinning on the Bay Bridge," *Engineering News-Record* (May 7, 1936): 657; I. O. Jahlstrom, "General Construction Report, Superstructure for the West Bay Crossing of the San Francisco-Oakland Bay Bridge" (May 1, 1937): 64-66.

weights on its cables to test the effect of each section of the stiffening truss before it was hoisted into place.[277]

The cables were held in place in the saddles atop the towers at Piers W-1, W-2, W-3, W-5, and W-6, as well as at the cable bent at the Yerba Buena Island Anchorage. A saddle was a cast steel piece, each weighing about 46 tons. Each was held to be the largest single-piece cast ever used in bridge construction at the time the Bay Bridge was built.[278] The stiffening trusses would be held into place by a series of suspender "ropes." These ropes are wire cables, each 2 ¼ inches in diameter. A rope was attached to the cables by a cable band, a metal clamp in two semi-circular parts which was bolted together with eight bolts at a prescribed location on the cable. There are 612 of these cable bands; altogether there are 43 miles or rope. The lengths of rope differ, depending upon the location within the catenary of the suspended span. One rope was put in place for each of the deck stiffening truss panels. The deck system was suspended from the suspender ropes, with the top of the stiffening truss hung from the rope.

9.5. Superstructure, East Bay Crossing

Contract 7 was awarded to the Columbia Steel Company, which relied upon the American Bridge Company for construction of the cantilever spans. The assignment for fabrication and erection of all steel east of the cantilever span (east of pier E-4) was subcontracted to the McClintic-Marshall Company, a subsidiary of Bethlehem Steel. Construction could begin on this contract only after Contract 4 had been completed. Owing to a relative ease of construction, the East Bay Crossing was completed nearly six months ahead of the West Bay Crossing; the work was completed and the East spans paved in April, 1936. The work proceeded without major mishap, although the contract was plagued with major accidents; more people died on this contract than any other contract. The one notable accident occurred in July, 1936, after the spans had been completed and finish work was underway. A fire broke out on Pier E-3, causing $10,000 worth of damage and forcing six men to leap into the Bay; all were successfully rescued.[279]

9.5.1. Cantilever Span, East Bay Crossing

The cantilever bridge part of the East Bay Crossing is carried on Piers E-1 through E-4. The cantilever bridge follows the essential design of all modern cantilever bridges, comprising five elements: two anchor arms; two cantilevered spans, which are built nearly symmetrical to the anchor arms (the anchor arms are 508' long, the cantilever arms 412'); and the suspended span, hung between the ends of the cantilevered spans. Because the suspended span was not supported on piers (it was, as the name suggests, suspended from the ends of the cantilevers), there are only

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[277] C. H. Purcell, Chas. A. Andrew, and Glenn B. Woodruff, "Cable Spinning on the Bay Bridge," *Engineering News-Record* (May 7, 1936): 259. Professor Beggs of the University of California, Berkeley had built this model to test different suspension bridge designs during early design work.

[278] This contention was made by U.S. Steel, which fabricated the saddles. The saddles were cast at a U.S. Steel subsidiary in New Jersey.

[279] *Oakland Tribune*, July 6, 1936.

three spans: from the anchor to the major piers on either side of the bridge, and the larger center span, which includes the cantilever and suspended spans. By this arrangement, the center span was by far the longest of the three. In the Bay Bridge, this center span was 1400', an impressive span and among the largest cantilever spans ever built.[280]

The towers, or columns, for the cantilever span are cellular in section in a cross form, similar in that respect to the towers of the West Bay Crossing. The cantilever bridge was 192' high at Piers E-2 and E-3 but 196' high at the ends and at the center of the suspended span. The upper chords (major members at the tops of the trusses) at either side of Piers E-2 and E-3 are built of high-strength steel eyebars; these eyebars were used only at the highest points above the anchor and cantilever arm spans, where these top chords are in tension only.

The cantilever spans were built in stages: anchor arm, cantilever arm, then suspended span. Three temporary bents were built on Yerba Buena Island, between Piers E-1 and E-2. Anchor arm elements were hoisted into place by a "traveler consisting of two guy derricks mounted side by side on a base that moved along the structure."[281] The suspended span of the cantilever bridge was built out from the cantilever, rather than being raised from the water, as was customary in most major cantilever spans built in the 20th century. The decision not to raise the suspension span was made chiefly on the basis of ocean conditions at the site, where rough seas made a conventional raising of the suspension span inadvisable.[282] C. H. Purcell described the construction of the cantilever span as the second "most ticklish" job in building the Bay Bridge, after the sinking of piers on the West Bay Crossing, because "changing weather and tidal conditions made the closing of the gap difficult to calculate to a nicety." The final link in the suspended span was jacked into place, using huge hydraulic jacks.

9.5.2. Spans East of the Cantilever

The East Bay Crossing includes five through truss spans, located immediately to the east of the cantilever span.[283] Each through truss span is 504 feet long, each comprising 12 42-foot panels. The trusses are 84 feet tall. The trusses are Warren trusses. These through trusses are carried on

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[280] Like so many other aspects of the Bay Bridge, the cantilever span was a record-setting span in some regards. Its center span was the third largest in the world at the time its was built, surpassed only by the Firth of Forth and Quebec bridges; it was the greatest such span in the United States. Its clear height at center span was greater than either the Firth of Forth or Quebec bridges: 185 feet versus about 150 feet. U.S. Steel, "San Francisco Oakland Bay Bridge," 69.

[281] U.S. Steel, "San Francisco Oakland Bay Bridge," 75.

[282] C. H. Purcell, "Dramatic Operation Marks Closure of Final Bay Bridge Cantilever Gap," *California Highways and Public Works*, September-October, 1936. 16-17.

[283] The cantilever span is itself technically a through truss, although a very specialized truss. Cantilevered trusses are so distinctive as to be treated separately from the more common truss types, such as those found to the east of the cantilever bridge.

braced steel towers or bents, similar to those used on the deck truss, or incline section to the east.

The remainder of the East Bay Crossing, from the truss spans to the touchdown on the old Oakland Mole, includes a long continuous deck truss, comprising fourteen spans, as well as ten plate girder spans. This long group of deck truss and plate girder spans is often called, collectively, the "incline section," denoting its ramping toward the Oakland touchdown. The deck truss spans (called "double-deck truss spans" by the contactor)[284] are uniformly 288' long, supported on braced steel bents, except for the piers east of E-17, where the trusses are carried directly on the concrete piers. The trusses are 38 feet deep, with the top of the trusses serving as the top deck of the roadway.

9.6. San Francisco Anchorage, Viaduct, and Approaches

The construction work associated with the Bay Bridge in San Francisco was built through a combination of contracts associated directly with the bridge (i.e. planned by the Bay Bridge Division and funded through the RFC loan) and related projects planned by the Division of Highways. (On the East Bay, virtually all approach work was planned and funded by the Division of Highways.) In addition, the construction work in San Francisco included a series of projects associated with the interurban system that were planned and built after the Bay Bridge had opened official in November 1936. The bulk of the bridge related construction in San Francisco was accomplished under Contract 3, awarded to the Healy-Tibbetts Construction Company. Contract 3 covered the anchorage, Pier W-1, and the concrete viaduct behind the anchorage. The approaches, including the on and off ramps, were built under Contract 15. The resident engineer for the state was N. W. Reese.

For ease of discussion, the San Francisco work directly associated with the bridge may be seen as comprising four major elements: the San Francisco anchorage; the land-based piers (Pier W-1 and Bents A and B); the concrete viaduct west of the anchorage; and the ancillary elements of the Fifth Street Plaza and the on- and off-ramps. As discussed in the preceding chapter, the bridge elements in San Francisco, particularly the anchorage and viaduct, were redesigned by the Board of Consulting Architects after the contract had been awarded. These changes slowed construction and resulted in a large number of change orders and extra work orders. This contract also involved the demolition of numerous buildings to make room for the anchorage and viaducts.

9.6.1. Building the San Francisco Anchorage and the Land Piers

The San Francisco anchorage is a massive block of concrete that serves two important purposes: to anchor the cables and support the elevated viaduct above. The function of the anchorage was described succinctly by Purcell, Andrew and Woodruff: "The San Francisco anchorage is of the gravity type, depending entirely upon the weight of 63,600 cu. yd. of concrete to resist the

[284] U.S. Steel, "San Francisco Oakland Bay Bridge," 71.

38,000-ton pull of the cables."[285] Because it was a gravity structure, building the San Francisco anchorage was essentially a huge earth-moving and concrete pouring job. The work was complicated by the fact that it took place within the narrow confines of the streets of San Francisco; virtually all of the other work took place in the open bay or on relatively unsettled stretches of Yerba Buena Island and the East Bay.

The timing of the construction of the anchorage structure was particularly important because the anchorage structure was a key element, not only of the suspension bridge but for the viaduct as well. The work stretched out for nearly the full length of the bridge construction. The anchorage site was excavated and concrete poured to the level of the cable anchors, prior to initiation of the cable spinning operation. Construction of the remainder of the structure, above the cable anchors, was coordinated with work on the viaduct.

Pier 1, a massive concrete pier east of the anchorage, exists to support the cable bent as well as the eastern end of the continuous spans of the viaduct. It is also the western terminus of the suspension bridge. Construction of this pier was, like that of the anchorage, chiefly an excavation and concrete-pouring job. Its construction was necessarily coordinated closely with that of the anchorage.

9.6.2. Building the Viaduct

Of all elements of the Bay Bridge project, the concrete viaduct most closely approximated conventional roadway construction. The viaduct, which extends from the top of the anchorage structure to the 5th Street Plaza, is essentially a reinforced concrete girder bridge that is double-decked over its eastern portion, between the anchorage and about 1st Street. As with all other elements of the San Francisco work, construction was complicated by two factors. First, the work took place within the narrow confines of the streets of San Francisco. Second, the work needed to be closely coordinated with that of other elements. Because the viaduct links with the anchorage, construction of the anchorage was closely tied in with the spinning of the suspension cables.

The viaduct ramped gently to a touchdown at Fifth Street, where it joined a rectangular plaza, with two diagonal street cuts, one for automobiles leaving the bridge, another for automobiles entering the bridge. Much of the original viaduct that led from the Anchorage to Fifth Street still exists but it has been nearly lost visually in the jumble of adjoining freeway ramps. What remains of The Viaduct in San Francisco is today identified by the California Department of Transportation as Bridge Numbers 34-118L and 118R, which function as ramps for U. S. 101. The alignment of the main viaduct, however, was not exactly that of either 34-118L or 118R. The westerly leg of the original viaduct, near its touchdown at 5th Street, serves today as an off-ramp

[285] C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Cable Anchorages, San Francisco-Oakland Bay Bridge," *Engineering News-Record* (October 31, 1935): 505. These figures do not match those of the resident engineer, who maintained that there are 67,750 cubic yards of concrete in the building, along with 1707 tons of re-bar. N. W. Reese, "Final Construction Report of the San Francisco Anchorage Section, Pier No. 1 to Rincon Hill, San Francisco-Oakland Bay Bridge, Contract No. 3," January 2, 1937, 5.

for State Route 101. The old 5th Street Plaza is still largely intact, although most of it is now below the freeway lanes that cross over it.

9.6.3. Building the Other San Francisco Approaches

As noted, only the straight-linc viaduct between the anchorage and the Fifth Street Plaza was funded by the Reconstruction Finance Corporation. All other work in San Francisco was treated as Division of Highways work, funded through gasoline tax revenues. The other approaches were built by Healy-Tibbetts, the contractor for the anchorage and viaduct. [286]

Specifically, this work involved: the "On-Ramp"; the "Off-Ramp"; and the truck ramp. The On-Ramp began at the intersection of Harrison and Fremont streets. The ramp passed under the viaduct and looped to join the viaduct at a point between Sterling and Rincon streets. It is a concrete girder bridge over most of its length. The Off-ramp left the viaduct at a point between Rincon and First streets, east of the juncture of the On-Ramp and viaduct. It is a reinforced concrete girder bridge. The truck ramp was simply an earthen ramp, dropping to a point at First Street.

The traffic circulation at the west end of the bridge has been dramatically modified, to an extent that it is difficult to equate the original elements with the existing elements, even though most of what was built in 1936 is still in place. The Off Ramp is largely intact and is identified as Bridge 34-116F. The On-Ramp still exists and is identified as 34-117S. This ramp is now an off-ramp for westbound traffic. The truck ramp, which has no modern bridge number, still exists and is an on ramp for eastbound traffic, at First and Essex streets.

9.7. Yerba Buena Tunnel, Anchorage, and Viaducts

Contract 5 covered essentially all of the work on Yerba Buena Island, including the anchorage, the tunnel, the land piers, and the viaducts. The work on this contract is comparable to that on Contract 3, the San Francisco land work, in that it in involved massive earth moving and a huge concrete pour. Clinton Construction Company was awarded the contract but it sub-contracted out a high percentage of the work. The major sub-contractors included: Plambo Brothers, excavation of the main vehicular tunnel; T. E. Connolly, excavation of the anchor tunnels and concreting of the vehicular tunnel; Sullivan Machinery Company, drilling for the "hard-rock" excavations; and Daniels Construction Company, which had the huge job of disposing of excavation spoils.[287] Contract 5, like Contract 3 in San Francisco, was affected by design changes from the Board of Consulting Architects, made after work was underway. These design changes resulted in a large number of Extra Work Orders as well as delays in the construction schedule.

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[286] M. M. Reese, Resident Engineer, "Final Report for the Construction of the San Francisco Approaches to the San Francisco-Oakland Bay Bridge," Contract 64TC24 (S.F.-O.B.B. Contract #15A), February 27, 1937, California Department of Transportation Library, Sacramento.

[287] Harry Carter, "Final Report of Yerba Buena Island Construction of the San Francisco-Oakland Bay Bridge in the City and County of San Francisco, Contract No. 5, January 7, 1937.

9.7.1. Yerba Buena Island Anchorage

The Yerba Buena anchorage is a conventional rock anchorage, rather than a gravity anchorage, as was the case with the San Francisco anchorage. Purcell, Andrew, and Woodruff describe the methods used to anchor the cables to the most solid rock available on the island:

> To secure adequate anchorage, a tunnel included at an angle of 37 deg. below the horizontal was driven 170 ft. into the rock for each cable. Grillage beams were placed at the bottom of each tunnel and were connected to the stand shoe by means of an eyebar chain. The cables were turned downward over a steel cable bent. The downward inclination was for the purpose of engaging an adequate mass of rock in as short a length as practicable.[288]

Purcell, Andrew, and Woodruff continue: "All elements of the anchorage are enclosed in a concrete structure which is treated architecturally to match the San Francisco anchorage." The concrete viaduct, leading to the vehicular tunnel is structurally integrated with the anchorage building.

9.7.2. Yerba Buena Island Tunnel

The Yerba Buena Island tunnel comprises one of the superlatives of the Bay Bridge, representing the largest bore tunnel in the world at the time it was built. The tunnel is in the shape of what is often called a "horseshoe: tunnel, although it is more accurately described as a segmental arch, with vertical sidewalls and an arched roof. The tunnel measures 76 feet across (at its widest), and 58 feet high (at the crest of the arch). The deck through the tunnel, of course, is two levels, corresponding with the levels elsewhere on the bridge. The roadways are carried on concrete decks through the tunnel, with the lower level on grade and the upper level being about mid-height in the tunnel openings.

The tunnel was excavated in sequential steps, with extensive concrete pours following each step. Sub-contractor T. E. Connolly, a firm with hard-rock mining experience, accomplished the excavation work. Initially, drifts were driven at the bottom of each sidewall, through dynamite blasting, drilling, and mucking. The mucking was speeded through construction of a temporary railroad track. Spoil was taken by track to a large disposal chute, where it was allowed to slide to the Corps of Engineers work site north of the Yerba Buena Island; the Corps was beginning the long process of filling the Yerba Buena Shoals to create Treasure Island, and was accepting any and all muck from the nearby tunnel excavations.[289] The pioneer tunnels were then extended by stoping until each sidewall had reached a height of 40'. Concrete was then poured in the

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[288] C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Cable Anchorages, San Francisco-Oakland Bay Bridge," *Engineering News-Record* (October 31, 1935): 506.

[289] Harry Carter, "Final Report of Yerba Buena Island Construction of the San Francisco-Oakland Bay Bridge in the City and County of San Francisco, Contract No. 5, January 7, 1937, 54.

sidewalls. A pioneer tunnel was then excavated near the center of the arch. The arch was then excavated to allow concrete pour on the barrel arch. The arch was lined with three feet of concrete. With the sidewalls and arch in place, the inner core of the tunnel was excavated. As a final measure, the two decks were poured and the tunnel surface finished in tile.[290] The tunnel excavation and paving proceeded without major incident.

9.7.3. Yerba Buena Island Viaducts

The concrete viaducts on Yerba Buena Island are similar to those on the San Francisco approaches -- essentially double-deck reinforced concrete girder spans. Concrete viaducts were built at either side of the tunnel; beyond the viaducts, continuous truss spans link with major bridge elements: the suspension bridge to the west and the cantilever span to the east.

9.8. Oakland Approaches

The Oakland approaches may be divided into two parts. The first part includes Piers E-23 through E-39, which is technically part of the bridge. These piers support 1100 feet of roadway, a length in which upper and lower deck traffic are separated. The Clinton Construction Company built this concrete roadway under Contract No. 8.[291] This part of the bridge was called the "concrete approach ramps." Owing to the removal of the bridge railway and reconstruction of the bridge for two one-way decks during the late 1950s, the approach ramps have been modified significantly.

The rest of the Oakland approaches were completed in a series of contracts let by the Division of Highways and funded through state gasoline tax receipts; this work was designed by the Bay Bridge Division but was not treated as part of the Bay Bridge project. The Oakland approaches are notable in two regards: for the fact that essentially nothing remains from the work in 1936; and for the highly complex, freeway-like design of the approaches during the 1930s. The East Bay approach was called the "Distribution Structure," a term that captured its complexity. The structure was rendered obsolete through post-war construction of a series of freeways in the area (Interstates 80, 580, and 880) which required new connections and demolition of most of the original ramps. The distribution structure was notable for the fact that it was designed to separate local and bridge traffic, and to separate different directions of bridge traffic, creating what was described as an "interlacing and complex structure" which featured 16 different grade separations.[292]

9.9. Other Minor Contracts

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[290] "San Francisco-Oakland Bay Bridge: A Pictorial Description," *California Highways and Public Works* (November 1936): 32.

[291] V. A. Endersby, "Final Construction Report of the Concrete Approach Ramps at the East End of the San Francisco-Oakland Bay Bridge, Contract No. 8," March 25, 1937.

[292] "East Bay Distribution Structure Includes 16 Grade Separations," *California Highways and Public Works*, (November 1936): 27.

While the bulk of construction was accomplished under Contracts 2 through 8, there were many other minor contracts for Bay Bridge construction. The contracts, however, were "minor" only in the context of the scale of the Bay Bridge. Contract 9, for example, was awarded to Bridge Builders, Inc. to paint the West Bay spans of the bridge, beyond the original field coats. This job involved nearly 187,254 man-hours and nearly 105,000 gallons of paint.[293] Contract 10 was for the Administration Building and Toll Plaza and was completed by the Clinton Construction Company. Contract 11 was for lighting on the bridge; it was completed with day labor. Other minor contracts included: 13, tunnel lining; 14, a garage on Yerba Buena Island; 15, on and off ramps in San Francisco; 18, features for World Fair on Treasure Island; 20, reinforcing details; 21, fire extinguishers; 22, alteration to maintenance buildings; 23, beautification of Rincon Hill; 24, fill at administration building; 41, distribution structure; 42, Folger underpass; 43, San Pablo Avenue subway; and 52, cables for protection against sabotage. Most of the contracts after Contract 9 were completed after 1936. In addition, there were a series of contracts associated with construction of railroad-related structures, including the Transbay Terminal Building, the railroad loop, and connecting tracks on the East Bay. These contracts were completed between 1937 and 1939.[294]

9.10. Building the Railroad Elements of the Bridge

For reasons discussed in Chapter 11, the railroad elements of the Bay Bridge were delayed for about two years beyond completion of the vehicular elements. The bulk of the railroad work was completed in three major contracts: one for rail work on the East Bay, awarded to J. H. Pomeroy; work on the bridge itself, awarded to the Pacific Bridge Company; and construction of the Transbay Terminal Building in San Francisco, awarded to McDonald-Kahn and Columbia Steel. A number of other, small contracts were needed to build substations for the electric railroad and to supply numerous other appurtenant improvements.

9.11. Conclusions Regarding the Construction of the Bay Bridge

The single most impressive fact about the construction of the Bay Bridge is that it was completed ahead of schedule, under budget, and without major incident. As with all other aspects of the Bay Bridge, the term, "major incident" must be appreciated against the scale of the undertaking. Dozens of people died. The caisson at W-6 tipped and was not righted for weeks. Pier E-3 sank 10 feet more than had been intended. A strand of cable wire snapped during spinning. Doubtless there were hundreds, perhaps thousands of other mishaps that were not reported in contract completion reports. A construction project of this magnitude is fraught with potential disasters, especially when accomplished above and below the unpredictable waters of San Francisco Bay. The remarkable fact about this construction is that it involved so few such disasters. On balance,

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[293] I. O. Jahlstrom, "General Construction Report for Superstructure Painting on the West Bay Crossing of the San Francisco-Oakland Bay Bridge," May 22, 1937.

[294] Copies of the Final Construction Reports for most of the minor contracts are available at the offices of Caltrans, District 4, Oakland, Division of Structures.

the project went remarkably well.

The success of the construction of the Bay Bridge may be attributed to the professionalism of the contractors. The performance of the contractors is especially important, given the haste with which the job was accomplished. The contractors were given substantial leeway in planning the project, including differing approaches to the construction methods as well as some of the design elements. The tower design for the West Bay Crossing, for example, was an innovation by the American Bridge Company to allow it to use its hammerhead derricks. The East Bay foundation work contract (Contract 4) allowed the contractor to choose between cofferdam, caisson, or crib excavation methods.[295] Virtually every contractor developed some innovation, major or minor, during the course of completing this work.

Credit for that success may be attributed as well to the good planning efforts of the Bay Bridge Division and the adept supervision by state employees. In addition to structural engineers, the corps of state employees included dozens of temporary hires, many drawn from the same construction trades.

Finally, the success of the construction project can be credited to the fact that it was a well-designed bridge. In this respect, both the Board of Consulting Engineers and the Bay Bridge Division engineers played very major roles. Modjeski, Moran, Moisseiff, and Derleth were visionary engineers but were also very practical men. Modjeski and Moran in particular had been involved in bridge design and construction sine the late 19th century. Moran died in 1937, only a few months after the bridge had been completed. Modjeski died in 1940. Although best known for their design work, both had overseen construction of dozens of bridges, as had Moisseiff and Derleth. Among the state employees, Andrew and Purcell had supervised construction of hundreds of small structures. Collectively, the state workers and the consulting engineers likely had hundreds of years of bridge construction experience.

The correspondence among these individuals during the design phase is dominated by discussions of potential construction problems. For example, one of the first resolutions adopted by the board, on January 28, 1932, concerned the relationship between design and construction considerations. The resolution, submitted by Moisseiff, read: "RESOLVED, that it is the opinion of the Consulting Board that in the construction of this bridge only such materials should be employed as have proved satisfactory in use in major structures. In a similar manner, only such construction processes should be proposed by the Design Division or by the Consulting Board, or if proposed by other should be accepted, as can show a successful record."[296]

The board, of course, could not live strictly according to that resolution because many of the processes they proposed had never before been tried and therefore could not "shown a successful record." The bridge was far too daring to have been built along the lines of proven methods.

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[295] V. A. Endersby, "Final Construction Report of the Substructure, East Bay Crossing of the San Francisco-Oakland Bay Bridge, Contract 4 and 4a," July 28, 1937, California Dept. of Transportation, Oakland, 5.

[296] Minutes of the Board of Consulting Engineers, Seventh Meeting of the Second Session, January 28, 1932, 1.

Nonetheless, the intent of the board was clear: the bridge was to be designed in such a way as to minimize problems during the construction phase. This intent, coupled with the experience to carry it out, accounts for a large degree of the success realized during the construction of the Bay Bridge.

10. CONSTRUCTION OF THE BAY BRIDGE FROM THE PERSPECTIVE OF THE WORKERS

The Bay Bridge was built by more than a dozen of the largest construction contractors in the country, and much of the credit for its timely completion must go to those companies. But it was also the work of thousands of workmen who performed tens of thousands of small tasks to bring the structure to fruition. These workers, most of them young men from the Bay Area, risked their lives daily during the construction of this monumental project. This chapter tells their story.

More than 8300 men would work on the construction project at one time or another, although the peak employment on any given day was around 4000. These men performed so many tasks that they defy easy categorization. Any attempt to capture the "typical" experience of these men is bound to fail because their experiences were so diverse. It is clear, however, that the experiences were much different for the tens of thousands of employees of the contractors, as opposed to the much smaller number of employees for the state.

10.1. Contractor Employees

Of more than 8000 people who worked on the bridge, the vast majority were employed by one of the construction contractors, with the bulk of these hired by the contractors for the major elements: the Transbay Construction Company, the Bridge Builders, Inc., and Columbia Steel/American Bridge Company. Unfortunately, little reliable data exists to document the life histories of these many men, most of whom worked on the bridge for a few years and moved on to other jobs and other areas. Their work experiences may be glimpsed from statistics and from a few scattered personal recollections.

We know the most about the workforce of Contract 2 (the West Bay Crossing substructure) because the resident engineer for the state, I. O. Jahlstrom, prepared a detailed analysis of the workforce for that job.[297] This contract, it will be recalled, was awarded to the Transbay Construction Company, which was a consortium of construction firms, including General Construction Company of Seattle, Morrison-Knudsen Company of Boise, McDonald and Kahn, San Francisco, Pacific Bridge Company, Portland, and J. F. Shea Company, Portland. The workforce on this contract fluctuated, peaking at 968 men in March 1934; it held at about that level between November 1933 and January 1935, before declining rapidly until the contract was completed in June 1935.

According to Jahlstrom's notes, most of these employees were hired by one or another of the constituent companies, with the General Construction Company of Seattle doing the bulk of the hiring. The population of workers was sufficiently fluid that any characterization of it would

[297] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937; Jahlstrom donated this completion report to the California Dept. of Transportation Library, Sacramento, along with reports for the West Bay superstructure and the painting contract (Contract 9). Only with Contract 2, however, did he offer any detailed comments on the workforce.

apply only to one moment in time. Jahlstrom used the workforce in March 1934 (the peak of employment) to draw general conclusions about its composition.

At that time, most of the workers came from the Bay Area. Of 968 men working in March 1934, 896, or 92%, came from California with 849 of them coming from the Bay Area. The others came chiefly from the Pacific Northwest, with 20 from Washington, 11 from Oregon, and 6 from Idaho; these northwesterners likely followed General Construction, Morrison-Knudsen, and J. F. Shea, all Washington, Oregon, or Idaho companies, to the job. The few remaining workers were from scattered areas of the United States, with only one, two, or three representatives from other states.

The work force was not unionized except for eight unionized crafts: welders, caulkers, hoist operators, riggers, structural iron welders, boatsmen, electricians, and painters. Not surprisingly, the unionized workers were among the best paid. During the peak employment month, the wages for all workers ranged from $26.67 a day to $5.00 a day, with a mean wage of $7.75.[298] Due to turnover, there were 1411 workers paid during that month, although the peak daily employment was 968. The most common classification was "laborer," a job that paid $5.00 a day. There were 453 men, about a third of the workforce, employed in that classification. The next biggest category was carpenter, a union job, which paid $8.00 a day; there were 182 carpenters. Other large job classifications were welder (94 at $11.00 a day) and pile driver (94 at $9.00 a day). The highest paid workers by far were the three divers, who made $26.67 a day, followed by a series of foremen, who were paid $13.00 a day. Generally, the men worked only 30 hours a week (five six-hour shifts) in response to employment conditions imposed by the RFC loan.

We know only a few details about the life histories of these workers. As noted, nearly all were Californians, although there was no specific preference for local hires written into the specifications for the job. The specifications did call out a preference for ex-servicemen and "prior preference" for ex-servicemen with dependents. Over the course of the contract, 24.7 percent of the workers were ex-servicemen; no record was made of the percentage of these that had families. The contract also specifically forbade hiring four groups of people: aliens, convicts, Chinese and Mongolians; it is presumed (although not specifically stated) that no such individuals were hired.[299] All of the workers on this contract were men.

The workforce profile may have been somewhat different for the contractor employees on the superstructure, all of whom worked for one or another subsidiary of U. S. Steel, particularly the

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[298] As discussed earlier, these wages may be compared roughly to modern values by using a factor of 12. A $5.00 daily wage, the lowest in the contract, translates to a wage of about $60 a day, or $7.50 per hour for an eight-hour day. As most workers worked only six hours per day, this would translate to a wage of $10 per hour in modern equivalencies. Carpenters were paid the equivalent of $12 an hour, based on an eight hour day. Welders were paid the equivalent of $16.50 an hour.

[299] The specifications regarding convict labor and racial prohibitions were straightforward: "No Chinese or Mongolian labor shall be employed... No convict labor shall be employed." The prohibition against "alien" labor was more detailed in that it specified forfeitures of $10 payments for each alien-day violation. The Jahlstrom collection includes the specifications for the contracts he managed.

American Bridge Company. There were only slightly fewer of these men than was the case with the substructure work. Contract 6, for example, was the contract for the superstructure of the West Bay. Peak employment there was 690 men a day, which was only about two-thirds of the 968 peak employees for the West Bay substructure.[300] Similar ratios probably applied to the work on the East Bay substructure and superstructure. The job classifications for the West Bay superstructure work were dominated by unionized classes of skilled workers, such as riggers, rodmen, stationary engineers, and machinists, who generally made more money than the substructure job classifications.[301] Anecdotal information suggests that a higher percentage of the high steel workers came from out of state than was the case with the substructure workers, and that the out-of-state workers were experienced steel workers, having worked on large buildings and bridges in the East and Midwest.

The actual experiences of these men are recorded in a few reminiscences, which, while difficult to summarize, offer some of the flavor of the times. Peter Stackpole, an adventurous photographer and the son of a nationally known sculptor, recorded the bridge construction photographically. During his work on the bridge, Stackpole spoke with an experienced bridge man, Joe Walton, whom he befriended during the job. Walton was from the East Coast and had worked on the Empire State Building, the Kill van Kull Bridge, and the Delaware River Bridge, as well as numerous smaller bridges, before he drove to California to work on the Golden Gate and Bay bridges. Walton recalled that he arrived in San Francisco in February 1934, penniless and two months before any steel work was to begin. Fortuitously, he met Jim Ward, a supervisor with the American Bridge Company. Ward knew Walton from his work on the East Coast and loaned him some money and arranged for future work on the bridge.[302] Ward would stay with the Bay Bridge until it was completed, before moving to a cantilever bridge job in Hartford, Connecticut, where he was killed.

Interestingly, Walton's recollections have little to do with the dangers of high steel work; perhaps he was so experienced that the work itself did not merit comment. Rather, he recalls fondly the camaraderie with the other workers, and their nightlife in San Francisco. Walton claims responsibility for the persistent myth that at least one man was buried in the concrete of the center anchorage. He maintains that he and some of his friends as a prank packed a pair of shoes into the final finish concrete on the center anchorage, which left the impression that someone had been buried in the concrete.[303]

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[300] I. O. Jahlstrom, "General Construction Report for Superstructure for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," May 1, 1937; Unfortunately, Jahlstrom did not analyze the workforce for this contract in the way he did for Contract 2.

[301] State of California, "Notice to Contractors, Contract, Specifications, Proposal, and Contractor's Bonds, Contracts No. 6 and 6A, Superstructure West Bay Crossing," n.d. early 1934, in Jahlstrom collection. This document lists the applicable classifications and prevailing wages.

[302] Peter Stackpole, *The Bridge Builders* (Corte Madera, CA.: Pomegranate Artbooks, 1984), 17-24.

[303] Stackpole, *The Bridge Builders*, 24. The persistent rumors hold that between four and seven men were buried in the center anchorage. The records of death for the Bay Bridge indicate that no such accident occurred. Two men died at the center anchorage, one from heart failure, one from a fall to the outside of the pier.

Alfred Zampa was another experienced high steelworker who worked on the Bay Bridge. Born to Italian immigrant parents, Zampa grew up in Crockett, California, near the Carquinez Bridge. He worked for a major sugar refinery in Crockett until 1926, when he was able to hire on with the company building the Carquinez Bridge. He enjoyed the high steel work there and chased bridge construction jobs across the country between 1927 (when the Carquinez work ended) and 1933, when the Bay Bridge work began. He worked on the suspension spans of the Bay Bridge and later went to work on the Golden Gate Bridge. He suffered a major injury while working on the Golden Gate Bridge. Zampa would ultimately work on 15 high steel bridge construction projects. Asked in 1986 about his favorite bridge among the three big Bay Area spans, he replied, "My favorite? Bay Bridge. Jesus, look at her. Two suspensions end to end, six different kinds of bridges, 8 1/4 miles long, deepest piers in the world. We lost 24 men; we'd dangle up there like monkeys driving shot iron. No net. You fell, that was it. They thought we was all crazy."[304]

Zampa would later recall the general character of high steel work, on the Bay Bridge as well as the Golden Gate Bridge. In 1986, he told John Van der Zee that many of the young men hired to work on the two bridges found that they could not handle the strain of the acrophobia that would sometimes seize them and leave them immobilized.

> People freeze up there. They hang on – they won't fall, but it would take three or four of us to break 'em loose. We'd put a line on 'em and let 'em down. They were mostly inexperienced men – they think they can do it but they can't. They say, "Don't look down." I never avoided looking down – it didn't bother me. I could look right down in the water and see big fish down there. You have to have a little bit of fear – not too much – way back here, in the back of your head. You can't daydream – or you'll take chances.[305]

How often this acrophobic seizure occurred, we do not know. Zampa's comments do, however, give some indication that building the Bay Bridge was no ordinary job experience for the thousands who worked on the project.

10.2. State Workers on the Project

The state engineers assigned to this job were exposed to many of the same dangers as the workers for the contractors. Dozens of state employees worked on the bridge; none were killed, although one was seriously injured when his legs were broken as he was caught between two barges.[306] Arthur L. Elliott, who would spend his engineering career with the California Department of Transportation, came to work for the Bay Bridge Division with no high bridge experience. Fifty years after the fact, he recalled his first experiences in high steel engineering:

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[304] "He Built Them All, Large and Small," *San Francisco Chronicle*, November 4, 1986, 36. Zampa's recollections on high steel construction are recorded in even greater detail in Van der Zee, *The Gate*. Zampa was still alive at the time that book was written, as were several other elderly and retired steel workers who had worked on the Golden Gate Bridge.

[305] Van der Zee, *The Gate*, 258.

[306] Arthur L. Elliott, "High Level Engineering," *Civil Engineering* (October 1986).

> I had been a resident engineer on a small bridge in Oregon where the steel trusses were maybe 30 ft in the air. So I shall never forget the day I first set foot on the Bay Bridge catwalk and started up toward a tower top and nothing but a little wire mesh and a lot of open air between me and the bay below. The worst aspect was not being able to show any fear. Those steelworkers were merciless, and to preserve our self respect we had to act nonchalant and follow along, walking those beams and planks, climbing though small holes and hanging by our teeth even though our clothes were drenched with cold sweat.[307]

In his recollections, Elliott says little about the lot of the contractor workers, except to note that many were taken aback by the conditions they would face working in the middle of San Francisco Bay, particularly during the winters of 1934-35 and 1935-36. Like Zampa, Elliott felt the greatest sympathy for the young men who showed up to work, unprepared for what they would face, mid-span and mid-Bay. "It was the depth of the Depression," he observes, "and there were many young men out there on the catwalk [of the West Bay suspension spans] glad to have a job of any sort. They came out in suit coats and light sweaters to face the cold winds and the fog, wrapping themselves in burlap sacks or bits of canvas they might find to try to keep warm."

I. O. Jahlstrom also came to the Bay Bridge Division as a resident engineer, to supervise and coordinate construction by the contractors. Jahlstrom was born in Oregon in 1900 and received a degree in civil engineering from Washington State University in 1923. He began working for the California Division of Highways in 1928, after having worked for several years with the Washington State Highway Department. He had worked as resident engineer on several large bridge construction jobs for the State of California, including the Bixby Arch Bridge, before transferring to the Bay Bridge Division in 1933. He would serve as resident engineer for the West Bay substructure (Contract 2), West Bay superstructure (Contract 6), and the painting contract (Contract 9).

In a 1982 oral history, Jahlstrom recalled that the Bay Bridge Division hired dozens of temporary workers, not only civil engineers but also men with industrial and construction backgrounds. "It was at the height of the Depression," he recalled. "At that time there were not only unemployed engineers, but many men experienced in shop and field inspection and men who had been construction superintendents. We hired these. I had two steel inspectors who came over from England; one became the head inspector."[308]

Jahlstrom, like Elliott, noted that the state workers were often as fearless as the contract employees were when it came to high steel work. He recalled one incident: "I remember another man that I worked with, Herb Deardorf. He was an inspector of cable and steel work. The first time I got to know about him, they were talking about the time he was celebrating the night after we had finished spinning cables. This fellow was walking down the cables before we had finished the hand line out there. It almost scared me to death. I said I suppose that's Herb up

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[307] Elliott, "High Level Engineering."

[308] "Highway Receollections of I. O. Jahlstrom," California Dept. of Transportation Library, Sacramento, 14.

there and they said he'd been a descendent of 'Daniel Boone.' I said he better not do any of this 'Daniel Boone' stuff. I hate to see a man walking on that round cable up there without any hand lines."[309]

One common thread in the recollections of workers, state or contractor, is the sense of accomplishment, of having worked on something important. That sense was not always experienced in nostalgic recollections. One state engineer was moved lyrically at the time by the experience. Peter Mourer, Jr., about whom little is known except that worked as a Junior Construction Engineer for the Bay Bridge Division, penned a poem, called "The Bay Bridge," at some point in late 1934 or early 1935. It read:

> How many minds and hands are joined to rear
> This towered path across the tide-swept bay!
> Men pitied Norton, but the engineer
> Has made his dreams reality. Today
> Gaunt towers pierce the foggy shroud of night
> And flood-lights gleam on blocks of man-made stone
> That bind to rock, against the water's might,
> An highway, such as gods did never own!
> Do they, secure in their place on high,
> Cold and undreaming, prideful of their sway,
> Feel, as they tread their yet unspoiled domain,
> That track that we fling across their virgin sky
> Is sacrilege? Surely, they too must pray
> That this, a madman's dream, we shall attain![310]

10.3. Accidents and Deaths during Construction

The type of construction employed on the Bay Bridge was inherently dangerous work and there were, of course, many accidents and deaths among the workmen. The reported "rule of thumb" in high bridge construction at the time was that there would be one death for every million dollars spent.[311] No equivalent rule has been found for non-fatal accidents but it was commonly understood that major accidents were likely to occur with frequency, as thousands of workmen made their way on to the caissons, derricks, suspension cables, into the Yerba Buena tunnel, and to the other highly dangerous work places.

We have the best record of accidents and fatalities for Contract 2, for which I. O. Jahlstrom kept copious notes. Thousands of men worked at one time or another on this contract, with a peak level, as noted, of 968. During the course of the contract, workers logged 214,870 "man-days,"

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[309] "Highway Recollections of I. O. Jahlstrom," California Dept. of Transportation Library, Sacramento, 16.

[310] *California Highways and Public Works* (February 1935): 21.

[311] Van der Zee, *The Gate*, 256. This "rule of thumb" is repeated throughout the literature on the Bay Bridge; its source has not been identified.

i.e. one man working one day. Over that time, 684 men were injured, resulting in a lost time of 15,561 "man-days." In terms of serious injuries (those requiring medical attention, by a resident first aid worker or doctor), there was one serious injury for every 386 man-days worked. The odds were such that a man working on the job for a year and a half was likely to suffer at least one serious injury.

Of the serious injuries, five were fatalities, 230 involved lost time, 322 required a visit to a doctor, and 127 were classified as "minor accidents requiring first aid."[312] Jahlstrom provided a detailed breakdown for the 230 lost-time accidents. Of these, 136 were listed as "crushed or severely bruised," 52 were "strains," 12 involved "objects in eye," and nine involved fractures. The other categories involved few instances, including burns, falls, infections, occupational diseases, and "miscellaneous." Two of these lost time accidents resulted in permanent disabilities.[313] As noted, there was one serious accident for every 386 man-days on Contract 2. No equivalent accounting has been found for the other contracts but the causes of the accidents likely differed from one contract to the next. The high steel contracts, for example, likely involved more accidents associated with falling, which accounted for a minor part of the accident rate for the foundation work.

The resident engineers for Contract 4, the substructure work on the East Bay, maintained detailed notes on injuries during a period of about one year, from August 1933 until August 1934. Thirty accidents were reported during that period, only one of which was a fatality.[314] The others may be categorized into broad types of serious injuries: seven broken legs; six finger injuries, two of which required amputation; three facial injuries and three foot injuries; as well as several broken arms and strained backs. These injuries typically resulted from workmen slipping, being hit by falling material, of being crushed by moving equipment or cargo. Some causes were unusual, including the broken leg suffered by A. Baldwin, when he got into a fight with another worker at the job site.[315]

Not surprisingly, the best-reported accidents were the fatalities. As discussed below, there is a slight confusion about the number of fatalities on the Bay Bridge, with the number ranging from 24 to 28. Whether the number is 24 or 28, men died on the job at a rate of about one every month and a quarter. There was no single incident that claimed more than one life. Ten men died in a single accident on the Golden Gate Bridge, for example, on February 17, 1937 as construction was nearing completion.[316] No similar large accident marred construction on the Bay Bridge;

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[312] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, 167.

[313] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, 168.

[314] Derived from "Miscellaneous File," under resident engineer's files for Contract 4, in California State Archives, F2517:180. These notes are loosely filed and do not necessarily reflect the full list of accidents. It is likely that more than 30 accidents occurred during this period.

[315] Derived from "Miscellaneous File," under resident engineer's files for Contract 4, in California State Archives, F2517:180.

[316] Van der Zee, *The Gate*, 269-281.

indeed, no more than one man died on any given day. Rather, men died with a predictable regularity, one at a time, on virtually all of the major contracts.

Jahlstrom provided a detailed accounting of the deaths of the five men who were killed working on Contract 2. While these fatalities are exceptional among the accidents, they do illustrate the nature of hazards posed by the foundation contract. The first fatality occurred on December 8, 1933, when scaffolding broke at Caisson 6, knocking a number of workmen 20 feet into the water. One, Edward S. Hill, was crushed between the scaffold and the caisson and was unable to swim when he hit the water. He ultimately died from the injuries as well as pneumonia.

Lloyd Evans, a diver, died of "caisson disease" (the bends) on December 17, 1933. This also occurred at Caisson 6, which was about to "land" at the time; this death occurred about one month before Caisson 6 began to tip. He was brought to the surface too quickly and suffered a heart attack. The next death occurred nearly a year later on December 5, 1934. Robert L. Poole, a rigger, was dismantling falsework for the fender on Pier 3 when he lost his balance and fell into what was described as a "heavy sea." His body was recovered days later.

In January of 1935, a carpenter, Adolph Silversten, fell from the top of the center anchorage, landing on the edge of the pier nearly 200 feet below. He died instantly. The final fatality on Contract 2 occurred in February 1935, as the contract was winding down. A carpenter, Christie Thompson, was attempting to jump from one platform to another, five feet below. The second platform collapsed when he landed, resulting in a fall of more than 25 feet. He survived for nearly a month before dying of his injuries. A final fatality was not carried as an industrial death. John Brannen fell into an open cylinder in Caisson 4. He was quickly pulled from the water but had already died of heart failure.[317]

A few additional details exist in newspaper articles to document the specific circumstances of death for many of the men who died on the other contracts. Arthur Lemoreaux died working on Contract 7, building the superstructure on the East Bay. He lost his footing while working on the cantilever span at Pier E-5, and fell about 185', hitting the pier itself. Lemoreaux was married but had no children; he had migrated to Oakland from the East Coast specifically to work on the bridge.[318] Charles Bazzill fell to his death working on Contract 6, atop Pier W-1, near the water's edge in San Francisco. He was working at night and slipped, apparently because he could not see his footing in the dark. His death caused the state to prohibit any further night work.[319] Bazzill was from St. Louis, Missouri and came west specifically to work on the bridge. He was 26 when he died, married with no children. Roy C. Bishop died at the age of 36, working on the East Bay superstructure. He was killed when an ornamental ball from the railing fell 180' from the deck,

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[317] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, 167-170. Brannen was not counted as a fatality by the state, but was counted as a fatality by newspaper accounts. This discrepancy probably accounts for all of the four contested deaths.

[318] *Oakland Tribune*, June 17, 1935. This and other articles cited are kept in binders at the Oakland Public Library, filled with newspaper clipping regarding construction of the bridge.

[319] *San Francisco Chronicle,* April 10, 1936.

hitting him on the head. He left behind a widow and three small children.[320] Paul Gurley was also killed working on the East Bay Superstructure, when he fell from the steel spans on Yerba Buena Island.[321]

Drawing from available information, several conclusions may be drawn regarding the causes of these many fatalities. First, the bulk of deaths occurred on the three most dangerous contracts – the West Bay piers (Contract 2), the West Bay superstructure (Contract 6) and the East Bay superstructure (Contract 7). Contract 7 appears to have been the most dangerous. Second, the major causes of death, in order, were falling, being crushed by falling objects, and drowning. These causes make sense, given the nature of the work – men working hundreds of feet above the cold waters of the Bay, with heavy equipment also being moved around on those high places. The table below summarizes what is known regarding the names, places of residence, date of death, and cause of death of the 28 known fatalities.

MEN KILLED DURING CONSTRUCTION OF THE BAY BRIDGE

NAME	RESIDENCE	DATE	CON-TRACT	CAUSE OF DEATH
Harry Hill	Unknown	08/04/33	5	Fell into Bay while working on dock.
Louis R. Knight	Oakland	11/26/33	4	Lost balance--fell into Bay from Pier E-4
William Morotzke*	Oakland	12/8/33	Unk.	Unknown
E. S. Hill*	Long Beach	12/10/33	2	Crushed fell into water, died from pneumonia
Lloyd Evans	Washington State	12/14/33	2	Caisson disease while working at Pier 6
Frank Swansick	2218 107th Oakland	04/21/34	4	Slipped and fell into center well of Pier E-15
George Lohsen	Unknown	05/26/34	5	Disappeared from barge while hauling dirt
George Weikert	1030 Larkin S. F.	09/18/34	7	Missed hold and fell while working on top deck above Pier E-22
Donald McEachern	440 Hyde S. F.	10/25/34	7	Knocked into Bay when post broke off
Bernard Hauffman	1273 Gold-en Gate-SF	11/12/34	6	Struck by falling bolt while working at bottom of Tower W-6
R. L. Poole	1159 Hyde S.F.	12/05/34	2	Swept off raft into Bay at base of Tower W-3
John Brannen	unknown	01/10/35	2	Heart failure at Pier W-4 (not an industrial fatality)
Adolph Silversten	975 Moul-trie--S.F.	01/28/35	2	Fell from beam on top of Pier W-4
Christy Thompson	506 Oak St. S.F.	03/06/35	4	Fell 40 ft to the floor of Pier 24

[320] *San Francisco Chronicle,* April 23, 1936.
[321] *Post-Enquirer,* June 3, 1936.

Henry Dennington	693 18th St. Oakland	06/05/35	6	Attempted to slide down Tower W-2 on rope
Arthur Lamoreaux	1042 45th St.	06/06/35	7	Fell from upper deck at Pier E-4
Michael Markey	1351 Ellis St, S.F.	07/02/35	5	Fell from Span E-1, West Anchor Arm of the Cantilever Yerba Buena Island
A. Dillard Lee	1204 Grand Alameda	08/17/35	8	Crushed by falling stringers (This fatality not charged against the bridge by Industrial Accident Commission)
John Carlson	3547 Mission--S.F.	08/19/35	3	Struck by earth slide at 2nd & Stillman Streets (Fatality not charged against the bridge by IAC)
Lawrence Stephens	1688 McAllister--S.F.	09/07/35	6	Brain punctured by wire at 20th & Illinois St. Plant (Fatality not charged against the bridge)
Walter Van Denburg	1161 Rhode Island--S.F.	09/16/35	7	Fell into Bay from lower deck
Marion Tavares*	Berkeley	11/6/35	Unk.	Unknown
Paul Shelton	350 Grove S.F.	03/28/36	3	Thrown from platform and over an I beam
Charles Bazzill	391 Valencia--S.F.	04/09/36	6	Fell from upper deck above Harbor Pier 26
Roy Bishop	856 58th Oakland	04/22/36	7	Struck in head by falling knob
Paul Gurley*	San Francisco	6/3/36	7	Fell while working on the viaduct on Yerba Buena Island
George Zinc*	San Francisco	6/7/36.	Unk.	Unknown
W. Aguado*	San Francisco		Unk.	Unknown

[Sources: *San Francisco Chronicle*, November 12, 1936 (special Bay Bridge issue), "Another Honor Roll," commemorating those who died; and undated, unattributed chronology in Bay Bridge files at Caltrans, Transportation Library. This highly specific chronology was almost certainly written by a resident engineer at the bridge, perhaps I.O. Jahlstrom. The names with asterisks are those that appear on the *Chronicle* list but not the Caltrans list.]

10.4 Labor Problems during Construction

The construction of the Bay Bridge was generally free from labor unrest, although it occurred during some of the fieriest years in the history of American labor-management relations, particularly with respect to labor relations in the San Francisco Bay Area. Labor problems associated with bridge construction were generally external to the bridge contractors and their workers; the bridge workers struck against the contractors only in sympathy strikes associated with other labor problems.

The project began inauspiciously, however, with the longest strike occurring just as work was getting underway. On August 24, 1933, the welders at the Moore Dry Dock Company, which was a subcontractor to the Transbay Construction Company, went on strike, halting virtually all work on the West Bay caissons. The strike was over wages and hours and was not settled until September 6.[322]

Far more serious labor problems were encountered during the spring and summer of 1934, in the midst of the great General Strike in San Francisco. The General Strike represented an escalation of labor unrest that began in May, when longshoremen in San Francisco went on strike. Conflict between labor, management, and ultimately the police and National Guard escalated throughout the summer of 1934, culminating in bloody confrontations in July.[323]

The General Strike came at a bad time from the standpoint of the Bay Bridge planners. During the summer of 1934, the substructure work was at its peak on both the West and East Bay Crossings. Substantial construction work was also underway on the San Francisco anchorage and approaches. During the most violent days of July, the strike shut down all aspects of work on the bridge. The most serious events occurred on July 5, the so-called "Bloody Thursday," in which several strikers were killed by police. Labor unrest spread throughout the city, forcing the state to shut down all operations on the bridge. Governor Frank Merriam described the conditions leading to the decision to close down bridge construction:

> I have been informed by Charles H. Purcell that all construction on the San Francisco-Oakland Bay Bridge has been abandoned due to strikers battles with police. Early this morning the hauling of dirt from excavations for the bridge viaduct on Rincon hill, Pier B on Main street, Pier B on Beale street, and Pier 1 on Spear street, at the intersection of the Embarcadero, was discontinued because of intimidation of the strikers. Rock throwing and violence drove off the 100 workmen of the Healy-Tibbetts Construction Company at 9:50 a.m. At 10:00 a.m. conditions forced the State bridge engineers, supervising the work, to flee from the job. The strikers are occupying Rincon hill, armed with rocks and clubs, and have driven the viaduct construction workmen from the spot. The bridge workers fear snipers in the shacks on Rincon hill. All bridge work is at a standstill in San Francisco and chief Purcell reports this delay will postpone when the hiring of steel crews can begin.[324]

The *Chronicle* reported that "police stormed Rincon hill and drove the entrenched strikers from that vantage point. Whistling bullets from Rincon hill fired by riflemen shooting at the police

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[322] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, 171.

[323] The General Strike in San Francisco is chronicled in David F. Selvin, *Sky Full of Storm: A Brief History of California Labor* (Berkeley: Center for Labor Research and Education, 1966). Labor violence began on July 3; the General Strike began on July 16, 1934.

[324] *San Francisco Chronicle*, July 6, 1934, 8.

drove the workers from the bridge jobs in line of fire." By mid-July, 3700 of the 4000 workers then working on the bridge had been idled.[325] On Contract 2, for which we have the best records, work was totally suspended between July 15 and July 20, with partial closures extending from July 13 through July 22. The work was suspended chiefly because the unionized craftsmen honored the call for a general strike. While these men accounted for a small percentage of the total workforce, their skills were considered so crucial that no other work could proceed without them. As I. O. Jahlstrom added, "Policy would have demanded suspension in any case, considering the hazards from possible sabotage and risks that non-union men would have taken running the gauntlet to and from the site."[326]

Apart from the welder's strike against Moore Dry Dock, which was a subcontractor to Bridge Builder's Inc. and sympathy strikes associated with the General Strike, there were no labor actions directly tied to the Bay Bridge construction.

10.5. Conclusions regarding the Workforce on the Bay Bridge

After 1929, the spokespersons for the Bay Bridge lobbied on its behalf in part because it would put thousands of men to work in good-paying jobs. In that respect as in so many others, the Bay Bridge was a success. More than 8000 men, most of them from the Bay Area, worked for several years on jobs that paid much better than other jobs that were available. That success was achieved, however, at a considerable price in human terms. Dozens of men died, hundreds more were injured seriously.

When the bridge was dedicated on November 12, 1936, a long line of speakers, from C. H. Purcell to Governor Merriam, praised the workers on the Bay Bridge and their contribution to the effort. Perhaps this tribute was politic, particularly in a labor union city like San Francisco. It is difficult to read the speeches, however, and not conclude that the feelings were sincere. Former President Herbert Hoover spoke fondly of the efforts by "these courageous men who daily risked their lives in its construction."[327] Public Works Director Earl Lee Kelly praised the courage of labor and the absence of labor action: "Labor has been more than fair to us and I hope that we have been fair to them."[328] C. H. Purcell, who knew better than anyone else how the bridge had been built, went out of his way to praise the workmen. Purcell lauded the efforts of everyone involved with the bridge, from the engineers to the politicians to the contractors. His longest remarks, however, were reserved for the workers:

> The intelligence of the American skilled workman, which enables a large organization to adapt itself to the newest mechanical developments, can not be equalled in any nation,

[325] *San Francisco Chronicle*, July 17, 1934, 1.

[326] I. O. Jahlstrom, "General Construction Report for Foundations, Piers 2, 3, 4, 5, 6 and 24 of Contract No. 2 for the West Bay Crossing of the San Francisco-Oakland Bay Bridge," February 27, 1937, 171.

[327] "Burning Barriers, Governor Merriam Opens San Francisco-Oakland Bay Bridge," *California Highways and Public Works* (November, 1936): 5.

[328] "Burning Barriers, Governor Merriam Opens San Francisco-Oakland Bay Bridge," *California Highways and Public Works* (November, 1936): 4.

> and to this great body of skilled labor on this structure I am sure the people of California are grateful. This great undertaking was carried on through the depression, under varying conditions, with no strike or serious labor dispute.[329]

The only worker who spoke at the event – assistant bridge foreman, Walter Gaines – made no distinction between skilled and unskilled workers. Urging the assembled crowd to remember the men who died working on the bridge, Gaines asked Californians to "Regard this bridge as a tribute to the American working man, both skilled and unskilled."[330]

So many things about the Bay Bridge had gone well in the years between 1931 and 1936. The bridge was designed in two years and built in about three, with no major mishaps during the construction phase. The project had weathered the great labor upheavals of 1934 with minimal lost time. And, as noted, thousands of workers had been lifted, temporarily at least, out of joblessness and poverty.

If it was an extraordinary achievement, it was also an extraordinary experience for the workers – all workers, from the engineers to the laborers. True, the project had gone well, with no strikes and fewer fatalities than had been expected. The statistics and the recollections of the workers, however, document that the project was hardly a routine construction project. All indications are that it was an adventure as well, filled with grave dangers and equally great satisfaction when the challenge had been met.

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[329] Charles H. Purcell, "Bridge Built in 40 Months with Saving of Over $7,500,000," *California Highways and Public Works* (November, 1936): 22.

[330] "Burning Barriers, Governor Merriam Opens San Francisco-Oakland Bay Bridge," *California Highways and Public Works* (November, 1936): 9.

11. HISTORY OF THE USE OF THE BAY BRIDGE BY INTERURBAN TRAINS: HOW THE BRIDGE WAS DESIGNED TO ACCOMMODATE THE INTERURBANS, HOW THE INTERURBANS FARED AND WHY THEY FAILED

The Bay Bridge was completed and opened to automobile, truck, and bus traffic on November 12, 1936. The electric trolley operation across the bridge was not completed until January 1939. This delay is sometimes cited as a cause for the decline of the trolley lines shortly after the bridge was opened. This chapter will explore two aspects of train service on the bridge: why the service was delayed; and why the service declined and ultimately failed in the years after 1939.

There can be no doubt that the Bay Bridge was designed for use by multiple transportation modes, specifically automobiles, trucks, buses, and interurban trains. The design of the bridge, particularly its loading, took into account its use by commuter rails, at a considerable extra cost over that of a vehicle-only design. Perhaps more important, the budget for bridge construction assumed that considerable revenue would flow from per-passenger charges to the railroads. In short, the bridge was designed to accommodate heavy use by interurbans and dedicated approximately one-quarter of the available deck space to that purpose. Nonetheless, that train service was short-lived. Almost exactly twenty years after the bridge was built, the interurban tracks were torn up and the bridge fundamentally reconfigured to accommodate mixed vehicular traffic on both decks. The basic question posed by this fact is: why did the interurbans fail so quickly? A related question is: who was responsible for this failure? More specifically, did the State of California contribute to that demise in its operations of the bridge, or was the cause of failure attributable to the interurban companies themselves?

11.1. General Statement of the Problem in Negotiations between the State of California and the Interurban Companies

The design of railroad-related elements was one of the most frustrating assignments facing the Bay Bridge Division engineers because it involved so many external factors. All aspects of the bridge design involved some degree of negotiations among competing parties. Arguably, C. H. Purcell's greatest contribution to the bridge was his skill as a negotiator and conciliator. He masterfully kept together a coalition of political and civic leaders from many Bay Area cities, cities that competed and argued with each other over transportation issues long before and after the Bay Bridge was built. The interurban design, however, was especially complex because it required negotiations with parties that were largely outside the political arena. It also involved negotiations with different interurban lines – the Key System and the Southern Pacific Railroad (and later the Sacramento Northern line as well) – that were economic competitors and unable to agree among themselves. These negotiations were further complicated by the involvement of the California Railroad Commission, which would need to approve any agreements between the state and the railroad carriers.

There were many important issues that needed to be resolved in these negotiations but five were the most important. First, the track alignment on the bridge itself and especially on the approaches needed to be designed in a manner that was acceptable to the interurbans. Second, it

was necessary for the three interurban companies, which had previously operated completely independent of one another, to use common facilities on the bridge, on the approaches to it, and in San Francisco terminals; the three carriers would have to reach agreement among themselves and with the state on how this would operate. Third, the state and the interurbans needed to agree on how the track and terminals would be paid for initially and how they would be maintained in the future. Fourth, the state and the interurbans needed to reach agreement on how much the train companies would pay to use the bridge. Finally, the state insisted on using only high-quality equipment on the bridge, equipment not owned by the railroad lines: the question was, who would pay to upgrade rolling stock of the railroad lines? Many of these questions had serious cost implications for the interurbans as well as the state, making this a negotiation over financial as well as engineering issues.

11.2. How the Negotiations Progressed between the State of California and Interurban Carriers

The leadership of the Bay Bridge Division initiated its consultation with the interurban carriers in October 1931. On October 21, C. H. Purcell held a meeting with W. H. Kirkbridge of the Southern Pacific Railroad.[331] The next day, Purcell, along with Charles Andrew and Glenn Woodruff had a similar meeting with A. J. Lundberg, President of the Key System.

The significance of these meetings is two fold. First, the meetings involved the leadership of the Bay Bridge Division, with the state being represented by the three highest-ranking officials of the division. Second, they occurred very early in the planning process for the bridge. The Bay Bridge Division and the Board of Consulting Engineers had been formally organized only a few months earlier. Virtually none of the major design issues for the bridge had yet been resolved. The interurban issue, of course, was a key design consideration and Purcell, Andrew, and Woodruff logically tackled it early on. The timing of these meetings is significant in light of what occurred later. The negotiations with the interurbans would stall for several years; no agreement was in place at the time the major bridge contracts were let. As a result, the interurban elements were not built at the same time as vehicular aspects of the bridge, resulting in a delay of more than two years in interurban use of the structure. Blame for those delays may be attributed to both parties but it cannot be said that the state did not initiate the negotiations on a diligent basis.

Purcell memorialized his October 22, 1931 meeting with Kirkbridge. He noted that he impressed on Kirkbridge that "we [the State of California] felt the proper solution of a trans-bay crossing was to plan for interurban service on the bridge; that it was felt the highest economic benefit would obtain to the two communities if this was brought about." Purcell emphasized that the state had postponed planning for the East Bay vehicular approaches "figuring it was only proper that the rail problem be studied first as, possibly, it was not as flexible as the highway connections." Purcell went on to state clearly the position of the state that it was essential for the

[331] Little is known about Kirkbridge except that he was relatively new to the management team at Southern Pacific at the time these negotiations took place. Don L. Hofsommer, *The Southern Pacific, 1901-1985* (College Station: Texas A&M Press, 1986): 131.

two interurban carriers to achieve some consolidation of operations (the Sacramento Northern was not considering use of the bridge at that time), at least on the bridge and in San Francisco. Purcell warned that the bridge would be built, with or without the participation of the railroad, and "that were it impossible to finance and to secure the cooperation of the railroads in financing an interurban structure, no doubt an automobile structure exclusively would be urged by the public, and would be the outcome in the end."[332]

The next day, Purcell, Andrew, and Woodruff met with representatives of the Key System, including its president, Lundberg. Purcell reiterated his concern that the bridge should be built to accommodate interurbans, but that it would be built as automobile-only, should negotiations fail. He restated his insistence that the two major companies decide upon ways of consolidating their operations across the bridge and in San Francisco. Lundberg assured Purcell that the Key System and Southern Pacific would soon fund a study of how to integrate operations on the bridge.[333]

During late 1931 and early 1932, Glenn Woodruff and his staff devoted a great deal of time in devising track layouts, station locations, and other matters the state had initially hoped would be designed by the railroads. In March 1932, for example, Woodruff sent a long memorandum to C. H. Purcell, transmitting eleven different alignments (labeled A through K) for interurban tracks in San Francisco, focusing on the location of a downtown terminal. The plans included one "suggested by the Interurban Companies," which called for two stations: one at First and one at Fifth Street. This plan was rejected outright by Woodruff because of the high cost of demolishing buildings, including the Chronicle Building at Fifth and Mission. Most other alternative looked at South of Mission locations, at Fourth, Second, or First Street. Woodruff's preference was an alternative between First and Fremont at Minna Street, the location that was ultimately selected.[334]

In March 1932, planning for the interurbans was apace with other planning for the bridge; most of the major elements were yet to be decided. Four days after the previously cited memorandum on terminal location, Woodruff sent Purcell another long memorandum concerning financial negotiations with the interurbans. He laid out six negotiating points. First, that the State of California would provide space for two interurban tracks on the bridge, with the tracks to be laid by the companies. Second, the companies would build all approaches to the bridge. Third, the companies would pay a toll of one cent per passenger. Fourth, the interurbans and state would agree to seek discontinuance of vehicular ferry service upon completion of the bridge. Fifth, that

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[332] C. H. Purcell, Memorandum, San Francisco, Oct. 22, 1931, Engineers Memoranda, C. H. Purcell, 000.050, California State Archives.

[333] C. H. Purcell, Memorandum, San Francisco, Oct. 23, 1931, Engineers Memoranda, C. H. Purcell, 000.050, California State Archives. The state's position that the interurbans should consolidate their operations reflected a longstanding position taken by the California Railroad Commission that the two major interurbans should consolidate all of their operations, not merely the bridge-related operations, because both were losing money. The context for consolidation, in other words, long predated construction of the bridge. See Adler, *Political Economy of Transit*, for a discussion of the larger state effort to unify the East Bay interurban lines.

[334] Woodruff to C. H. Purcell, March 10, 1932, Engineers Memoranda, Glenn Woodruff, 000.050, California State Archives.

the state and interurbans would agree to reimburse the ferry companies for losses. Sixth, that the interurbans would agree to help maintain the bridge, once the bonds had been retired and the tolls removed.[335]

Although negotiations seemed apace in March 1932, the situation was changing rapidly and there was little room for error. The most frantic design work was underway in 1932, with state engineers hoping to go out to bid later that year or in early 1933. During the same period, the most intense negotiations were underway with the Reconstruction Finance Corporation, discussions that affected every aspect of bridge design. Negotiations with the railroads stalled during 1932, however, and it was then that the railroad situation became worrisome. In mid-November, 1932, Charles Andrew wrote a two-page memorandum to Purcell, indicating that he was not optimistic about the outcome of negotiations between the Bay Bridge Division and the railroads, and urging Purcell to consider turning the whole matter over to the Railroad Commission. He wrote:

> The question arises as to procedure in these negotiations.
> (a) Shall we sit down with the railroad officials and discuss the data we have available, terms and agreement; later this to be submitted to the Railroad Commission for revision and discussion;
> (b) Or shall we request that the Railroad Commission appoint their experts to sit in on such negotiations;
> (c) Or shall we join in the request jointly with the interurban companies to ask the Railroad Commission to settle the terms for the use of this facility;
> (d) Or shall we proceed directly to the Railroad Commission and ask them ourselves to go into the entire matter and furnish us with a report with recommendations or a decision in the matter.[336]

The need for a speedy resolution in late 1932 was due to the on-going negotiations involving the California Toll Bridge Authority and the Reconstruction Finance Corporation, which were entering a crucial stage. As discussed in an earlier chapter, the RFC approached the "self-liquidating" loans much in the manner of a private lending institution, seeking assurances of revenue streams to liquidate the loans. In the absence of agreement between the state and the interurbans, however, no such assurances could be given for those costs attributable only to the interurban facilities.

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[335] Woodruff to C. H. Purcell, March 14, 1932, Engineers Memoranda, Glenn Woodruff, 000.050, California State Archives. The issue of how to compensate ferry operators was, of course, complicated by the fact that the Southern Pacific, a major interurban carrier, was also part owner of the Southern Pacific Golden Gate Ferries, which had a near monopoly over vehicular ferry service.

[336] "Memorandum on Procedure to Settle Questions - San Francisco-Oakland Bay Bridge," November 15, 1932, Engineers Memoranda, Charles Andrew, 000.050, California State Archives. In fairness to all parties, the interurban question was the only aspect of bridge design that required approval by the Railroad Commission, a fact that contributed to the delay in its resolution.

Unfortunately, not all such costs could be segregated. The entire facility – bridge, approaches, interurban facilities (including the Transbay Terminal), and incidental buildings (toll booths, substations, and so forth) – was estimated to cost $72 million. The cost of a mixed-use bridge (interurban and vehicular) was in the range of $17 to $20 million more than a vehicular only bridge, owing to several factors, including the external facilities, the track, and the heavier loading on the bridge members.[337] The state declared its intent to build interurban features, as a separate "representation" that was ancillary to the agreement with the RFC: "The Bridge Authority declares, but not as a condition of this application, that it is its intention to provide for railroad trackage and facilities for interurban traffic on the San Francisco-Oakland Bay Bridge and approaches."[338]

In the absence of an agreement with the interurbans, the state had three options in its negotiations with the RFC: attempt to get a loan for all of the work; get a loan for a vehicular bridge only; or get a loan for a bridge that was structurally capable of handling the interurbans, but without the external interurban improvements, such as the Transbay Terminal, track, substations, and so forth. In the end, the state took the third course, seeking a $62 million loan, which would build the bridge to a level that would accommodate the interurbans but without the external interurban improvements. The agreement between the state and the RFC was silent with respect to the interurbans, although it was the understanding of both parties that the state would return for additional loans to build the railroad elements, once agreement has been reached.[339] The agreement between the state and the RFC was reached in late 1932 and early 1933, and construction commenced in April 1933. Agreement between the state and the railroads would take several additional years to complete.

In a sense, the decision to separate out the railroad costs was fortuitous in that it took the pressure off the state and the railroads for a quick resolution. It was unfortunate in another sense, however, because the construction phase of the bridge was in many respects even more time-consuming for state engineers than had been the design phase. The final negotiations with the railroads took place while thousands of workmen were in place and one of America's truly heroic construction projects was underway. Glenn Woodruff hints at his annoyance at negotiating with the railroads in a December 4, 1934 letter to Modjeski's office. In the heart of the letter, Woodruff discusses the need for having some Modjeski and Masters inspectors in place for spinning the cables for the suspension spans, planned for February 1935. He adds: "Have been working like the devil, fighting the railroads and trying to work out plans for adding interurban facilities to the bridge."[340]

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[337] At various times, the Bay Bridge Division attempted to estimate the difference and produced different figures. The estimated difference, however, was never less than $17 million or more than $20.

[338] Quoted in Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge," 29.

[339] This is the recollection of Leland Cutler, who was a party to both phases of negotiations. Leland W. Cutler, *America Is Good to a Country Boy* (Palo Alto: Stanford University Press, 1954), 177.

[340] Woodruff to Frank L. Master, December 8, 1934, Engineers Memoranda, Glenn Woodruff, 000.050, California State Archives.

Others seem to have felt the same frustration in dealing with the interurban lines. In June 1934, Clyde L. Seavey, President of the California Railroad Commission, wrote a joint letter to executives of the Southern Pacific Company and the Key System, summarizing his view of the situation with respect to interurbans and the Bay Bridge. He observed:

> In view of the time which has elapsed since the construction of the Bridge became an assured reality, it is felt that there is some justice in the complaint that your companies have been dilatory in the conduct of the negotiations which we understand have been underway for a long time. The progress of physical construction of the Bridge is now so far advanced that the actual physical work in connection with railway facilities should be under way at this time. Many studies have been made dealing with this matter and a great amount of data is available but in our opinion the whole matter is hinged upon a definite program of future management and to proceed in an expeditious and orderly manner it is in our opinion imperative that the consummation of a plan of unification be decided upon at an early date.[341]

As 1934 drew to a close, state officials were fearful that the entire Self-Liquidating Loan program of the RFC would disappear with a "sunset" clause in the enabling legislation. [In actual fact, the RFC program in the public works field was drastically scaled back early in 1935 and was eventually folded into the Public Works Administration, or PWA.][342] Fear of the demise of the program led state negotiators to develop an interim agreement with the RFC to fund railroad construction, dependent upon successful agreement with the railroads.

The level of frustration felt by state planners is documented in the minutes of a November 30, 1934 meeting of the Financial Advisory Committee of the San Francisco-Oakland Bay Bridge. This committee, it will be recalled, met periodically to offer advice on issues that affected the financial well-being of the larger bridge project. The membership of the Committee changed from time to time but always included very prominent financial leaders of the Bay Area. At its meeting of November 30, the committee included: George Cameron, editor of the *San Francisco Chronicle*; Joseph Knowland, editor of the *Oakland Tribune*; A. P. Giannini, founder of what would become the Bank of America; Leland Cutler, an insurance executive and head of the San Francisco Chamber of Commerce; Harrison Robinson, the chair and a prominent Oakland attorney; and several other prominent business leaders.

The meeting began with a long presentation by Robinson on the history of negotiations with the Key System and the Southern Pacific Railroad, which had been handled by Robinson, Knowland, and Cutler on behalf of the state. The talks had been delayed, in his view, largely over the issue of a unified operation by the two major interurban carriers. The state and the carriers had reached

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[341] Clyde L. Seavey to F. L. Buckhalter, Southern Pacific and A. J/ Lundberg, Key System, June 5, 1934. This letter and other documents about the interurbans and the Bay Bridge are included as appendices to Leland Cutler's *America Is Good to a Country Boy*. These are the only appendices Cutler includes in his autobiography, a fact that reflects the importance he attached to these negotiations.

[342] James Stuart Olson, *Herbert Hoover and the Reconstruction Finance Corporation, 1931-1933,* 81.

tentative agreement on an arrangement through which the Key System would operate all trains over the bridge, repaying the Southern Pacific for the use of its cars. That agreement was nearing completion, in Robinson's recollection, when the president of the Southern Pacific "sat here one day ... and announced that it is all off and the next thing we moved up was a joint operation that involves separate contracts with the Key System and Southern Pacific. Those contracts have gone through I think 11 or 12 drafts."[343]

Robinson confessed that the railroad had the upper hand because the state had no ability to counter with alternatives, such as substitution of bus service or the creation of a state-owned railroad to accomplish the same purpose. Buses, he felt, could not adequately handle the volume while state ownership was beyond the legal and financial capabilities of the California Toll Bridge Authority. If either alternative existed, Robinson insisted, "Then we could say to the railroads, 'Here are the terms on which you can use the Bridge; otherwise you are through.'"[344] The greatest fear of the committee was that the RFC would refuse to loan any more money on the bridge if the state and the railroad could not reach agreement. "It is my best judgment the R.F.C. would ask, 'Gentlemen, you are asking for a lot of money when you ask for fifteen million dollars to have a cat and dog fight."[345]

Robinson proceeded to outline the terms of the interim agreement between the state and the two interurban carriers. The most controversial element was a provision through which the state would furnish new rail cars for the two lines to use. Robinson seemed almost apologetic about this provision. "Here is one thing we never expected to do. We expected the railroads to provide their own cars. Now a long while ago they said, 'We won't put any money into this thing. We will not invest a dollar.' And we were in no position to draw a gun. We had no gun to draw."[346] The sticking point was the insistence by the state that only high quality equipment operate on the bridge and the fact that neither line had equipment that could meet the specifications. The two lines, for example, were operating very old cars that worked on different voltage. "If any new cars are bought," Robinson concluded, "we will have to buy them."

Several other members were surprised. "To buy new cars?" Giannini inquired, "Where will we get the money?" F. M. McAuliffe observed, "It is hard for the public to understand why the railroads are allowed to go over the bridge without investing money."[347] The agreement involved spending about $4 million, of a total loan of $15 million, to supply the railroads with equipment capable of being used on the bridge. This fact caused committee members to question the ability of the interurban traffic alone to pay for the $15 million loan. C. H. Purcell suggested that the automobile tolls might provide a cushion to make up for any train-related deficits. "I think our automobile traffic is going to surprise you on this," Purcell observed. To which Giannini added,

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[343] Minutes of the Financial Advisory Committee of the San Francisco-Oakland Bay Bridge, November 30, 1934. These minutes are retained at Caltrans, District 4, Oakland, Central Records, Box 421.

[344] Minutes, November 30, 1934 3.

[345] Minutes, November 4, 1934, 5.

[346] Minutes, November 4, 1934, 11.

[347] Minutes, November 4, 1934, 22.

"The Carquinez Bridge has been going big. You can't stop autoing in California. You can't stop this country. Just watch us."[348]

In the end, the committee approved unanimously the tentative agreements with the interurban carriers. With this approval in hand, the Financial Advisory Committee could proceed to draft a tentative agreement with the RFC, contingent upon reaching final agreement with the railroads. On December 31, 1934, the Financial Advisory Committee of the California Toll Bridge Authority presented the tentative agreement with the RFC, negotiated by Cutler, Knowland and Robinson. In their report to the California Toll Bridge Authority, the three-member subcommittee could scarcely disguise their frustration in dealing with the Southern Pacific and the Key System. The committee report included the following comments:

> The delays of the Carriers in commencing contract negotiations were well known to public officials, to the heads of civic organizations and to many interested citizens on both sides of the bay... It was also well known that the power of the RFC to make loans of this call must, under the law, be exercised on or before January 31, 1935. Between the above mentioned 19th day of October, 1934 and November 20, 1934, much progress has been made in negotiations with the Carriers over the terms of the proposed contracts; and numerous redrafts of agreements evidencing the progress of negotiations has been made. But the negotiations were far from completed and many differences existed (and still exist) between your Committee and the Carriers.[349]

In that agreement, the RFC committed to lending an additional $10 million for "acquiring terminals, viaducts, trackage and rail connections, storage yards, signal and interlockers, substation and power supply lines, the purchase of new equipment and alterations to equipment, including cab control, together with the purchase of all real property necessary thereof." The agreement carried seven conditions. First, the California Toll Bridge Authority would need to agree to the resolution. Second, the RFC had to receive "satisfactory assurance that any interurban ferry service ... shall be abandoned and their franchises canceled and surrendered." Third, the state must show that all elements of the agreement are consistent with state law. Fourth, the state needed to show that agreement had been reached with the carriers "satisfactory to Counsel for this Corporation." Fifth, the state needed to show that the Railroad Commission had approved the agreements. Sixth, the state needed to show that the bonds were legal. Finally, the state needed to show that the work could be accomplished with the funds available.

Of the various conditions, the most onerous was the need to present proof of agreement with the railroads. The RFC proffered the agreement in mid-December, 1934 and the California Toll Bridge Authority approved it in January 1935. The final agreement was not reached with the Key System and Southern Pacific until March 6, 1936; a third agreement was reached with the Sacramento Northern Railway in September 1938. The initial agreements, then, occurred about eight months before the bridge was opened to vehicular traffic; the agreement with the third

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[348] Minutes, November 4, 1934, 16.

[349] Cutler, *America Is Good to a Country Boy*, 257.

carrier came nearly two years after the bridge was opened to automobiles, trucks, and buses. These delays in negotiating agreements, more than any other single factor, accounts for the fact that automobiles could use the Bay Bridge in late 1936 but the trains were not running until 1939.

The agreements were nearly identical between the state and the Key System and the state and the Interurban Electric Railway; the Southern Pacific lines were re-incorporated as Interurban Electric just prior to the agreement. The state agreed to compensate the companies for the cost of modifying rolling stock, to a specified maximum. The Key System alone was given $2,470,000 for this purpose. Although not part of the agreement, the state also paid for all improvements to the railroad approaches and in construction of the San Francisco loop and Transbay Terminal.[350]

The ceremonial laying of the first tie for the bridge railway system occurred on November 29, 1937, at the Oakland approach. Another ceremony marked the laying of the first tie on the bridge itself, in February 1938. Construction involved elements that extended far beyond the limits of the bridge, including a Transbay Terminal Building in San Francisco, an extensive loop of elevated railways connecting the bridge with the downtown terminal, as well of numerous railway bridge structures on the Oakland side. The first trains were powered across the bridge and into the Transbay Terminal on January 15, 1939.[351]

11.3. Operation of the Interurban Lines after 1939

The interurban lines used the Bay Bridge for only a little longer than it took to negotiate an agreement and build the facilities. The Interurban Electric Railway and Sacramento Northern used the bridge for less than two years, abandoning their lines in early 1941. The Key System, which had the business to itself after 1941, maintained its service until 1956, when it applied to abandon all rail service in favor of its "motor coach" or bus line.

Many reasons could be put forward for the early departure of the interurbans after very expensive improvements made by the state to accommodate them. The simplest explanation is that ridership was generally disappointing. The table below presents the raw numbers for interurban passengers on the Bay Bridge between 1939 and 1952. The figure is combined for the Key System, Interurban Electric, and Sacramento Northern in 1939-41 but for the Key System alone, 1942-1952. The 1952 figure represents a doubling of a six-month total.

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[350] The agreements are analyzed in: Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge." One of the most disastrous outcomes of the failure of the interurbans was the fact that the state re-acquired millions of dollars worth of rolling stock it did not want and could not use and which had little re-sale value. When the IER and Sacramento Northern folded in 1941, the state re-took possession of 63 cars for which it had paid $1,730,077. The state was able to recoup $29,355 from the sale of those cars, or about 2 percent of original value. Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge," 35.

[351] Demoro, *The Key Route*, 82-82.

INTERURBAN RIDERSHIP ACROSS THE BAY BRIDGE[352]

Year	Ridership
1939	19,799,826
1940	18,424,411
1941	14,023,306
1942	16,365,820
1943	21,396,813
1944	23,942,134
1945	26,469,118
1946	22,177,212
1947	17,015,228
1948	15,630,648
1949	13,868,116
1950	11,811,795
1951	10,254,986
1952	10,055,118

While the trend was generally downward, ridership on the interurbans experienced two peaks: in 1939, while the Golden Gate International Exposition was still in progress, and in 1942-45, when tens of thousands of sailors were stationed at Treasure Island, both mid-span on the bridge. The latter development was not necessarily good news because, by agreement with the federal government, those sailors rode free. Those free rides were not insignificant; in 1945, nearly 11 million of the 26.5 million passengers on the Key System rode for free.[353] The decline after 1945 was sudden and dramatic, falling in 1952 to a level of 37 percent of the 1945 total. That decline would continue until the service was discontinued in the mid-1950s.

The cause of this decline differs from one line to the next. The Southern Pacific's Interurban Electric Railway system, built specifically for use on the bridge, folded within a few years of its inaugural runs. One historian attributes this decline to two factors: internal management problems of the Southern Pacific, chiefly a competitive disadvantage relative to the Key System, owing to archaic and overpaid wage structures; and the fact that the IER had limited coverage in the East Bay, making it non-competitive relative to the Key System, the automobile, or bus service.[354] The Southern Pacific applied to the railroad commission to abandon the line, citing monetary losses, and service was discontinued in January 1941. The situation with the Sacramento Northern Railway is more complicated because the system was so much more complicated. At one time extending as far north and east as Chico, the SN system had always been built around long-distance commuting. The SN hoped to bring commuters to San Francisco from Contra Costa County and Pittsburg. This service was even more short-lived than the IER; the Contra

[352] Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge."
[353] Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge."
[354] Trimble, *Interurban Railways of the Bay Area*, 18-19.

Costa service was abandoned in August 1940 and the Pittsburg service in June 1941.[355]

As to the Key System, the failure of the interurban lines may be attributable to many factors. Without attempting to weigh the relative importance of each, the following discussion refers to four developments that contributed to the demise of the Key System's lines over the Bay Bridge.

One cause of failure was the fact that the company competed against itself by running buses over the Bay Bridge. The Key System initiated bus service from the East Bay during the 1936-39 interregnum, when the Bay Bridge was open to vehicular but not to train service. It continued to offer bus service from the East Bay to Treasure Island during the Golden Gate International Exposition. The Key System bus program expanded after the Southern Pacific abandoned its IER operation, in part because the abandoned line could be served more conveniently by buses than though complicated switches between Key System and old Southern Pacific tracks. Whatever their reasoning may have been, the leaders of the Key System aggressively expanded their bus service between 1939 and the 1950s. By 1951, the ridership was closing in on its train ridership: 7,241,000 passengers on buses vs. 10,254,000 on its trains.[356]

Another related factor was the sale of the line to National City Lines, Inc. in 1946. National City was a Chicago-based holding company financed by several large corporations with interests in bus, truck, and automobile parts and services, including Firestone Tire & Rubber, Phillips Petroleum Corporation, Standard Oil of California, Mack Manufacturing Co., and General Motors Corporation.[357] National City also bought transit lines in Glendale, Long Beach, Pasadena, Sacramento, Stockton, and San Jose, and was responsible for closing down all of those other lines in favor of bus transport. Beginning in 1946, National City began to abandon its smaller feeder lines in favor of bus service.

A third factor was the decline in the quality of service on the Key System interurbans, including deterioration of its equipment and rails. The Key System equipment had begun to fall apart even before it began service on the bridge in 1939. Heavy use during World War II only accelerated the rate of deterioration. The need for major investment in equipment modernization scared away many potential investors in the company and hastened the sale of the system to National City Lines. National City showed little interest in spending money to modernize the rail system. In a 1957 "Preliminary Report on Trans-Bay Transit," prepared for the newly-formed Alameda-Contra Costa Transit District, the consultant, DeLeuw-Cather, observed: "There is every

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[355] Trimble, *Interurban Railways of the Bay Area,* 122-123. The best source for the history of the Sacramento Northern Railway is Harry W. Demoro, "The Sacramento Northern," *Locomotive & Railway Preservation,* November-December, 1988, 13-26. The Sacramento Northern system survived in the Sacramento Valley and in parts of the Bay Area through the late 1950s.

[356] Legislative Auditor, "Financial History of the San Francisco-Oakland Bay Bridge," 27; Demoro, *The Key System Route,* 108-110.

[357] "Financial History of the San Francisco-Oakland Bay Bridge," 38; Demoro, *The Key System Route,* 120-122. The National City Line was indicted in 1947 by the federal government for conspiring to monopolize the nation's transit business and for monopolizing the sale of bus-related goods, including buses, tires and tubes. It was convicted on the second count but acquitted on the first. Adler, *The Political Economy of Transit,* 67.

evidence that transbay rail services have been purposely allowed to deteriorate during the last decade by a management devoted to bus service."[358] Whether through deliberate sabotage or neglect, the failure of the Key System management to modernize helped drive away new and existing patrons.

A fourth factor was a rapid reduction in automobile tolls on the bridge. Initially established at $.65, the automobile tolls were reduced to $.50 in 1937, to $.40 in 1939, and to $.35, $.30, and finally to $.25 in three reductions in 1940.[359] Initially, the toll reductions were justified as necessary to combat revenue losses associated with diversion of automobiles from the bridge to the Southern Pacific Golden Gate Ferry service, which had reduced its rates earlier. Subsequent reductions were justified on the basis of favorable refinancing of parts of the RFC loan package, which reduced the burden on the tolls. Whatever the reason for the toll reductions, they no doubt hastened a diversion of ridership away from the Key System, which did not reduce its rates and, in many instances, increased them.

The Key System in January 1955 formally applied to the California Railroad Commission for permission to abandon all aspects of its rail service. In a 1954 report, the company explained its rationale for abandonment of rail service:

> Such motorization would be more economical and give more frequent service to transbay patrons. Also, motorization would obviate an estimated $3 million expenditure for rail rehabilitation which would be required to provide a smooth pavement in track areas as demanded by the cities. Furthermore, continuance of rail operations is no longer sound economically as the railway was designed to carry 50 million passengers annually whereas traffic has dwindled to less than 8 million passengers annually.[360]

The last trains crossed the Bay Bridge in 1958. In 1960, the Key System bus lines were taken over by the newly-formed Alameda-Contra Costa Transit District (AC Transit), beginning an entirely new chapter of publicly-owned and operated transit lines in the Bay Area. AC Transit and others would continue to use the Bay Bridge as well as the Transbay Terminal Building and connecting loop, which was re-configured for bus-only service as the first step in rebuilding the Bay Bridge. That reconstruction is discussed in greater detail in Chapter 13 of this document.

11. 4. Conclusions Regarding the Use of the Bay Bridge for Mass Transit

Two important conclusions may be drawn with respect to the use of the Bay Bridge for rail transit: it was built into the plans of the bridge from the outset; and it was short-lived. The disparity between those two conclusions is the subject of interpretation. The state of California spent tens of millions of dollars – nearly one-quarter the total cost of the bridge — to make it

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[358] Quoted in Adler, *The Political Economy of Transit*, 247.

[359] The toll reductions were highlighted in *California Highways and Public Works* (November 1936): 26; (March 1937): 6; (June 1939): 1; (January 1940): 19; (June 1940): 20; and (July 1940): 5.

[360] Quoted in Demoro, *The Key Route*, 131.

usable for use by rail-based transit lines. There is no reason to believe that the planners of the Bay Bridge intended on anything but a successful relationship with the interurban carriers.

The relations between the state and the carriers, however, soured during construction of the bridge, a fact that delayed completion of the rail facilities for several years after the bridge was opened to buses, cars, and trucks. That delay no doubt contributed to a decline in rail ridership, as potential riders recognized the convenience of automobile as well as bus service. The carriers created competition on their own, expanding greatly their bus service while rail service declined. By the early 1950s, the Key System planners had decided on their own to abandon rail service.

The planners of the Bay Bridge had anticipated some "deflection" of rail use to automobile use as early as 1930, recognizing that the bridge would result in time savings to automobile commuters that exceeded similar savings for rail passengers. Their projections in 1930, however, were for rail transit use that was far greater and automobile use far less than was the actual case. As late as 1937, for example, the state held to projections of 50 million rail passengers using the bridge system.[361] The causes for that miscalculation are many, not the least of which was a deflection that far exceeded expectation.

[361] C. H. Purcell, Chas. E. Andrew, and Glenn B. Woodruff, "Bay Bridge Rapid Transit System," *Engineering News-Record* (May 27, 1937): 770-772.

12. CELEBRATIONS AT THE COMPLETION OF THE BRIDGE

Bay Area residents, particularly San Franciscans, have historically been adept at staging celebrations for major events. The Panama Pacific Exposition of 1915, for example, was a grand gesture commemorating the completion of the Panama Canal. The completion of the Bay Bridge was surely cause for celebration as well. Bay Area residents had watched the bridge in-progress for more than three years. Although there had been talk of a bridge of this sort since the 1920s, it was not until the great suspension towers and the East Bay cantilever spans began to rise that the possibility of a completed bridge began to seem tangible. The actual closing of the spans in the summer of 1936 propelled planners for the state and the local communities to put together major celebratory events.

Local political leaders, particularly those in San Francisco, decided to take a two-part approach to this celebration. One set of events would occur at the time of the opening, which was set for mid-November 1936. Another, far more ambitious series of events, would take place several years later, celebrating the Bay Bridge as well as the Golden Gate Bridge, which was opened in early 1937. The second event was a world's fair, dubbed the Golden Gate International Exposition. This chapter addresses the two events.

12.1. Blessing of the Bridge, October 29, 1936

The first event to mark the opening of the bridge occurred about two weeks before the formal opening and was attended by only a handful. In late October 1936 Eugenio Cardinal Pacelli toured California as part of his general duties as Secretary of State to the Vatican. He spent two days in San Francisco, conducting services at various facilities of the Catholic Church. At his insistence, however, the Cardinal was taken the see the largely completed but as yet unopened Bay Bridge. His tour occurred early in the morning of October 29. According to newspaper accounts, he was accompanied by a very small entourage, including Archbishop J. J. Mitty of San Francisco and Count Enrico Galeazzi, who was traveling with the Cardinal. Although not mentioned in press accounts, it may be presumed that the tour of the construction zone was led by officials from the state. The group stopped at the center pier for the double suspension spans (Pier W-4) where the cardinal blessed the bridge. The text of that benediction was not recorded by those present.[362] The decision to bless the bridge was made by Cardinal Pacelli himself, who expressed an interest in seeing the bridge the day he arrived in San Francisco. Three years later in 1939, Cardinal Pacelli was elected as Pope Pius XII. He would serve until his death in 1958.

12.2. Celebrations, November 11-15, 1936

The events in mid-November, 1936 were ultimately the more successful of the two major groups of celebrations, simply because they occurred at the time of the opening of the Bay Bridge and were focused only on the completion of this great span. The world's fair did not open for another three years and was dedicated to both the Bay Bridge and Golden Gate Bridge. The celebrations

[362] *San Francisco Chronicle*, October 28, 1936; October 29, 1936.

of the two bridges were largely lost in the grandiosity of a fair that involved exhibits from throughout the United States and the world, and which ultimately adopted a theme of Pacific Unity, a theme that extended far beyond the original concept of celebrating the bridges. If there was a single moment when the Bay Area stopped to take stock of the significance of the completion of the Bay Bridge, it was a four-day period that extended from November 11 to 15, 1936.

The four-day event was planned in a somewhat coordinated manner by the State of California and the various communities, particularly San Francisco and Oakland. The state, with the active involvement of the governor's office, took charge of the official dedication ceremony, while San Francisco, Oakland, Berkeley, Alameda and other communities planned their separate events within their respective jurisdictions.[363] The general approach included a small group of events on November 11 (which was also Armistice Day), the formal dedication ceremonies on the November 12, when the bridge actually opened to traffic, galas and parades throughout the Bay Area on November 13, and a parade and closing events in San Francisco on the 14th.

The events of November 11 were necessarily segregated by the two sides of the Bay, as the bridge was not yet open. As noted, November 11 was also Armistice Day and Bay Bridge-related celebrations dovetailed with Armistice Day events. These included an Armistice Day Parade in Oakland, a military pageant in Berkeley, and two football games, one in San Francisco (University of San Francisco vs. Texas A&M) and one in Berkeley (two Army teams, one from San Francisco and one from Oakland). [364]

The heart of the celebration occurred on November 12, the day the bridge actually opened. The festivities began at approximately 9:00 AM, with the completion of a boat race from Sacramento and Stockton, which terminated at Pier 3 in San Francisco. At 10 AM, 500 pleasure and working boats left from San Francisco to form a "Marine Parade" from San Francisco to Yerba Buena Island and back. At the same time, 250 aircraft from Navy carriers in the Bay began a massed flight of the Bay from San Mateo to San Rafael. Also at 10 AM, the various dignitaries who would speak at the official opening began to assemble near the Oakland tollbooths. The official dedication was planned to occur at 10:40 AM in Oakland and at 11:00 AM in San Francisco; it was delayed for about one hour. The festivities continued well into the night, with various air shows in the early afternoon, a yacht regatta at noon, a luncheon with Governor Merriam in Oakland at 12:00 PM, an air parade of China Clippers at 3:00 PM, various Navy ship races in the late afternoon, the official lighting of the bridge at 5:30 PM, and numerous balls in the evening, including a Navy Ball at the Fairmont Hotel in San Francisco, two separate Navy enlisted men's balls (for white and black sailors) in Oakland, and a public ball at the Oakland Auditorium.[365]

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[363] Cutler, *America Is Good to a Country Boy* offers a brief discussion of how these events were put together.
[364] "Official Souvenir Program: San Francisco-Oakland Bay Bridge Celebration," 5. These page numbers refer to a 1986 reprint of the 1936 program, a copy of which is retained at the Transportation Library, Caltrans, Sacramento.
[365] Official Souvenir Program," 6-10.

On November 13, San Francisco staged a huge parade in the afternoon on Market Street between the Ferry Building and City Hall with hundreds of marching bands, drill teams, military companies from throughout the United States, dozens of floats, and other displays. The day was capped off with fireworks and several balls in San Francisco hotels. Another huge parade was held in San Francisco on the night of November 14, with a "history of bridges" theme. Various floats were assembled to represent "man's first bridge," "Pont Neuf," "Horatio at the bridge," and similar themes. Other floats came from around the world. More balls were held at San Francisco hotels. Minor closing festivities continued on November 15, including a football games at Kezar Stadium (St. Mary's vs. Santa Clara) and boat races.

Two things were surprising about the four-day festivities: how well they were attended and how quickly traffic on the bridge grew congested. Crowd estimates are notoriously inaccurate but contemporary press accounts concluded unanimously that the events of mid-November, 1936 were among the most well attended in the history of the Bay Area. Early indicators of a large crowd showed in hotel reservations: San Francisco hotels were fully booked for the first time in a decade. Visitors came from throughout California and other parts of the nation: "By bus, train, airplane, and private autos," declared the *San Francisco Chronicle*, "they surged in to see the latest engineering wonder of the world and to join in festivities Thursday, Friday, and Saturday."[366]

The evening events of Thursday, Friday, and Saturday night (November 12, 13, and 14) were by far the best attended, far outpacing the actual dedication ceremony during the day on November 12. The parades on November 13 and 14 drew crowds that surprised even experienced observers. "A city gone mad!" reported Earl Ennis in the *Chronicle,* regarding the parade of November 13. "San Francisco has seen many celebrations, including the exposition of 1915. But not in the memory of the oldest inhabitants has there been witnessed such a spontaneous outpouring of enthusiasm as marked the formal opening of the great transbay bridge."[367] Estimates of the crowd varied widely; San Francisco police contended that more than one million people lined the streets on November 13 to watch the parade. The crowd on Saturday night by all accounts was even larger. It was unusually warm for mid-November and dozens of people were treated for heat-related health problems.

Apart from crowd sizes, the most remarkable aspect of the celebration was the traffic. The events involved two types of attractions: the parties and parades in San Francisco, and the bridge itself. Part of the thrill of the celebration for many people was driving across the new bridge, which people did in numbers that stunned event planners. This outburst of pleasure driving, combined with the parades and other events on both sides of the Bay but especially in San Francisco, created huge traffic jams. The congestion first appeared on November 12, when the bridge opened. According to a headline in the *Chronicle*, the events of that day created "The Greatest Traffic Jam in the History of San Francisco."[368]

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[366] *San Francisco Chronicle*, November 12, 1936: 1.

[367] *San Francisco Chronicle*, November 14, 1936: 4.

[368] *San Francisco Chronicle*, November 13, 1936: 3.

The situation only got worse as the festivities progressed. Bridge toll takers could not provide an accurate count but local newspapers estimated that 150,000 cars passed over the bridge during the first 36 hours.[369] When the parade had ended in the early evening of November 13, traffic in San Francisco approached gridlock. "Hours after the pageant ended, traffic was in a hopeless snarl at a half dozen Market, Mission, Howard and Folsom street intersections," one newspaper reported. "Street cars piled up for blocks, autos moved at snail's pace, pedestrians walked with difficulty and crossed intersections with a hop, skip, and jump to avoid being struck down." The evening parade on November 14 caused even worse congestion. As one reporter put it: "To drive an automobile within a block of Market Street from any of the radiating streets meant extrication of the car, and in many instances of the passengers, too, utterly impossible."[370]

Although the parades and galas were the focus for the vast majority of people, the formal dedication ceremony on November 12 was of greatest interest to the national press and to subsequent historians. Like most formal occasions of the sort, the ceremony involved a select group of dignitaries who were invited, based upon seniority and degree of involvement with the project. The list of participants in this event was apparently the subject of some controversy, as the invitation carried with it symbolic acknowledgment of the roles played in the decade-long campaign to build the bridge. Some individuals were included by consensus: Governor Frank Merriam, who attended virtually every opening of a major public works project during his administration; C. H. Purcell, commonly acknowledged to be the man who built the bridge; and Public Works Director, Earl Lee Kelly, who, among other things, was Purcell's boss.

Controversy surfaced over the list of civic and political leaders from the Bay Area and elected officials from beyond the Bay Area. The choice among local and civic leaders was difficult simply because there were so many of them, and many who had worked early on the campaign were no longer in office or in a leadership role. The choice among major elected officials was complicated by the fact that the political climate had changed enormously between the initial planning for the bridge, when the nation was overwhelmingly Republican, and its completion, when a majority of American voters were Democrats.

A particularly sticky situation concerned the roles of ex-president Herbert Hoover, who was arguably the most steadfast political supporter of the Bay Bridge, and President Franklin Roosevelt, who succeeded Hoover as president at about the time the construction bids were opened. In the recollections of Leland Cutler, Hoover had strained relations, not only with Roosevelt but with California Republican political leaders as well. Cutler recalls that "This [November 12 celebration] brought out all of the temperaments of the United States and the Bay Area into action." Cutler was involved in planning the festivities in San Francisco and, in his recollection twenty years after the fact, had invited Hoover along with Charles Marx, who had been a member of the Hoover-Young Commission. He did so without consulting with Governor Merriam whom, Cutler notes, "didn't get along too well with Mr. Hoover." Merriam was

[369] *San Francisco Chronicle*, November 14, 1936: 5.
[370] *San Francisco Chronicle*, November 15, 1936: 1.

scheduled to cut the chains to open the bridge, as he did for all such official ceremonies, which caused Mark Requa (also a member of the Hoover-Young Commission) to send an angry telegram to Cutler, stating "I note that on November the twelfth at 10:00 A.M. the bridge ceremonies take place and that Governor Merriam cuts the chain. Merriam had as much to do with this as a resident of China. The man that ought to cut that chain is Herbert Hoover."

President Roosevelt was unable to attend the ceremony but sent U. S. Senator William McAdoo, Democrat from California, to speak on his behalf. According to Cutler, some jockeying was necessary to determine who would ride with Governor Merriam in his car as it went from one end of the bridge to the other -- Herbert Hoover or McAdoo. As a compromise measure, Hoover and Marx were given their own car, while McAdoo rode with the governor.[371]

As had been the case throughout planning for the bridge, it was necessary to plan for two separate ceremonies, one in Oakland, the other in San Francisco, with approximately equal fanfare given to each. The ceremonies began in Oakland, where a large crowd gathered near the toll plazas. A platform had been erected to accommodate a long line of speakers. Event planners had assembled a collection of antique transportation vehicles and living history displays, arranged between the crowd and the platform: an ox-drawn cart, a stage coach, and, as described in a state magazine, "an Indian squaw and papoose on a drag from Oroville and prospectors and their burros from Placerville."[372]

Harrison Robinson, an Oakland attorney who had headed the Financial Advisory Committee for the Bay Bridge, directed the Oakland ceremonies. Brief remarks were made by Robinson, Mayor William McCracken of Oakland, William Hamilton, the chair of the Alameda County Board of Supervisors, Mayo E. N. Ament of Berkeley, and W. J. Buchanan, chair of the Contra Costa County Board of Supervisors. Former governor C. C. Young then spoke, emphasizing his pride in his role in establishing the California Toll Bridge Authority and his conclusion that "privately owned bridges had no proper place in a great publicly owned state highway system."[373] Young introduced C. H. Purcell, calling him "the man who built the bridge."

Purcell used the occasion to recount the history of the design and construction of the bridge. He was uniquely qualified as a bridge historian, having worked on every important aspect of the bridge since his initial study of the problems with private toll bridges in 1928. Although he knew first-hand the many political machinations that had gone into the bridge's approval and knew even better the many debates over bridge design, Purcell spoke of little but the construction of the bridge. For example, he used nearly one-third of his brief presentation to discuss the problems involved in closing the cantilever span, highlighting the use of jacks to bring the last pieces together and the use of huge "pins" to connect them.

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[371] Cutler, *America Is Good to a Country Boy*, 175-176.

[372] "Burning Barriers, Governor Merriam Opens San Francisco-Oakland Bay Bridge," *California Highways and Public Works* (November 1936): 2. The entire issue was devoted to the dedication ceremonies.

[373] "Burning Barriers," *California Highways and Public Works*, 2.

This focus on the technical aspects of the latter stages of construction was characteristic of Purcell's remarks generally. No other person knew better than Purcell the intricate political maneuvering involved in assembling a united Bay Area coalition, wrangling with the Army, the Navy and the Reconstruction Finance Corporation, battling with the railroads, and negotiating through differences of opinions among his engineers and architects. Arguably, Purcell's greatest achievement was keeping the delicate coalition together from the late 1920s through completion of the bridge; that coalition would rapidly disintegrate after 1936. His remarks, however, addressed only the technical aspects of the bridge's history, which may have reflected his own interest or his conclusion that there was a sufficient number of politicians on the program to address such matters. His only non-technical observation pertained to the workmen, of whom he said that the bridge "is a tribute to the intelligence of the American working man, which can not be equaled by any other nation." Having concluded his brief history, Purcell noted simply: "The engineers and those connected with the construction of this great bridge have worked hard during these past three years. We now turn the structure over to the people for their use."[374]

Public Works Director Earl Lee Kelly and Charles Henderson of the Reconstruction Finance Corporation made additional remarks, addressing the regulatory and financial history of the bridge. Kelly spoke only briefly of the politics of the bridge, perhaps in deference to Herbert Hoover, who followed him and understood the political situation better than anyone else. Like Purcell, Hoover recalled the history of the building of the bridge, although he focused on political rather than technical issues. He had particularly high praise for leaders of San Francisco and Oakland who had kept together the coalition for the bridge: Leland Cutler, Harrison S. Robinson, George Cameron, Joseph R. Knowland, James Rolph, and others. But Hoover was an engineer as well as a retired president, and reserved his highest praise for the engineering group: "But above all them are the engineers and workmen who combined all those centuries of knowledge with courage and imagination -- your own chief engineer, Charles Purcell and his able assistants, Charles Andrew and Glenn Woodruff, are men whose courage and whose knowledge combine not only the product of these generations of ideas but from their own genius designed and built this bridge."[375]

Henderson had little to do with the design or construction of the bridge but earned a place at the dais because of the crucial role of the RFC in financing bridge construction. The bridge, he declared was "soundly financed and soundly built... It is not only a monument to the genius of Charles H. Purcell, the engineer in charge, it is a symbol of the unlimited capacity of modern men, working together through government, to unify the physical world around them. May we all work with equal success to unify, not only the physical world around us, but the hearts and goodwill of men."[376]

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[374] C. H. Purcell, "Chief Engineer Purcell Tells Construction Story of the Bridge," *California Highways and Public Works* (November 1936): 7.

[375] "Burning Barriers," *California Highways and Public Works*, 5.

[376] "Burning Barriers," *California Highways and Public Works*, 4.

The closing remarks were reserved for Governor Frank Merriam. Merriam would actually make two speeches that day: one in Oakland, the other in San Francisco. In his Oakland address, he emphasized chiefly the financial aspects of the bridge construction, pointing with pride to the fact that it was built under budget and ahead of schedule. In his San Francisco remarks, Merriam was more contemplative, musing about the place of the Bay Bridge in American history. "We cannot dedicate this bridge," he observed, "without noting the remarkable advancement of the last 300 years. In reviewing that history we discover that out progress has evolved out of the common struggles of men. In the records covering these few centuries we find two threads of philosophy that run through the whole fabric of American life. The one expounds the theory of isolation, the other extols the ideal of cooperation." The people of the Bay Area and California, Merriam concluded, held to the latter theory and the Bay Bridge reflected their adherence to the ideal of cooperation. "This bridge which we dedicate today stands as a symbol of cooperative achievement for this residents of this local community, the State and the Nation. We have learned that isolation stimulates fear while cooperation inspires confidence. Isolation never advances commerce, business, industry and culture. It curtails rather than impels a feeling of community consideration. Accordingly, we dedicate this great structure as a part of the highway system of California to the use of the people in an emblem of friendship and neighborly association."[377]

After concluding his remarks, Merriam opened the bridge to traffic. Merriam had the good fortune to be governor at a time when a host of major highway projects were dedicated. He would preside over the dedication of the Feather River Highway, the Big Sur Highway, the Arroyo Seco Parkway, and numerous other major road projects. Merriam and his staff were masters at theatrical opening ceremonies, with each dedication employing some increasingly grandiose variation on the traditional ribbon-cutting ceremony. The great steel bridge inspired a steel-oriented theme. State officials had strung a steel chain across the roadway and equipped Governor Merriam with an acetylene torch to cut it. Merriam successfully burned through the chain, allowing the official party to cross the bridge to San Francisco, where parallel ceremonies were conducted at the Fifth Street plaza at the base of the approaches. The way into San Francisco had been blocked by another chain, this one of gold, but the governor was able to cut it with the same torch. When the San Francisco ceremonies had been completed, President Roosevelt in Washington, D. C. telephoned a signal to workers on the two sides of the bridge, who flashed green lights as a signal that the bridge was open to the general public.

Governor Merriam's remarks regarding the cooperation symbolized by the bridge were remarkably accurate, particularly when seen in the context of transportation planning in the Bay Area after 1936. The bridge had indeed been built with the almost unanimous support of every city and county in the region. Rarely, if ever, have the communities of the region stood so united behind a single program, particularly a major transportation project. The Bay Bridge encountered no substantial opposition from within the Bay Area or California generally during the years in which it was planned and built. That strong coalition lasted from the early 1920s through 1936. Great opposition existed elsewhere, chiefly in Washington, D. C., but the political history of the

[377] "Governor Merriam at Dedication Pays Tribute to Workers and Looks Forward to a Toll-Free Bridge," *California Highways and Public Works* (November 1936): 16.

bridge in California is remarkable for the degree to which Californians, particularly Bay Area residents, stood together for its construction. That coalition began to fall apart almost as soon as the bridge was opened. But for the festive days in mid-November, 1936, all speakers could agree that the many people of the region agreed on at least one thing, that the Bay Bridge was a good idea and a great bridge.

12.3. The Bay Bridge and the Golden Gate International Exposition

The Golden Gate International Exposition, or GGIE, was originally planned as a celebration of the completion of the Bay Bridge and Golden Gate Bridge. Many of same people – most of them San Franciscans – who had worked in support of the Bay Bridge were also involved in the early planning for the World's Fair. Leland Cutler, for example, helped plan the Bay Bridge, the celebrations in November 1936, as well as the GGIE. A few of the planners for the Bay Bridge also made that transition. Timothy Pflueger and Arthur Brown, Jr., the principal architectural consultants for the Bay Bridge, were also on the Architectural Commission for the exposition and designed some of the individual buildings there.[378]

The fair, however, was held nearly three years after the Bay Bridge had been completed. By the time it opened, neither the Bay Bridge nor Golden Gate Bridge was any longer a novelty. In addition, the mood of the nation and the world had darkened considerably since 1936, as war broke out in Europe and Asia. Although formally dedicated to the accomplishments of these two bridges, the Golden Gate International Exposition had little to do with either. As one measure of the distance between the World's Fair and the bridges, neither of the bridges is mentioned except in passing in a long collection of reminiscences of the fair compiled by Patricia Carpenter and Paul Torah.[379] People remembered the fair, the rides, the exhibits, but no one recalled the fact that the fair was initially intended to honor the two bridges.

Of the two bridges, the Bay Bridge was arguably more directly linked to the GGIE by the fact that the fair occurred on an island mid-span on the bridge. The GGIE was held on Treasure Island, a man-made island built by the Corps of Engineers on the Yerba Buena Shoals, a flat just north of Yerba Buena Island. The Bay Bridge construction effort had contributed to the building of Treasure Island; all of the waste from the Yerba Buena Island tunnel was carried off and used in the fill for the island.

It appears that the exposition had a bigger impact on the bridge than the other way around. Although the bridge had been open to vehicular traffic for more than two years, the bridge railway opened at about the same time as the exposition: the railway opened on January 15, 1939, the exposition on February 18. Neither the vehicular bridge nor the bridge railway had been

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[378] Patricia F. Carpenter and Paul Torah, *The San Francisco Fair: Treasure Island, 1939-1940* (San Francisco: Scottwall Associates, 1989). Brown designed the Court of Honor and the Tower of the Sun. Pflueger designed the Court of the Nation and Court of Pacifica. Irving Morrow, the architect of the Golden Gate Bridge, also designed a building at the fair, the Alameda-Contra Costa Building.

[379] Carpenter and Torah. The bridges are mentioned only in the foreword but not in any of the dozens of interviews in the book.

planned to accommodate any more than incidental traffic from the mid-Bay island; the great focus for both modes had been termini in Oakland and San Francisco. The GGIE, which drew about 10 million people per year, forced the state and the interurban carriers to rethink the basic design of the transportation network. The state elected to develop major improvements to the street access to the fair for automobiles, trucks, and buses, necessitating a separate group of contracts for the Bay Bridge Division.

Although rail service theoretically could have served the fair, the trains traveled through Yerba Buena Island not Treasure Island, which was more than a mile from the entrance to the fair. The interurban carriers elected to serve fair customers through alternative means. The Key System, the dominant carrier, used different means in each of the two fair years, 1939 and 1940. In 1939, the system revived its old rail-ferry system from the Key System Mole. The line temporarily re-opened the ferry building at the foot of the bridge, carrying specially designated "X" (for exposition) lines to the ferry building, where passengers could board ferries which ran on 20- to 40-minute intervals to Treasure Island. In 1940, in a move that signaled the future of the company, the Key System switched to bus service from the East Bay to the fair, while shifting its ferry boats to the San Francisco-Treasure Island service.[380]

In addition to celebrating completion of the bridge, the Golden Gate International Exposition had been planned as a means of paying for the filling of Yerba Buena Shoals, to create land for a proposed San Francisco airport. Treasure Island was not the only airport site eyed by San Francisco; in the late 1920s, the city had acquired land in San Bruno and began operating Mills Field, the site of the modern San Francisco International Airport.[381] The mid-Bay site was nonetheless favored by many business leaders in San Francisco because of its proximity and the fact that it was easily connected via the new bridge. The airport idea, however, fell apart almost as soon as the exposition had closed. By 1940, the Navy was in the second year of what was arguably the greatest military build-up in American history, particularly in California.[382] The Navy acquired Treasure Island from San Francisco on a temporary basis; the Navy would ultimately control the island for nearly 60 years.

The collapse of the mid-Bay airport plan and the Navy build up on Treasure Island foretold events that would change dramatically all aspects of the Bay Area, including the operations of the Bay Bridge. The world's fair had already skewed the anticipated traffic patterns on the bridge; there were many more buses and automobiles using the bridge in 1939 and 1940 than had been expected, owing at least in part to the huge crowds at the fair. The great military build-up, which began long before Pearl Harbor, would only accelerate those trends. The war itself actually retarded bridge vehicular and bus traffic chiefly due to gasoline and tire rationing. In 1945, however, the trends that were first apparent during the fair accelerated at rates that astonished

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[380] Demoro, *The Key System*, 101-102.

[381] Scott, *The San Francisco Bay Area*, 220.

[382] Roger W. Lotchin, *Fortress California: From Warfare to Welfare, 1910-1960* (New York: Oxford University Press, 1992) is the best single volume study of the impact of pre-war preparedness on the economy of the Bay Area and California generally.

most observers. Even before Japan surrendered in September 1945, the leaders of the Bay Area and state transportation officials had begun discussing how to replace, reconstruct, or supplement the Bay Bridge. The unanimity that characterized planning for the Bay Bridge, and which was correctly applauded in the celebration of November 1936, would never come together for another transportation project of such magnitude. The "second crossing" first discussed during World War II was never built, chiefly because Bay Area residents could not agree on where, when, how, or even whether it should be constructed.

13. OPERATION OF BAY BRIDGE AFTER CONSTRUCTION

Since its completion in 1936, the Bay Bridge has operated without interruption, except for about a month in late 1989, when it was closed due to damage from the Loma Prieta Earthquake. The history of the bridge over that period of more than 60 years has been one of yeoman service. Three major developments highlight the role of the bridge in the transportation network of the Bay Area, and help explain the substantial modifications that have occurred to it. These are: consideration of a Second Crossing during the 1950s; reconstruction of the bridge, 1959-1963; and repair and retrofitting of the bridge following the Loma Prieta Earthquake.

13.1. Consideration of a Second Crossing during the late 1940s and 1950s

During the 1940s and early 1950s, a variety of factors conspired to diminish the ability of the Bay Bridge to operate as it had been designed. Among these were: military build-up in the Bay Area before and during World War II, including massive defense contractor work; the decline of the interurbans; construction of freeways on both ends of the bridge; and a general dispersal of population and work sites around the Bay Area. These factors were not unrelated. The decision to build freeways, for example, was at least partially in response to the great increases in population and economic activity spurred by the war effort. Freeways in turn facilitated a dispersal of population and employment centers. The interurbans, as discussed in Chapter 11, declined in part due to internal problems but also in response to changes in driving patterns attributable to improvements in highway service. Whatever the causes, the symptoms of the problem were congestion in the automobile lanes of the top deck of the bridge. As this condition worsened, the most commonly proposed solution was construction of a new bridge to the south, almost always called the Southern Crossing.

In time, however, the Southern Crossing proposal became almost inextricably intertwined with two closely-related issues: what to do with the Bay Bridge, were the interurbans to fail altogether; and how to provide some degree of mass transit service, especially for the East Bay-to-San Francisco commute, again, if the interurbans were to fail? The Southern Crossing proposal would be debated for many decades – it has its proponents today – but the momentum for its construction effectively died in 1958 when the interurbans were removed from the bridge and the bridge was reconstructed for automobiles, trucks, and buses.

The first serious look at a Southern Crossing came from an unexpected source: the War Department. As American involvement in World War II appeared to be all but inevitable, both the Army and Navy began huge build-ups in California, including massive investments in the Bay Area. The Navy was especially active, building a Naval Air Station on fill north of Alameda, a huge supply depot in Oakland, a station on the Treasure Island site of the Golden Gate International Exposition, and a shipyard at Hunters Point in San Francisco. Concerned about the capacity of the Bay Bridge to serve the military traffic, Congress directed the Army and Navy to convene a Joint Army-Navy Board to study the need and feasibility from the standpoint of national defense of the federal government building a bridge between Hunters Point in San

Francisco to Bay Farm Island in Alameda.[383] San Francisco political leaders, concerned at the congestion that had already appeared on the upper deck of the Bay Bridge, supported this federal inquiry. The board, reporting in November 1941, recommended against such a bridge, as it was not necessary for national defense purposes.[384]

Bay Bridge congestion was abated to a degree during World War II due to gasoline and rubber rationing. At the end of the war, however, both the state and federal governments began to re-study the idea of a new bridge. In 1945, the state legislature directed the Department of Public Works to study the feasibility of a new bridge, while Congress in 1946 mandated the creation of a new Joint Army-Navy Board to re-study the issue.

Both state and federal reports were released in January 1947. The state studied eleven different locations for a new bridge but recommended intensive study of two: a high-level bridge, immediately parallel to but slightly north of the Bay Bridge; and a causeway-tube structure between Army Street in San Francisco and Fifth Street in Alameda. The first bridge was essentially a re-creation of the Bay Bridge, reusing old plans wherever possible. The second bridge was a variation on the Southern Crossing, although somewhat further north than other alternatives.[385] The Department of Public Works recommended immediate construction of the parallel high-level bridge. The federal study by contrast focused on three bridge locations, including the causeway-tube Southern Crossing alignment treated in the state report. It also studied a bridge even further south, between Candlestick Point and Bay Farm Island. The Army-Navy Board recommended that one of the Southern Crossing alternatives be adopted. The board also opened the question of how better to provide mass transit to the area. The board concluded that the elevation of rails on the bridge were incompatible with future subway transit development, and urged consideration of an underwater tube, dedicated for transit use.[386] This transit tube idea would ultimately be realized as part of the Bay Area Rapid Transit (BART) system.

Conflicting recommendations – the state's call for a parallel high bridge and the War Department's endorsement of a Southern Crossing – opened a long and sometimes quarrelsome debate among Bay Area communities, tearing apart the consensus that had supported the original Bay Bridge. San Franciscans, concerned about deteriorating transit service by the interurbans, supported the Army-Navy findings, which included a Southern Crossing vehicular bridge (perhaps including through train connections as well), built in conjunction with an underwater tube to improve rapid transit service. San Francisco opposed the parallel structure because of the

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[383] A detailed history of the early planning for a Southern Crossing is presented in Division of San Francisco Bay Toll Crossings, "Southern Crossing of San Francisco Bay," December 1955, California Dept. of Transportation Library, Sacramento.

[384] David W. Jones, "California's Freeway Era in Historical Perspective," July 1989, Institute of Transportation Studies Library, University of California at Berkeley, 266.

[385] Division of San Francisco Bay Toll Crossings, "Southern Crossing of San Francisco Bay," December 1955, California Dept. of Transportation Library, Sacramento, I-4.

[386] Jones, "California Freeway Era," 270; Seymour Adler, *The Political Economy of Transit in the San Francisco Bay Area, 1945-1963,* Berkeley: Institute of Urban and Regional Development, 1980.

disruptive impact that additional approaches would have on traffic in the city. East Bay cities generally supported a parallel structure, reasoning that it could most easily be designed, funded and built.

Although no action was taken on any of these suggestions, the idea of a Southern Crossing was kept alive through the consistent lobbying of San Francisco civic and political leaders. In 1949, the California Assembly appointed a fact-finding committee, with the inclusive title of Assembly Fact-Finding Committee on Tideland Reclamation and Development in Northern California, Related Traffic Problems and Relief of Congestion on Transbay Crossings. This committee hired a Board of Consultants to study means of relieving congestion on the Bay Bridge. The Board included O. H. Ammann, chief engineer of the Port Authority of New York and the designer of the George Washington Bridge, and Ole Singstad, who had worked as the design engineer on the Holland Tunnel and as chief engineer on the Lincoln Tunnel, both in New York City.

In June 1949, the Board of Consultants recommended a three-stage solution to traffic congestion on the Bay Bridge. In Stage I, the railroad service on the Bay Bridge would be removed, freeing up two lanes of roadway for automobile service. In this scheme, the upper deck would have been reserved for automobiles while the lower deck would have served mixed automobile, truck, and bus traffic. In Stage II, a four-lane Southern Crossing Bridge would have been built. In Stage III, the state would have built cantilevered decks on either side of the upper deck of the Bay Bridge, adding four additional lanes, two on either side of the bridge.[387] The Southern Crossing suggested by the board would have begun at about Army Street in San Francisco, proceeding due east across the Bay before turning northeast to land at 5th Street in Alameda. New roadwork on Alameda and a tunnel under the Inner Harbor would have connected the bridge with Clay Street in Oakland.

In October of 1949, the Department of Public Works prepared a major report, which soundly rejected the recommendations of the Assembly Consultants. Among other objections, the department projected that Bay Bridge tolls could not pay for the three stages except over a long period of time, with Stage III being delayed until 1964. The department also concluded that many motorists would choose not to use the Southern Crossing, resulting in continued congestion on the Bay Bridge, even with the new lanes on both decks. The department also felt that unsafe driving conditions would result from the mixed traffic on the lower lanes as well as continued safety problems on the upper deck, which had experienced problems with head-on collisions.

The Department of Public Works ceased to work on the Southern Crossing in 1950. As the Department noted in a 1955 report, "Because of the differences of opinion as to where the next crossing of San Francisco Bay should be built, together with a fundamental disagreement as to the purpose and objective to be served by any new Bay crossing, all work by this Division on the

[387] Division of San Francisco Bay Toll Crossings, "A Report to Department of Public Works on Additional Toll Crossings of San Francisco Bay, As Proposed by Consultants to Assembly Interim Commission," October 1949, California Department of Transportation Library, Sacramento.

parallel bridge was suspended on June 30, 1950."[388] In 1951, several bills were introduced in the legislature to settle the question of where a new bridge should be located, but these failed.

While work on the Southern Crossing ceased, some Bay Area leaders pursued actively the other half of the Army-Navy Board recommendation: that rapid transit be re-built around an underwater Bay crossing, abandoning the bridge's rail connections. In 1951, the California legislature passed legislation to create a commission to study the needs of regional transit called the Bay Area Rapid Transit Commission.[389] In addition to laying a foundation for the creation of BART, this commission weaned the Bay Area communities from their support of the interurbans. When the Key System ultimately decided in 1955 to abandon service, no Bay Area city or county protested. Support for mass transit persisted but was re-oriented toward public rather than private carriers.

The Southern Crossing proposal was revived in 1953, when the legislature passed a law identifying the Southern Crossing as the preferred location for a second bridge, on an alignment between Third and Army in San Francisco and Bay Farm Island in Alameda. The 1953 legislation set in motion a series of detailed studies by the state, as well as applications for necessary permits from the War Department. In 1955, the Division of Bay Toll Crossings submitted a detailed plan for a Southern Crossing to the legislature. The undertaking stalled, however, due to financial considerations. Specifically, the Division of Bay Toll Crossings concluded that 25-cent tolls on the Bay Bridge and the new Southern Crossing would not be sufficient to pay for construction of the Southern Crossing. The department concluded that the residents of the Bay Area, who had fought hard to get the Bay Bridge toll down to a quarter, would raise "considerable opposition to raising tolls."[390]

Other events also worked to kill any momentum toward building a Southern Crossing. The most important development was the decision by the Key System in 1955 to seek permission to abandon its lines across the Bay Bridge. This decision essentially sealed the fate of the Southern Crossing. If the rails were to be removed, the Bay Bridge capacity for automobiles, trucks, and buses would be increased by about 25 percent. To maximize use of that new capacity, however, would require fundamental reconstruction of many elements of the bridge, a job that would absorb for years to come any excess toll revenues available to the state. In addition, San Francisco, Oakland, and other supporters of BART, began to campaign for use of Bay Bridge revenues (which were in surplus by the late 1950s as the original bonds were quickly being retired) to subsidize construction of a mass transit tube under the Bay.[391] While a surplus existed, it was not nearly enough to maintain the existing bridge, reconstruct it for vehicular traffic only, build an underwater transit tube, *and* pay for a Southern Crossing. Although the state would continue to study and to some degree lobby for a Southern Crossing through the 1970s, the strong

[388] Division of San Francisco Bay Toll Crossings, "Southern Crossing of San Francisco Bay," December 1955, 1-5.
[389] Jones, "California's Freeway Era," 273.
[390] Division of San Francisco Bay Toll Crossings, "Southern Crossing of San Francisco Bay," October 1956, California Dept. of Transportation Library, Sacramento, I-3.
[391] Jones, "California's Freeway Era," 279.

campaign for such a bridge died in 1955 with the decision of the Key System to abandon its use of the Bay Bridge.

13.2. Reconstruction of the Bay Bridge, 1959-1963

The abandonment of the interurban lines on the Bay Bridge ultimately settled the issue of whether to build a Southern Crossing or rebuild the Bay Bridge. The failure of the interurbans freed up approximately one-quarter of the available roadway on the bridge, theoretically increasing the capacity of the bridge for automobiles, trucks, and buses by about that amount. State planners argued that the capacity would actually increase by 35 percent, despite the fact that the lanes on both decks were to be restriped at the time of the reconstruction, reducing the number from six to five in each direction.[392]

The Key System petitioned to abandon its line in 1955; in 1956, the California Toll Bridge Authority ordered its staff to begin planning for the best use of the abandoned rail lanes. In 1957, the legislature authorized this study and appropriated funds for that purpose.[393] In its preliminary report, the staff estimated that the work would cost $35 million and in 1957, the legislature ordered the authority to proceed with the work.[394]

At first glance, the abandonment of the interurban lines would appear to affect structurally only the southern half of the lower deck of the bridge, i.e. the quarter of the bridge that had been used by the trains. In actuality, however, the loss of the interurbans affected all aspects of traffic on the bridge, leading to the decision to transform the bridge into two one-way decks for mixed traffic. Unidirectional traffic in turn would require massive reconstruction of the bridge. If the state had not decided on unidirectional traffic, the full lower deck would have been reserved for the exclusive use of trucks and possibly for buses, which were to replace some part of the service the interurbans. The total bridge traffic, however, was far busier than anyone had anticipated. In 1930, the state had projected that 10.8 million vehicles would cross the bridge annually.[395] By 1950, the actual count was nearly 33 million and growing to over 40 million by the time of the reconstruction.[396] Lane space under such conditions was an extremely valuable commodity. There was little sentiment for leaving the lower deck for trucks and buses alone. If the capacity of the bridge were to be optimized, the logical plan was to reconfigure traffic for two one-way decks each carrying mixed traffic.

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[392] Norman Raab, quoted in Seymour Adler, *The Political Economy of Transit in the San Francisco Bay Area, 1945-1963,* Berkeley: Institute of Urban and Regional Development, 1980, 252.

[393] N. C. Raab, "Bay Bridge: First Phase of Reconstruction for Added Capacity Completed," *California Highways and Public Works*, July-August, 1960, 36. The state's plan for reconstruction was not without controversy. East Bay transit supporters hoped to preserve the bridge rails for future public mass transit or to preserve the train lanes for exclusive bus service. Adler, *Political Economy of Transit,* 260-261.

[394] Division of Bay Toll Crossings, Department of Public Works, "Reconstruction of the San Francisco-Oakland Bay Bridge," March 1957. The authorizing legislation is included as Appendix B-1.

[395] Hoover-Young, 54.

[396] N C. Raab, "Bay Bridge: Second Phase of Reconstruction Nearing Completion," *California Highways and Public Works,* January-February, 1962, p. 37.

The reconstruction of the bridge was complicated by three factors. First, it was difficult to finance. The state was reluctant to take on additional bond obligations for the work, particularly since the Bay Bridge was generating a surplus of about $8 million a year.[397] That surplus was not adequate, however, to fund the entire $35 million reconstruction at one time; the work therefore needed to be staggered on a "pay-as-you-go" basis over several years. Second, the bridge could not at any point be closed to traffic; it was already one of busiest stretches of roadway in the country by 1957 and total closure was unthinkable. Third, the engineering for the work was far more complex than might have appeared at first glance.

The technical problems of reconstructing the bridge stem from the fact that it had been designed for a particular mix of traffic on each of the two levels and the traffic mix would change dramatically on both levels after reconstruction. The upper deck was designed for automobile loading and heights; only the lower deck was designed to carry a significant number of heavy vehicles and only the lower deck was tall enough to carry trucks through the Yerba Buena Island tunnel. The basic challenge for work on the bridge proper was two-fold: to strengthen the upper deck to carry truck and bus traffic; and to rebuild both decks in the Yerba Buena Island tunnel, to gain room for trucks and buses in the upper deck through the tunnel. The task was complicated, of course, by the decision not to close the bridge at any time during the reconstruction. A third task, equally complicated, involved reconstruction of the approaches on both ends of the bridge to accommodate the new unidirectional traffic pattern and to reuse the old railroad loop in San Francisco to accommodate use of the Transbay Terminal by buses. This task was made more difficult by the fact that freeways had been built or were under construction on both ends of the bridge, necessitating that the new connections be built to freeway standards and traffic distribution patterns.

Recognizing their funding problems and the need to keep the bridge open to traffic, state planners elected to accomplish the reconstruction work in three phases between 1959 and 1963. The first phase dealt chiefly with the San Francisco approaches and bus links to the Transbay Terminal. The busway reconstruction was relatively simple because the loop was built to accommodate heavier loads than needed for the buses, and because the buses would in the short run continue to use the lower level for both directions of travel. Buses were using the loop and the Transbay Terminal building by July 1959.[398]

Before any work could begin on the San Francisco approaches, however, it was necessary to decide which level of the bridge would be westbound and which eastbound. This decision was made on the basis of the work requiring the lesser degree of reconstruction of the San Francisco approaches. Making the top level westbound was less disruptive, although still very complex. The approaches were rebuilt in 1959 and 1960 to accommodate two one-way traffic, although the new traffic pattern could not be used until the bridge itself was reconstructed in later phases. The 1959-60 rebuilding of San Francisco approaches affected all of the original ramps as well as the

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[397] Division of Bay Toll Crossings, "Reconstruction..." 24.

[398] N. C. Raab, "Bay Bridge: First Phase of Reconstruction for Added Capacity Completed," *California Highways and Public Works*, July-August, 1960, 37.

many newer connectors to the James Lick and Central freeways, which were built in the early 1950s. The first phase work also involved strengthening the upper deck of the viaduct in San Francisco to accommodate truck and bus traffic, chiefly through the installation of prestressed concrete floor beams.[399] During the first phase, the state also paved the area of the lower deck of the West Bay Crossing previously used by the trains, opening those lanes for use by trucks and buses.

The second phase of work on the bridge, which took place in 1961, included paving the rest of the train track spaces, reconstructing the Yerba Buena Island tunnel and viaducts, and strengthening the upper deck on the West Bay Crossing. The paving of the roadway was a routine step. The strengthening of the upper deck and reconstruction of the tunnel were far more demanding tasks.

Strengthening the upper deck was the easier of the two. The bridge had been designed for a very heavy loading, owing to the anticipated presence of many rail cars as well as the weight of the rails on the lower deck. Removal of the rails and railroads gave the designers a considerable cushion with which to add new members to the upper deck.[400] This problem was solved chiefly by installing new transverse joists midway between the originals, effectively cutting in half the spans of the deck members.

The tunnel reconstruction proved to be far more difficult. As one participant recalled: "Reconstructing the decks in the Yerba Buena tunnel and the adjacent concrete viaducts taxed the ingenuity of the designers, the fortitude of the contractors, and the cooperation of the commuters." [401] Much of the work on strengthening the upper deck could be accomplished while working in the lightly traveled lower deck, without affecting traffic on the upper deck. To create clearance for trucks on the upper deck, however, required lowering the upper deck 16", something that could not be accomplished without some impact on upper deck traffic.

The key to the reconstruction was a temporary movable construction bridge mounted on the bottom of the upper deck. This device was called a "movable steel bridge" by its designer and had a span of 26' (i.e. covered 26' of roadway) and a width of 58', the width of the tunnel. The tunnel reconstruction may be seen as constituting four basic steps. In the first step, the truck lanes on the bridge were lowered to meet the grade of the railroad lanes. The railroad lanes on the south side of the tunnel were about one foot lower than the truck lanes, which occupied the northern half of tunnel. By lowering the truck lanes, the tunnel deck achieved a uniform grade and provided clearance for lowering of the top deck. In the second step, the movable bridge was put into place. The temporary bridge was the height of the unreconstructed deck, allowing all work to proceed below it. Working only at night, workers would saw away the upper deck;

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[399] N. C. Raab, "Bay Bridge: First Phase of Reconstruction for Added Capacity Completed," *California Highways and Public Works*, July-August, 1960, 38-40.

[400] The design loading was 7000 lbs./ft., while the new loading was 4800 lbs./ft. Removal of the rails reduced the loading by another 1000 lbs./ft. Charles Seim, "A Second Life," *Civil Engineering*, October 1986.

[401] Seim.

traffic would continue but driving only on the temporary bridge. Work took place in one half of the lower deck at a time to retain half-deck service for the trucks. In addition to removal of the old deck, the original center piers in the tunnel were removed. New precast, post-tensioned concrete deck units were brought to the site and hoisted into place, again, on one half of the bridge at a time.

The third and final phase of the work was accomplished in 1962 and 1963, and involved strengthening the upper deck on the East Bay Crossing, resurfacing of the upper deck, and additional approach reconstruction. As a final step, the state built a connector to the railroad (now bus) loop in San Francisco to provide access for westbound buses, which previously had used the lower deck exclusively.

Of the various elements of the third phase of work, strengthening the upper deck proved to be the most complex. The principal objective of this work was to reduce the length of the longitudinal spans for the deck slabs. In a manner similar to work on the West Bay, new joists were installed midway between the existing joists, which were attached to the existing stringers. Adding "understringers" reinforced the stringers themselves. These additional stringers were bolted into the bottom flanges of the original stringers.[402]

The East Bay Crossing was resurfaced, in part because the deck was already showing fatigue after 27 years of use, and in part to get rid of the tiles that had delineated the six lanes of traffic. A lightweight compound was used to minimize dead load on the upper deck and the bridge generally. In addition to repaving, this phase of work resulted in a new ramp for buses in San Francisco and reconstruction of the approaches to Yerba Buena Island. The reconstructed bridge opened to unidirectional traffic on October 12, 1963. The project engineer for the state was N. C. Raab, who had worked with the Bay Toll Crossings/Toll Bridge Authority since it was created in 1932. Raab retired three months before the rebuilt structure was opened to traffic.

This reconstruction would change the Bay Bridge in terms of its appearance as well as its function. The work had a considerably negative impact on the historical integrity of the Bay Bridge; the Bay Bridge has been modified to a much greater extent than the Golden Gate Bridge, for example, with the bulk of those modifications attributable to the 1959-63 work. This work changed the function of the bridge to the extent that it removed rail service and integrated automobile traffic with trucks and buses. The reconstruction did not change traffic patterns in the Bay Area, however, so much as changes in traffic patterns forced the reconstruction. By the time the work was completed in 1963, the thinking of Bay Area planners had shifted to a broader regional transportation plan, in which mass transit would be carried in its own Bay crossing, with the Bay Bridge serving as a trunk line connecting to a half dozen freeways that met at both ends of the bridge. The reconstructed bridge was no longer a multi-modal structure but a connector between some of the busiest highways in the world.

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[402] E. R. Foley, "Bay Bridge Reconstruction," *California Highways and Public Works*, March-April 1964, 48.

13.3. Failure of the Bridge during the Loma Prieta Earthquake; Impacts of Retrofit Work on It

The Bay Bridge remained unchanged structurally between the completion of the reconstruction in 1963 and the disastrous Loma Prieta Earthquake in 1989. During that quarter century, the bridge served in its new vehicular-only capacity, while much of the rest of the Bay Area transportation network evolved rapidly. The Bay Bridge arguably became less important during those years simply because the transportation options multiplied. In no sense, however, did it fade into insignificance. The bridge was by far the busiest structure in the area and the key link between the East Bay and San Francisco. At the time of the reconstruction, for example, the bridge was rebuilt to handle a capacity of 110,000 cars daily. It was carrying about 240,000 cars a day at the time of the earthquake.

Just how important it was became dramatically apparent at 5:04 PM on October 17, 1989. Fortuitously, the afternoon rush hour traffic was lighter than usual that day, a condition that is generally attributed to the fact that the third game of the 1989 World Series was set to begin at 5:30 PM at Candlestick Park in San Francisco, a game involving the two Bay Area professional baseball teams, the San Francisco Giants and the Oakland Athletics.[403] Traffic eastbound on the bridge was moving at an average speed of 48 mph, while westbound was moving at 54 mph.

The California Highway Patrol later attempted to reconstruct the series of events that occurred just after the earthquake struck. A high percentage of drivers were listening to pre-game coverage of the World Series on their car radios and first recognized a problem when the radio stations went off the air. The physical sensations associated with the quake differed on the various structural elements of the bridge, ranging from mild to violent shaking of vehicles. Drivers in the tunnel reported feeling no movement but were aware of problems because the tunnel lights went out. Drivers on the suspension span felt a side-to-side movement on their vehicles. The most violent movement was felt by drivers on the East Bay Crossing, particularly by those on the through truss spans. These drivers immediately slowed down to a 10 to 30 mph speed and there were few accidents attributable to the earthquake or subsequent slowdown in traffic.

The earthquake caused little noticeable damage to the bridge except at Pier E-9, which is the juncture of the through truss and continuous deck truss sections of the East Bay Crossing, about one-half the distance between Oakland and Yerba Buena Island. The E-9 tower is unique among the Bay Bridge piers. It was built in a four-column box shape, with one side supporting the eastern end of the through truss bridge and the other side the western end of the continuous truss, with two 50-foot connectors spanning the two bridge types. These metal beam deck connectors were rigidly attached to the continuous trusses but were free moving on bearing seats on the through truss side. The earthquake apparently caused the through truss and continuous truss sections to move in opposing directions, with the continuous truss element moving farther and

[403] This was the conclusion of the California Highway Patrol. State of California, Department of Highway Patrol, "Loma Prieta Earthquake Summary Report," 1990, 4.

faster than the through truss; the continuous truss is thought to have moved 5 1/2 inches to the east and about an inch to the north.[404]

Both 50-foot connectors fell, probably because the top deck fell first, impacted the lower deck, causing it to fail as well. The fall was from the west side, where the connectors were on seat bearings. The lower deck remained attached on the east end, while the upper deck broke on both ends and became wedged in a ramped position between the lower and upper deck levels. The bridge at that point was effectively closed in both directions, with the closure situated about one mile west of Oakland, approximately midway between Oakland and Yerba Buena Island.

Relatively few vehicles were on these connectors when they failed. One automobile was westbound on the upper deck when it collapsed. The driver had come to a full stop in response to the motion of the earthquake. When the top deck fell, the automobile fell with it, wedging in a ramped position with the upper deck, resting against the beams of the lower deck. The driver and his female passenger crawled out through the car windows and walked back to Oakland. Both were seriously injured and the car, in the view of the Highway Patrol, suffered "total damage."[405] A motorcyclist was traveling at an estimated 75 mph and just missed going over the brink of the collapsed section. He was able to turn around and drive back to San Francisco. A commuter van, filled with 13 people was headed east on the lower deck and happened to be crossing Pier E-9 when the top deck fell. The upper deck struck the van as it was crossing the pier; the van was able to climb up the lower deck, which was sinking as well, and arrived in Oakland with relatively little damage.

The only fatality associated with the failure occurred as hundreds of vehicles on the bridge attempted to find a way off. No police were on the bridge at the time of the earthquake. Some drivers left their vehicles to work as traffic police, as did a tow truck operator for the California Department of Transportation and employees of the Navy Station at Treasure Island. Together, these volunteers helped stage a reasonably orderly evacuation, generally by directing traffic to turn around and drive against the posted directions toward San Francisco and Oakland on both decks.

Westbound traffic east of the collapse was easiest to redirect; these drivers simply turned around and drove one mile east to Oakland, traveling the wrong way on the upper deck. Eastbound traffic east of the collapse simply continued in the approved direction. Traffic west of Yerba Buena Island also dispersed easily; the westbound traffic continued in the approved direction to San Francisco, while eastbound traffic turned around and returned to the city driving the wrong direction. Those who could exited at Yerba Buena Island and crossed up to the upper deck, returning by driving in the approved direction. The problem arose for traffic that was east of Yerba Buena Island but west of the collapse. These drivers could not return to Oakland and could proceed to San Francisco only after the traffic west of them had been cleared away. In addition, no volunteer or official traffic control emerged in this area and drivers were left in a

[404] State of California, Department of Highway Patrol, "Loma Prieta Earthquake Summary Report," 1990, 10.
[405] State of California, Department of Highway Patrol, "Loma Prieta Earthquake Summary Report," 1990, 10.

state of confusion.

The lone fatality occurred along this stretch of bridge, east of the island and west of E-9. A female driver and her brother were eastbound on the bridge near Yerba Buena Island when the earthquake struck. The traffic came to a complete halt when she was just east of the island. At the instruction of a Caltrans worker, she turned back to the island and drove around to the upper deck, headed to San Francisco. For reasons now unknown, the driver suddenly turned the car around, headed east, and drove toward Oakland at a high rate of speed. She was traveling an estimated 49-mph at the time she hit the gap at E-9. The car was airborne for about 40 feet, striking the steel of the collapsed upper deck. The driver died instantly; her brother survived.[406]

Chaos reigned for only a few hours until the bridge could be cleared, but the disruption to the transportation network was much more long-lived. Although there were hundreds of incidents of isolated damage, the greatest impact of the Loma Prieta Earthquake was felt at the Bay Bridge and at the two-level Cypress Structure, which fed traffic into the bridge in Oakland. The Bay Bridge would be repaired in about one month; the Cypress reconstruction was still in progress nearly a decade later. The difference may be explained by the relatively minor damage to the Bay Bridge; the Cypress Structure was destroyed altogether and could not be repaired. It may be explained, as well, by the relative importance of the two structures. There were ways around the Cypress Structure; the Bay Bridge stood alone as a link between Oakland and San Francisco.

Work done to the Bay Bridge after Loma Prieta may be seen as comprising three phases, each increasingly complex and expensive. The first step was a relatively minor repair to the two collapsed 50-foot sections at Pier E-9. This work was designed in a great hurry by a team of engineers from the Department of Transportation, headed by Bob Bridwell. The damaged sections were cut into pieces and craned away from the site. New girder seats were installed at the edges of the remaining floor beams from the through truss and continuous truss sections. New I-beams were installed on those seats and precast deck sections were laid over the beams.[407]

The second, far more complex, task involved retrofitting the bridge, the better to withstand future seismic events. The final phase may involve construction of a new East Bay Crossing between Yerba Buena Island and Oakland. The second phase has only begun at the time of this writing, while the third phase is under discussion. This work, which will change the appearance of the Bay Bridge far more than the 1959-63 reconstruction, is part of the future of the Bay Bridge, not part of its history.

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[406] State of California, Department of Highway Patrol, "Loma Prieta Earthquake Summary Report," 1990, 10.

[407] This work is described in two articles in *Going Places*, the in-house magazine of the California Department of Transportation. November-December, 1989, 5; January-February, 1990, 10-11.

14. SIGNIFICANCE OF THE BAY BRIDGE

The Bay Bridge has such an institutional presence in the Bay Area that it is difficult to identify separable aspects of it or areas in which it has achieved significance. The three areas of significance addressed below – transportation, engineering, and political history – capture most of the significance that the bridge has achieved over the years. These areas overlap, however, and have implications for a wide range of social, economic, political, and technological issues in the Bay Area and California generally.

14.1. Significance in Transportation

The importance of the Bay Bridge in the transportation history of the Bay Area and California is ultimately best measured quantitatively, by the standard measure of traffic volume, the Annual Average Daily Traffic, or AADT. The AADT for the Bay Bridge in 1998 is about 274,000 or more than one-quarter of a million automobiles, trucks, and buses crossing the bridge each day.[408] Rarely in the history of bridge construction have such figures been equaled. The figures for other Bay Area bridges are high but only a fraction of that for the Bay Bridge. The AADT for the Golden Gate Bridge, for example, is 116,000, while the figure for the Carquinez Bridge is 105,000. In California, the only structures with comparable or larger AADTs are freeway interchanges, which are bridges only in the most generous definition of the term.[409] At present and in recent decades, the Bay Bridge has achieved profound importance to the transportation history of the Bay Area simply on the basis of the volume of traffic it carries, which is an astonishing number. Virtually all of this traffic enters or leaves the Bay Bridge through freeway connections in San Francisco or on the East Bay approach.

The status of the Bay Bridge as a connector for a series of freeways, however, dates only to the post-war era; it has functioned well in that capacity only since the 1959-1963 reconstruction. It was not intended for the bridge to operate in that manner; the expectation at the time the bridge was built was that the bulk of people crossing it would do so in interurban trains and in buses. The larger role of the Bay Bridge in the transportation history of the Bay Area must be appreciated in the manner in which it was transformed from a multi-modal structure to a trunk-line freeway connector. Of particular interest is the question of the degree to which the bridge itself affected the trends that led to its transformation.

As shown in earlier chapters, the transportation network of the Bay Area was already in transition at the time that the Bay Bridge was first planned. The political campaign to build the bridge proceeded throughout the 1920s, a decade in which automobiles and trucks emerged as major elements of the local transportation network. It is difficult to overestimate the importance of the

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[408] AADT data is from California Department of Transportation, Traffic Operations Program, Traffic and Vehicle Data System Unit, web page. The date of collection for data varies from one route to another, but is no older than 1996.

[409] The Santa Monica Freeway, for example, has an AADT of 320,000. Major interchanges have combined AADTs of more than half a million.

emergence during the 1920s of the automobile as the transportation mode of choice for most Californians. The huge increase in automobile registration and use during the 1920s contributed greatly to the economic prosperity of that decade and transformed virtually every aspect of transportation in California and the nation, and had profound impacts as well on settlement patterns, patterns of retail sales, and a host of other aspects of community development. Although automobile sales increased nationally, automobile manufacturers regarded California as the "bottomless pit" market for their products. California had led the drive toward automobile use even before 1920 and maintained a huge edge over the rest of the nation in automobile registration at the end of the decade.[410]

While the interurban rail lines remained the primary commuter mode in the Bay Area in 1930, those lines were rapidly losing their share of the commuter market to automobiles. This trend toward transbay automobile commuting was pronounced, despite the long ferry rides and high ferry tolls needed to sustain that trend. There are doubtless many reasons for the growing preference for automobile commuting; these reasons have been explored at length in many studies. To many writers, the choice of the automobile was not merely a transportation preference but was part of a cultural phenomenon: hence, the term, "car culture," which is more closely associated with California than any other place.[411] Whatever the combinations of reasons for it, the fact is that great numbers of the people of the Bay Area during the 1920s adopted the automobile as their preferred commuter mode, as well as the preferred transportation mode for all purposes. This interest in automobile transportation was not restricted to the East Bay-to-San Francisco commute. Traffic congestion appeared everywhere in the Bay Area during the 1920s, and state and local transportation agencies responded by constructing new or improved highways in all parts of the Bay Area.

The decade of the 1920s was notable for the many daring transportation projects that were planned or built in the Bay Area, one of which was the Bay Bridge. Most of the other important transportation undertakings were set aside for the exclusive use of automobiles and trucks. This was the case with the Bayshore Highway and East Bay Highway, the Caldecott Tunnel, and the Golden Gate, Carquinez, and Dumbarton bridges. The Bay Bridge certainly fits with this group of projects in that 75 percent of its lane capacity was devoted to automobiles and trucks. The Bay Bridge was also distinct within that group, however, in that it included lanes for mass transit use, lanes that were provided at tremendous expense to the state. However unsuccessful the attempt may have been, the planners of the Bay Bridge went to great lengths to ensure that the bridge would be useful for mass transit as well as automobile and truck usage.

The long-range significance of the Bay Bridge in the transportation history of the Bay Area is not that it became an automobile-truck bridge after 1963 but that it was planned as a multi-modal

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[410] The crucial place of California in this regard is highlighted in: James L. Flick, *The Car Culture*. Cambridge: MIT Press, 1975. Flick credits automobile sales for the prosperity of the 1920s and points to declining sales late during the 1920s for contributing to the depth of the Great Depression.

[411] Flick, *Car Culture*. Flick also uses the term, "automobility" to refer to the range of other changes that came as a result of widespread automobile use, including road improvements, parking lots, suburban settlement patterns, automobile-oriented shopping areas, and so forth.

structure in the early 1930s. The design of the Bay Bridge was a summation of the elements of the transportation system that existed in the region during the late 1920s and early 1930s. The designers of that bridge, led by officials of the Division of Highways, never seriously considered building it as a highway-only structure. From the outset, those planners and designers and all of their political allies in the Bay Area, assumed the bridge would include a substantial mass transit component. While it responded to a clear trend toward automobile travel, the bridge was designed to reflect the realities of transportation in the area at the time, specifically to the fact that interurban commuting was an important part of the network and was projected to continue so into the foreseeable future.

Two things happened to change those projections: automobile use continued to increase, even during the Great Depression, and the interurban lines failed. The failure of the mass transit element of the Bay Bridge may be attributed to short-term as well as long-term developments. In the short run, the failure of the state to reach agreement with the interurban lines delayed operation of the mass transit system for more than two years, between November 1936 and January 1939. Those two years no doubt were crucial in introducing Bay Area commuters to the pleasure of quick and relatively congestion-free automobile commuting across the Bay Bridge and likely accelerated the diversion of the commute pattern from rails to automobiles. The World's Fair in 1939 and 1940 may have actually hurt the cause of the interurbans in that the trains could not compete with buses or automobiles because they could stop only at a distance from the fair grounds. The interurban lines contributed to their own demise by running buses over the bridge, competing directly with their own trains. And, of course, two of the interurbans (the Southern Pacific and Sacramento Northern) simply quit the business after about two years, with little attempt to develop a ridership base. The National City ownership, which bought the Key System in 1946, had little interest in salvaging the distressed rail operation. The National City group bought the line at a time in which it desperately needed major investment to modernize its equipment; the group did not make those investments and began to shut down rail lines in favor of buses within a few years of its purchase of the system.

In the long run, however, it may be concluded that the private mass transit carriers were already beginning to fail before the bridge was built. This failure arose from a combination of factors, including many internal problems with the companies. They were collapsing chiefly due to decreasing patronage, which may be attributed in turn to increasing popularity of automobiles or to declining interest in the slow and increasingly antiquated interurbans, or, more likely, through a combination of both factors. In any event, one conclusion is inescapable: the state did not force the interurbans from the Bay Bridge. One by one, the carriers abandoned the service of their own accord.

Transportation planning in the Bay Area followed separate and sometimes contradictory patterns after 1945 and particularly after the failure of the Key System in the 1950s. In one trend, the Bay Area was ringed with freeways, many of which were fitted with direct connections with the reconstructed Bay Bridge. In the other trend, Bay Area counties assembled the Bay Area Rapid Transit (BART) system, one of the more comprehensive rapid transit systems in the nation, as well as a host of smaller publicly-owned commuter lines, including the Alameda-Contra Costa, or

A-C system. There were supporters of both trends; indeed, many interests supported both as necessary components of a balanced transportation network. The fact that BART is in many instances built in freeway medians or shoulders is indicative of this kind of thinking, in which both freeways and mass transit are considered as necessary parts of an integrated transportation system.

Ultimately, the supporters of mass transit and freeway construction would do battle in San Francisco in what has been called the "Freeway Revolt" of the late 1950s and early 1960s.[412] San Franciscans took a stand that freeways, particularly elevated roadways, were not in keeping with the visual fabric or the transportation network of their city. That decision was not, however, binding on the other communities in the Bay Area. Freeway construction and widening proceeded apace outside San Francisco long after the "Freeway Revolt" and is ongoing today.

The simultaneous investment of Bay Area communities in mass transit and freeway construction resulted in a transportation network that is unique in California and unusual in the national perspective as well. It is as if the people of the Bay Area have embraced settlement patterns that are characteristic of both the East and West Coasts, of, say, Manhattan and Los Angeles. BART is quite successful; the daily ridership on BART is nearly the same as the AADT on the Bay Bridge (250,000 passengers on BART, 274,000 vehicles on the bridge). And BART is by no means the only mass transit agency in the Bay Area; separate but smaller districts operate in each of the Bay Area counties and other lines, such as the Peninsula Commute Service, are operated by joint power arrangements among several jurisdictions. BART and the smaller lines now handle most of the transit responsibilities that were originally assigned to the interurban elements of the Bay Bridge.

The bridge after 1963 assumed its current role as freeway connector across the Bay, a role that has grown increasingly more important through the years. The engineers who rebuilt the bridge, for example, thought it had a capacity of 110,000 AADT, less than half what it now carries. This huge increase occurred in large part in the years after BART had become operational. Bay Area residents have expressed their transportation preferences through their actions; many drive, many use mass transit. The nearly equal numbers of passengers on BART and vehicles on the Bay Bridge symbolize this two-mindedness of the people in the area in this regard.[413]

The place of the Bay Bridge in the transportation system of the Bay Area, then, must be understood in two parts: before and after 1959. Immediately upon construction, the bridge assumed a place at the very center of the transportation network of the region, carrying mass transit as well as highway traffic. Its role in the larger transportation has changed dramatically but not its importance.

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[412] This "revolt" is chronicled in detail in David W. Jones, "California's Freeway Era in Historical Perspective," Berkeley: Institute of Transportation Studies, 1989.

[413] The Bay Bridge was a financial supporter of mass transit, long after the interurban lines had been removed. The underwater tube for BART was funded by revenues from the Bay Bridge, based upon legislation passed in 1962. "BART History," BART web site; Adler, *Political Economy of Transit*, 268.

14.2. Significance in Engineering

In 1952, the American Society of Civil Engineers, as part of its centennial year celebration, decided to select "Seven Wonders of the United States," based upon the significance of these "wonders" in the field of civil engineering. The selection was finally made in 1955. Thirty-three projects were considered in the final group, from which a seven-member committee selected the seven finalists. The Bay Bridge was the only bridge or highway-related structure in the group.[414] The ASCE designation does not suggest that the Bay Bridge is the only significant American bridge, nor does it necessarily indicate that the Bay Bridge is the most significant of American bridges. It does, however, affirm that the Bay Bridge belongs with the first rank of important American bridges when considered from the standpoint of engineering achievement.

Just as transportation significance lends itself to a quantitative measure, the significance of the Bay Bridge in engineering history has most often been stated in numerical terms. At the time it was built, state engineers pointed with pride to the superlatives of the structure: its great length (four and one-half miles over water, the longest in the world); the great depth of its piers (over 230 feet, the deepest in the world); the great total length of the suspension span (the combined length of the suspension bridges was greater than any other suspension span); the great length of the cantilever span (1400', the third longest in the world and longest in the United States); the great masses of concrete, steel, wood, and other materials that went into the bridge; and so forth.

The superlatives associated with the Bay Bridge are true and accurate measures of the greatness of the accomplishment and are excellent indicators of the importance of what the bridge engineers achieved. There is no indication that the designers of the bridge set out to establish world records, although they realized early on that such records unavoidably would be broken. Rather, the bridge designers set out to accomplish a particular goal – building a double-deck, multi-modal structure between Oakland and San Francisco. That was their goal and accomplishment; the world's records came along naturally.

A more discrete analysis of the significance of the Bay Bridge may be submitted by emphasizing four aspects of its design and one aspect of the process through which it was designed. The most distinctive element of the design process was the fact that the bridge was designed in a period of about two years, and was built in about three years. The most distinguished elements of the design are: the total length of the bridge; the use of a double-suspension bridge design on the West Bay Crossing; the great depth of its piers; and the use of multiple bridge types in a single structure. Each will be analyzed separately below.

The great haste with which the Bay Bridge was designed and built may be explained by the desire of the leadership of accomplish four goals: to fulfill promises made to the governor, the

[414] The October 1986 edition of *Civil Engineering* includes a discussion of this process. This issue was largely devoted to a history of the Bay Bridge, upon its 50th year. The other six "wonders" are: the Chicago sewage system; the Colorado River Aqueduct; the Empire State Building; Grand Coulee Dam; Hoover Dam; and the Panama Canal, which was still part of the United States in 1955.

legislature and political leaders in the Bay Area; to get the bridge paying revenue as soon as possible to cut down on huge interest payments to the RFC; to put people to work as soon as possible; and to get the plans finalized as soon as possible to have a project that could be approved by various governmental agencies, particularly the War Department and the RFC. C. H. Purcell and the Bay Bridge Division had made many promises during the course of nearly a decade-long political campaign for approval of the bridge. They no doubt felt a moral and political need to deliver on those promises as soon as possible; that need was referenced repeatedly in their correspondence. The need to avoid interest charges was also frequently cited as a requirement for early project completion. Early during the design process, the engineers were forced to move plans along in order to have a project plan that could be approved by the War Department and the RFC. Finally, all parties involved cited the need to get the project under construction in order to provide thousands of good paying construction jobs for Depression-ravaged Californians. This, of course, was one of the key promises made to the political leadership and one of the most convincing arguments for approving the project.

For all of these reasons, the Bay Bridge Division state employees and the Board of Consulting Engineers labored at a pace that is unthinkable under ordinary circumstances today. Only in rare instances in recent decades have major projects been designed and built at this pace. The repair of the Bay Bridge after the Loma Prieta Earthquake and the rebuilding of major Southern California freeways after the Northridge Earthquake were accomplished with this type of dispatch. These were done, however, under emergency circumstances. There was no such emergency in 1930, except for the general emergency of the Great Depression. The Bay Bridge was designed as if there were such an emergency, but the urgency had as much to do with making good on political promises as with solving a transportation emergency.

The fact that the Bay Bridge is very long – more than four miles across the water – is in many respects a summation of many of the other important design elements. The double-suspension span, for example, would not have been necessary except for the great length from San Francisco to Yerba Buena Island. The deep piers relate to the terrible foundation conditions across the Bay, and not to the great total length. The poor foundation conditions were exacerbated, however, by the fact that the bridge was so long, making it unavoidable that some of the piers would have to be built in the worst areas of the Bay floor. The Golden Gate Bridge, for example, also had relatively poor foundation conditions and its pier work was very difficult. The pier difficulties, however, were minimized because there were only two of them, which could be built relatively close to the shoreline, where conditions were best. The use of multiple bridge types is more a function of the poor foundations than the total length of the bridge. Again, the great length increased the number of piers, and the superstructure types were selected, especially on the East Bay Crossing, as a response to foundation conditions. The fact that the Bay Bridge is more than four miles long is impressive in and of itself. It is especially impressive, recognizing the related engineering problems that went with that length. The dramatic length also helps explain the importance of the bridge in transportation terms, defining the great crossing that the bridge solved. In the end, the great length of the bridge defines its significance in bridge engineering as well as its significance in transportation history. Brave and heroic engineering achievements were needed to solve the problem of how to bridge San Francisco Bay. The will to undertake

such a great challenge was fortified by the fact that the bridge was badly needed.

The double-suspension span of the West Bay Crossing was so unusual that it is best considered as the first of its kind.[415] There is no indication that the engineers working on the bridge went out of their way to develop a unique bridge type. The correspondence between the various engineers, particularly those on the Board of Consulting Engineers, sometimes included indications of a desire to build new and daring bridge types. It was a tempting possibility, given the great sums that were to be spent and the great engineering challenges. There was, however, surprisingly little discussion of such matters. Leon Moisseiff and Daniel Moran were advocates for one grand suspension bridge that would be two miles long between San Francisco and Yerba Buena Island. Their support for this huge span was based at least in part on the desire to accomplish something that had never been done before. Daniel Moran's passionate plea for this great suspension bridge deserves to be quoted again:

> We would further call the attention to the Board [of Consulting Engineers] to the greater advantages, to the cities of San Francisco and Oakland, of a single span design; first, because it would provide the best possible water way for shipping and; second, because it would undoubtedly create a bridge which architecturally and spectacularly would appeal to the civic pride of both Cities, and would attract and interest all of the surrounding districts. In my opinion such a bridge would attract so many visitors to the two Cities, that in the course of years the profit to the two Cities, from this source alone, would more than compensate for the relatively small difference in cost. It would be impossible to estimate how much the City of New York and Brooklyn profited by the spectacular achievement of the Brooklyn Bridge, or how much St. Louis benefited by the Eads Bridge. We feel sure that if you consider the value of the bridge to the two communities, there will be no hesitancy in giving a very considerable value to the difference between the cost of such a bridge as compared with a bridge which would place an extremely large pier in the center of the channel, which would place five piers in the channel instead of two, and which would also indicate that the design was one adopted for economical reasons rather than for reasons based on harbor requirements plus architectural requirements.[416]

Moran felt that the bridge would appeal to the pride of the Bay Area "architecturally and spectacularly"; one suspects that it appealed to his own pride on the same basis. If there was an interest in doing something new and dramatic, that interest weighed in favor of the single great suspension bridge.

The double suspension bridge was perhaps less spectacular but was equally unique. Purcell ultimately decided upon the double suspension design, however, because it strayed least from known technologies; it was risky but far less so than the one great suspension bridge or the highly

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[415] United States Steel, "San Francisco Oakland Bay Bridge," 1936, illustrates the only known predecessor to the double-suspension bridge design, an 1841 bridge in Prague, Czechoslovakia across the River Moldau; 19.

[416] Moran and Proctor to Woodruff, November 9, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives.

speculative continuous suspension design. Purcell adopted this design, in other words, because it was the least unusual of his three major choices. This fact speaks strongly to the difficulty of the overall undertaking, that the most unusual aspect of the bridge was selected as the least innovative of available choices.

The very deep piers came about strictly as a function of the condition of the Bay floor. Again, there is no indication that the engineers consciously sought to break any world records. They sought to build stable foundations in the Bay floor and the world records followed naturally. Purcell regarded this as the "trickiest" part of the entire project and the only part that experienced anything like a construction emergency, when the PierW-6 caisson tipped. It should be recalled that the deepest East Bay and West Bay piers are roughly the same depth but for different reasons. On the West Bay, the depth was defined as the depth to bedrock. The East Bay piers were sunk to a level where the hardest clay could be found. Pier E-3 reached the greatest depth by accident; the caisson continued to sink uncontrollably and gained an extra 10 feet on that basis.

The use of multiple bridge types on the East Bay Crossing, and the fact that the East Bay Crossing is different from the West Bay, also came about in response to foundation conditions. The engineers decided on a suspension span on the West Bay Crossing in an effort to minimize the number of piers there. Once they realized that the East Bay Crossing piers could not be taken to bedrock, they eliminated a suspension bridge from consideration on that side of the island. They elected to build multiple bridge types as a way of minimizing the weight of both the substructure and superstructure.

In the final analysis, the Bay Bridge is a very complex structure because it was also a very bold undertaking. All of the important elements of it, from the deep piers to the multiple bridge types to double-suspension bridge to the great length, were solutions to the problems posed by this daring crossing. These elements were compromises that the state engineers and consulting engineers developed as they worked to solve the problem. That the solution worked well is a testament to the talent of people involved in that process.

14.3. Significance in Political History

Finally, the Bay Bridge represents an unusual and important chapter in the political history of the Bay Area. As much as in any region in the United States, local governments in the Bay Area have long competed and disagreed with one another over transportation and a host of other issues. This was the case before, during, and after the long campaign to build the Bay Bridge. The Bay Bridge is important in that it came into being through a long campaign that was supported with near unanimity by the political and civic leaders of the region. It is nearly unique in that respect, particularly within the context of transportation history in the area. Many great projects have received broad support but nothing like consensus. BART, for example, was supported by 61% of the voters in three counties, but was rejected by two major counties, San Mateo and Santa Clara. Other substantial projects failed because no consensus or even a majority agreement could be reached. The Southern Crossing failed because of deep divisions between

San Francisco and East Bay communities over the issue. The "freeway revolt" in San Francisco pitted the city against state interests and put an end to an ambitious program of freeway development there. Rarely if ever has a transportation project been endorsed so strongly by the residents of the region as was the case with the broad regional support for the Bay Bridge.

The easiest explanation for the near-unanimity of support for the bridge is that the bridge was badly needed. In 1930, millions of commuters made their way from the East Bay to San Francisco annually, using a reasonably efficient but burdensome combination of interurban and ferries or automobiles and ferries. The ferry links slowed down the commute considerably and clogged the bay with ferryboats. The idea of carrying that traffic across the Bay on a structure appealed intuitively to political leaders and commuters alike.

The appeal of the bridge to broad groups of Bay Area residents may also be attributed to the fact that it promised benefits to a broad range of interests, including interurban passengers, automobile drivers, and trucking firms. The perceived benefits were also dispersed geographically. The political leaders of Oakland and San Francisco were adamant supporters of the bridge, at least in part because neither group saw advantages accruing to one city at the expense of the other. The smaller communities, such as Berkeley and Alameda, supported the project as well, seeing many benefits and few disadvantages.

During the 1920s, much of the support for the bridge may be interpreted in the context of the tremendous support for automobile-related improvements during that period. As discussed under significance in transportation, Americans during the 1920s embraced the automobile in a manner that extended well beyond the vehicle itself. In a decade that was generally characterized by tax decreases, for example, voters throughout the United States endorsed substantial gasoline taxes to pay for road improvements. One student of the gasoline tax observes that "never before in the history of taxation has a major tax been so generally accepted in so short a period."[417] The popularity of, or at least the lack of opposition to, the imposition of gasoline taxes during this period is an indicator of the broad support for highway improvements.

As noted elsewhere, the Bay Bridge was but one of a long list of very important highway improvements in the Bay Area during this decade. While it was not exclusively a highway project, the Bay Bridge was assuredly a major investment in the function of the highway system in the Bay Area. The other important projects from the period, such as the Caldecott Tunnel and Golden Gate Bridge, affected areas peripheral to the major population centers of the Bay Area. The Bay Bridge was at the heart of the Bay Area, connecting the two great cities of the region and linking with major highways on both ends. Despite the fact that it was a multi-modal structure, the Bay Bridge was one of the most important highway connections ever to be conceived in the region.

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[417] John C. Burnham, quoted in Flick, *Car Culture.* 150. The quotation in in Burnham's "The Gasoline Tax and the Automobile Revolution," *Mississippi Valley Historical Review* 48: (December 1961), 435-459.

If it is true that Americans and Californians in particular were supportive of highway work during the 1920s, that generalized support no doubt contributed to the broad support for the Bay Bridge. The interest of motorists in the bridge likely extended far beyond the group of people who would use the bridge to commute to work. It is likely, for example, that many people who commuted on the interurbans and ferries also owned cars that they used for purposes other than commuting. While the population of San Francisco and Alameda counties rose rapidly during the 1920s, car ownership rose at an even faster pace. In 1929, there were 111.3 automobiles per 1000 residents. By 1929, there were 247.2 per 1000 residents, a little below the statewide average but far above the national average.[418] With automobiles ownership so broad, it is likely that many motorists supported the bridge for purposes other than commuting – San Franciscans to drive to Oakland and points East, Oakland residents to shop in San Francisco, and so forth.

During the 1930s, when the bridge was designed and built, political support for it was galvanized by the economic emergency of the Great Depression. Local newspaper articles about the bridge during the 1930s almost always included some reference to the number of people who would be employed on it and its immediate contribution to the local economy. The bridge was already a popular undertaking, even in the absence of these employment figures. The promise of good jobs, however, no doubt helped sustain the coalition of support during the crucial years in which it received final support and during design and construction.

The popularity of the Bay Bridge – or at least the absence of organized opposition – may also be attributed to the political acumen of the leaders of the campaign to build the bridge. Dozens of people and organizations were involved in this campaign: the early leadership of the Motor Car Dealers' Association; the important role of San Francisco political and civic leaders during the mid-1920s; the combined efforts of state leaders and Bay Area civic and political leaders during the late 1920s and early 1930s; the continuing leadership role of the state leaders to maintain the coalition until the bridge had been completed. So many individuals were involved that it is somewhat misleading to single out the efforts of a small number of them. These individuals waged a clever and effective campaign and appear to have genuinely liked one another in most cases.

If individuals were to be called out, a large measure of the success of the bridge campaign may be attributed to the political acumen and perseverance of two individuals: Herbert Hoover and C. H. Purcell. Hoover was the highest-ranking supporter of the bridge, championing it as Secretary of Commerce and as president. He also knew how to get the job done. When the campaign foundered due to opposition from the military, for example, Hoover established a commission that forced military leaders to meet on a par with the local political leadership of the Bay Area. It is pointless to speculate about whether the Bay Bridge could have been completed without Hoover's support. It is highly unlikely, however, that it could have been built during the 1930s, absent Hoover's strong support.

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[418] Hoover-Young Commission, "Report to the President," 73.

Of all leaders representing the State of California or the Bay Area, C. H. Purcell was by far the most effective. As discussed elsewhere, Purcell's role in the design of the bridge may have been overstated in the euphoria upon construction of the bridge in late 1936. By contrast, his importance as a political leader was not given sufficient recognition. Purcell stepped into his job as Highway Engineer (the equivalent of today's Director of the Department of Transportation) in 1928 and the same year was asked to develop a study of whether the state should build the Bay Bridge as a state-owned toll bridge. In 1929 and 1930, he was immersed in the Hoover-Young studies. Between 1930 and the opening of the bridge in November 1936, Purcell was thoroughly immersed in all aspects of the design and construction of the bridge.

In reading Purcell's correspondence during these years, one is impressed, not so much by his command of the engineering issues but by the great skill with which he balanced competing concerns over the bridge. Purcell, for example, made numerous trips to Washington, D.C. during this period, appearing before Congress, the War Department, and the RFC. He organized or attended dozens of meeting with civic and political leaders in the Bay Area. He worked closely with the leadership of three administrations in Sacramento, those of governors C. C. Young, James Rolph, and Frank Merriam. Remarkably, he would retain high-ranking positions (Highway Engineer or Director of the Department of Public Works) through two additional administrations, the two-year administration of Culbert Olson (a Democrat; all the others were Republicans) and the long tenure of Earl Warren.

During the period, 1928 through 1936, Purcell exhibited traits of resolute decisiveness and great flexibility and a laudable ability to know when one or the other was appropriate. Two cases illustrate this point. In the negotiations with the interurban lines, others on his staff as well as political leaders in Sacramento were so frustrated as to consider scrapping the interurban connections and building an automobile-only structure. Purcell stayed with the negotiations, however, and was able to achieve agreement, albeit too late for simultaneous train and vehicular service openings. Purcell did not record in detail why he was so committed to making the interurban lines work. He was raised in Nebraska and had worked in Oregon before coming to California. He had no experience in working with transit before the Bay Bridge, and had little involvement with the field after the bridge was built.[419] The reason for his resolute conviction to incorporate a transit element on the bridge had not been explained satisfactorily. It may reflect his conviction that transit was needed; it may reflect his commitment to fulfill promises made to Bay Area leaders; or it may be these reasons plus others. Whatever his motivation, Purcell was dogged in his determination to get the job done but diplomatic and flexible as to how it could be accomplished.

Purcell's decision late in the design process to appoint a Board of Consulting Architects reflects the same mix of decisiveness and flexibility. Important political interests, particularly in San

[419] During the late 1940s, the City and County of San Francisco attempted to hire Purcell away from the Division of Highways to work as a transit administrator in that city. Purcell expressed interest but ultimately decided to stay with the State of California as Director of Public Works. The proposal by San Francisco is documented in detail in Purcell's papers and newspaper clippings retained in the manuscript collection of the California State Library, Sacramento.

Francisco, had in 1932 and 1933 begun to criticize the work of the Bay Bridge Division on aesthetic grounds. These interests included not only the architectural and artistic communities but business leaders as well. Purcell acted quickly to blunt this criticism by appointing an architectural advisory board. In his dealings with the board, however, Purcell held firm against any suggestions that, in his view, would drive up the budget, slow construction, or diminish structural integrity.

A final point that is of interest in terms of the political history of the bridge: this incredibly expensive public works project was approved, designed, and built without a popular vote. There is a long list of great public works projects that have been built in California: the Bay Bridge, the Golden Gate Bridge, the Central Valley Project, the Los Angeles Aqueduct, the Colorado River Aqueduct, the Hetch Hetchy Project, the Arroyo Seco Parkway. Typically, these projects are so large and potentially controversial that some type of popular vote would have been required, to approve the project or its bonds. This was not always the case; the Arroyo Seco Parkway and Colorado River Aqueducts were approved without popular votes. The fact that the Bay Bridge was built without single popular votes is remarkable in the often-contentious history of transportation development in the Bay Area.

The absence of a popular vote may be interpreted in several ways. One obvious explanation is that such a vote was not necessary within the formal administrative structure of the state and the Bay Area. The State of California in 1928 established the California Toll Bridge Authority specifically to create a mechanism through which the bridge could be designed, financed, and built. The existence of this separate authority took the bridge away from the usual funding cycles of the State Highway System and insulated it from political controversies at the State Capitol in Sacramento or the various city halls in the Bay Area. No formal vote of the people was required and none was solicited.

In a larger sense, however, the vote was not needed because there was no substantial controversy about the project. Everyone seemed to like the idea, from San Francisco to Oakland, and from Sacramento to Washington, D.C. This essential support must have seemed a blessing to Purcell and the engineers of the Bay Bridge Division, as they worked frantically to solve the great technical problems posed by the structure. It took an optimist to think the bridge was feasible from a technological standpoint. The nearly unanimous support for the structure probably contributed to that optimism and was the underlying reason why this monumental adventure came to such a successful conclusion.

APPENDIX 1. TIME LINE FOR THE PLANNING, CONSTRUCTION, AND OPERATION OF THE BAY BRIDGE

1920. Golden Gate Ferries offers vehicular ferry service across the Bay.

1921. San Francisco receives first proposals for a private toll bridge franchise between San Francisco and Oakland.

1921. Initial borings into Bay floor, conducted by Ralph Modjeski and John Vipond Davies, with funds provided by the San Francisco Motor-Car Dealers' Association.

October 1921. War Department rejects San Francisco's application for a permit to build a bridge between Oakland and San Francisco.

May 1927. San Francisco releases a major study of the economic and technical feasibility of the Bay Bridge, conducted by Ridgway, Talbot, and Galloway, commonly called the Ridgway Report.

May 1927. San Francisco state senator Roy Fellom introduces legislation, mandating a study by the Department of Public Works, of the feasibility of the State of California taking over existing private toll bridges and building new toll bridges, including the Bay Bridge.

June 1927. San Francisco applies again for a War Department permit for a Bay Bridge, based upon the recommendations of the Ridgway Report.

October 1927. The War Department again rejects the application of San Francisco for a permit for the Bay Bridge.

1927. Port Department (now Board of Port Commissioners) established in Oakland, facilitating expansion of the Port of Oakland.

1927. Carquinez Bridge constructed, a private toll bridge built by the American Toll Bridge Company.

1927. Key System declares bankruptcy, reorganized by Alfred Lundberg.

1928. C. H. Purcell appointed Highway Engineer, Division of Highways. He would later serve as Chief Engineer for the Bay Bridge.

March 1928. Congress holds hearing on a bill by U. S. Senator Hiram Johnson to approve the Bay Bridge permit, over the objections of the War Department. The bill does not pass.

October 3, 1928. Officials of the State of California and San Francisco meet to discuss the feasibility of the state building the Bay Bridge. Meeting concludes with joint statements by Governor C. C. Young and Mayor James Rolph, supporting state construction of the Bay Bridge.

1928. The California Department of Public Works releases a report, in response to 1927 legislation, recommending that any new toll bridges in California be built by the state.

January 18, 1929. Senator Roy Fellom of San Francisco introduces a series of bills in the California legislature which together: created the California Toll Bridge Authority; established as state policy that toll bridges would be owned by the state; authorized the California Toll Bridge Authority to build the Bay Bridge; and provided $50,000 to conduct preliminary engineering work on the Bay Bridge.

1929. Bayshore Highway dedicated, providing a new alignment along the Peninsula between San Jose and San Francisco.

1929. Southern Pacific Golden Gate Ferries created, merging Southern Pacific and Golden Gate vehicular ferry services.

June 10, 1929. California Toll Bridge Authority created.

August 13, 1929. President Herbert Hoover announces creation of Hoover-Young Bay Bridge Commission.

October 7, 1929. Hoover-Young Commission convenes.

July 22, 1930. Hoover-Young Commission reconvenes to consider technical recommendations by the California Department of Public Works.

August 6, 1930. Hoover-Young Commission releases it recommendations, including recommendation for a Rincon Hill-Yerba Buena Island-Key System Mole alignment.

1931. War Department approves permit for the State of California to build the Bay Bridge on the Hoover-Young approved alignment.

1931. California Legislature approves $650,000 for design work on Bay Bridge, money that would be repaid from bridge tolls.

Early 1931. Director of Public Works appoints C. H. Purcell as Chief Engineer for the Bay Bridge. He did not relinquish his other job as Highway Engineer.

Early 1931. Purcell hires Charles Andrew as Bridge Engineer, the number two position in the engineering team on the Bay Bridge. Andrew was loaned to the Bay Bridge Division from the Bridge Department of the Division of Highways.

Early 1931. Purcell hires Glenn Woodruff to serve as Engineer of Design for the Bay Bridge. Woodruff was working for Ralph Modjeski in New York City at the time.

Early 1931. Purcell, Andrew, and Woodruff begin hiring 50 engineers and allied professionals to form the core of the Bay Bridge Division, which was responsible for designing the Bay Bridge. The Bay Bridge Division was not initially controlled by civil service regulations.

January 1931. Purcell begins corresponding with Ralph Modjeski regarding design issues for the Bay Bridge. Modjeski would become the chair of the Board of Consulting Engineers, but that appointment did not become official until August 1931.

August 1931. The Board of Consulting Engineers formally established, comprising Ralph Modjeski, Daniel Moran, Leon Moisseiff, Charles Derleth, Jr., and Hal Brunnier.

October 5, 1931. First formal meeting of the Board of Consulting Engineers in San Francisco. The board would meet periodically between 1931 and 1937.

January 25-30, 1932. The second formal meeting of the Board of Consulting Engineers in San Francisco. This was by far the most important meeting, in which the board approved the double-suspension design for the West Bay Crossing and discussed the range of options for the East Bay Crossing.

January 1932. Congress and President Herbert Hoover approve creation of the Reconstruction Finance Corporation (RFC).

April 18-22, 1932. The third formal meeting of the Board of Consulting Engineers in San Francisco. During this session, the board approved the cantilever design for the East Bay Crossing and details of foundation work on East and West Bay Crossings.

July 1932. Congress and President Herbert Hoover approve the Emergency Relief and Construction Act, which created the Self-Liquidating Loan program of the RFC, the program that financed construction of the Bay Bridge.

August 1932. California applies for a loan under the RFC's Self-Liquidating Loan Program. The loan will not be approved until April 1933.

August 29, 1932. The Art Commission of San Francisco informs the Bay Bridge Division that any plans that affect San Francisco must be reviewed and approved by the Art Commission. This requirement ultimately led to appointment of a Board of Consulting Architects.

January 31, 1932. The American Institute of Architects petitions the state, recommending appointment of a Board of Consulting Architects.

February 28, 1933. Bids solicited for the eight major construction contracts.

April 28, 1933. Final RFC approval of the state Self-Liquidating Loan application. Construction bids accepted the same day.

April 1933. Governor James Rolph announces appointment of a three-member Board of Consulting Architects, including Timothy Pflueger, Arthur Brown, Jr., and John Donovan.

April 1933. The Board of Consulting Architects meet for the first time.

July 10, 1933. Formal ceremonies initiating construction on the bridge. President Franklin Roosevelt remotely ignites a dynamite charge on Yerba Buena Island.

August 4, 1933. Harry Hill killed working near Yerba Buena Island, the first man killed. Ultimately 28 men would die. These deaths occurred one at a time; there was no single large-scale accident involving more than one death.

August 24, 1933. Welders at the Moore Dry Dock Company go on strike. There was never a direct strike against any of the contractors; Moore Dry Dock was the only sub-contractor affected by a direct strike. In 1934, the General Strike in San Francisco shut down all contractors.

November 6, 1933. Purcell announces as policy that no recommendations of the Board of Consulting Architects will be considered if they exceed the allotted contract money for the bridge element in question.

January 14, 1934. The caisson at Pier W-6 tipped, creating the most dramatic emergency of the construction work. The caisson would not be righted until March 3, 1934.

March 1934. Most of the major work of the Board of Consulting Architects completed. The board would continue to work on ancillary items, such as the toll booths and transit terminal in San Francisco.

July 3, 1934. The beginning of violence associated with the General Strike in San Francisco. The Bay Bridge contractors shut down for most of the month in response to the strike.

January 11, 1935. Contract 2, the foundation work for the West Bay Crossing the first major contract to be completed.

May 1935. The Bay Bridge Division decides in favor of a silver color for the bridge. The Bay Bridge Division engineers had favored black, the Board of Consulting Architects had favored gray. Aluminum was a compromise acceptable to both parties.

September 18, 1935. A cable strand broke at Pier W-4, creating the only major mishap in construction of the superstructure of the suspension spans.

March 6, 1936. The State of California reaches agreement with the Key System and Southern Pacific over how bridge railway facilities will be designed and financed. The failure of the state and the rail carriers to reach agreement was the principal cause of the delay in constructing interurban facilities on the bridge.

July 1936. A fire erupted on Pier E-3, creating the only notable mishap on construction of the Easy Bay superstructure.

November 12, 1936. The Bay Bridge formally opened for vehicular (automobile, truck, and bus traffic). Railroad facilities would not be completed until January 1939.

November 29, 1937. Ceremonial start of construction of railroad-related facilities on the bridge.

January 15, 1939. First interurban train service between Oakland and San Francisco.

1939-1940. Golden Gate International Exposition, approximately mid-span on the bridge.

1941. First Army-Navy Board report on the need for a Southern Crossing of San Francisco Bay. The report recommended against federal construction of such a bridge.

1941. Two of the three interurban carriers on the Bay Bridge abandon service.

1947. Second Army-Navy Board report recommends construction of a Southern Crossing. A Division of Highways report of the same year recommends construction of a parallel San Francisco-Yerba Buena-Oakland bridge.

1949. Board of Consultants to California Assembly recommends three-stage improvements to relieve congestion on Bay Bridge, including widening the top deck of the bridge and construction of a Southern Crossing.

1951. California legislature creates the Bay Area Rapid Transit Commission, which would evolve into the BART District.

1955. Key System, the last of the interurban lines to use the Bay Bridge, petitions for the right to abandon service.

1959-1963. The Bay Bridge was reconstructed, taking off tracks and converting two decks for unidirectional automobile, truck, and bus traffic.

October 17, 1989. Loma Prieta earthquake destroys two 50' roadway panels above Pier E-9. Bridge is reopened a few weeks later.

1990s. Long discussions by California Department of Transportation and local transportation officials about how to make the Bay Bridge safer during earthquakes.

APPENDIX 2.

ORGANIZATIONAL LIST FOR BRIDGE DESIGN BY THE DIVISION OF HIGHWAYS, EARLY 1930'S

California Department of Public Works
Earl Lee Kelly, Director (after 1932)

California Division of Highways
C. H. Purcell, Highway Engineer

Bridge Department, Division of Highways
Charles Andrew, Bridge Engineer (on loan to Bay Bridge Division, 1931-36)
Frank Panhorst, Acting Bridge Engineer, 1931-36

ORGANIZATION LIST FOR BRIDGE DESIGN FOR BAY BRIDGE, 1932-36

California Department of Public Works
Earl Lee Kelly, Director (after 1932)

California Toll Bridge Authority
Earl Lee Kelly, Director

Bay Bridge Division of the Department of Public Works
C. H. Purcell, Chief Engineer
Charles Andrew, Bridge Engineer (on loan from the Division of Highways, 1931-36)
Glenn Woodruff, Engineer of Design

Board of Consulting Engineers for the Bay Bridge
Ralph Modjeski
Leon Moissieff
Daniel Moran
Charles Derleth, Jr.
Henry Brunnier

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SOURCES FOR PLANS AND PHOTOGRAPHS

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Project Files. For list of boxes, see attachment "A".

Caltrans District 4 Map Room - 10th floor, 111 Grand Avenue, Oakland, CA
(510) 286-5043, Microfilmed Project Drawings. For list of contracts, see attachment "B".

Caltrans District 4 Archives - 10th floor, 111 Grand Avenue, Oakland, CA
(510) 286-0628, Original Project Drawings. For master index to these drawings, see attachment "C". (Note: Storage of these drawings is currently divided between Caltrans offices in Oakland and Sacramento).

Caltrans Archives – 3rd floor, 1727 30th Street, Sacramento, CA
(916) 227-8011, Original Project Drawings, (Note: Storage of these drawings is currently divided between Caltrans offices in Oakland and Sacramento).

Hammon, Jensen, Wallen & Assoc., 8407 Edgewater Drive, Oakland, CA
(510) 638-6122, Historic Aerial Photograph Collection

Humboldt County Historical Society, P.O. Box 8000, Eureka, CA
Historic Photograph Collection

Moulin Archives, 526 2nd Street, San Francisco, CA
(415) 541-9454, open 8:30-5:00 Copyrighted Photograph Collection

Oakland Museum, 1000 Oak Street, Oakland, CA
(510) 238-3005, Historic Photograph Collection

Oakland Public Library – Oakland History Room, 125-14th Street, Oakland, CA
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