SAN FRANCISCO - OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

Replacement vs. Retrofit

Retrofit plans to 65070, p. 7-1.

April 2000

04-SF-80 - KP 12.2 / KP 14.3
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RU 4251
HA4S3 Seismic Retrofit

Caltrans

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INTRODUCTION

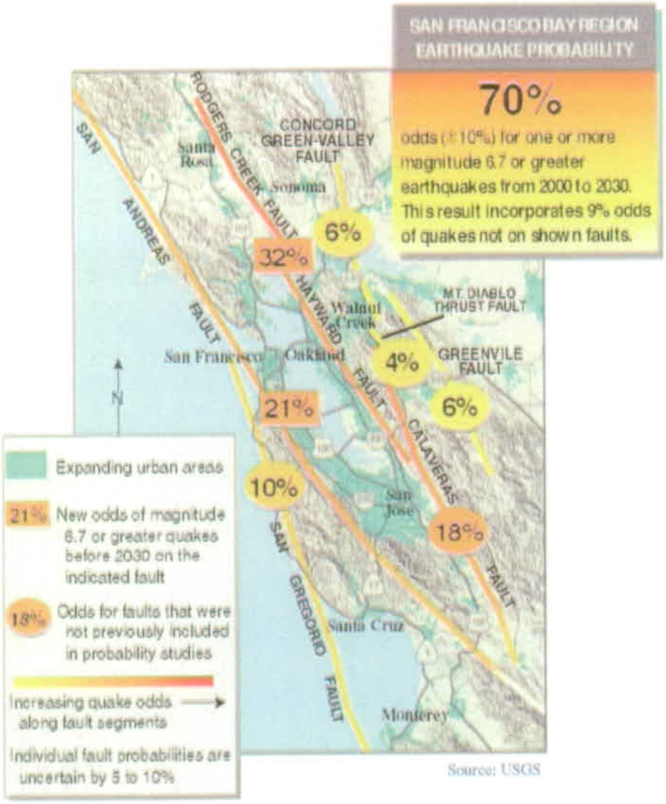
The purpose of this report is to summarize:

- The studies prepared for the Retrofit Alternative
- Caltrans' decision to consider replacement of the east span of the San Francisco-Oakland Bay Bridge (SFOBB) in addition to retrofit
- The identification of replacement as the preferred alternative

The purpose of the East Span Seismic Safety Project is to provide a seismically upgraded "lifeline" vehicular crossing for current and future users between Yerba Buena Island (YBI) and Oakland. A lifeline connection

Comparison Matrix – Retrofit vs. Replacement

	ISSUE	RETROFIT	REPLACEMENT
Public Safety	**Seismic Performance and Damage After Major Seismic Event**	Moderate to major damage. Weeks to months of repair. Performance not as reliable as new bridge. Normal traffic may never be allowed back on bridge. Replacement may be necessary, at a time when entire region will need emergency funding. Post-earthquake recovery to region impaired.	Minor to moderate damage. Operational within hours (at reduced speeds). Normal service restored within weeks to months once deck joints are repaired. Post-earthquake recovery to region enhanced. Seismic Advisory Board (a panel of outside experts from academia and the private sector) and two independent Value Analysis studies concluded that bridge should be replaced and not retrofitted.
	Time to Achieve Seismic Safety	Seismic safety not achieved until all retrofit work is completed; approximately six years after start of construction.	Seismic safety achieved for westbound traffic 3 ½ years after start of construction, eastbound traffic 4 ½ years after start of construction.
	Lifeline Connection	No. Would NOT provide safe route for emergency equipment and supplies.	Yes. Would provide safe route for emergency equipment and supplies.
	Construction Exposure	Significant construction above and adjacent to traffic lanes, highly constrained construction zone next to traffic	Vast majority of construction is away from the existing traffic. Some construction exposure during the tie-ins for the detour routes.
Public Convenience	**Bicycle / Pedestrian Path**	None.	4.7 meter (15.5 foot) wide pedestrian/bike path elevated 0.3 meters (1 foot) above the roadway.
	Traffic During Construction	Many lane closures but not during commute hours; scheduled during the day, evening and nights. This does affect construction duration. Some lane closures almost every day for various construction activities.	Minimal impact. New bridge constructed adjacent to existing bridge, then traffic switch. Traffic switch will involve nighttime traffic controls.
	Traffic After Construction	Bridge will continue to operate as it does today.	The replacement will operate significantly better due to existence of standard lanes, 2 shoulders in each direction providing a refuge area for disabled vehicles and emergency vehicle access. Overall bridge operation will be enhanced.
Cost-Effectiveness	**Life Expectancy**	50 years	150 years
	Design / Construction Cost	$1.085 billion (escalated to 2002 at 3%/yr)	$1.5 billion (escalated to 2002 at 3%/yr)
	Life Cycle Maintenance	Bridge will need to be redecked in about 20 years. Continuous painting of entire structure. Over time, increased traffic will cause spreading of commute hours and affect maintenance work windows.	Modern structure, mostly concrete; steel portion will have a modern paint system requiring minimal maintenance and painting.



Source: USGS

emphasizes the urgency for all communities in the Bay Area to continue preparing for earthquakes.

ALTERNATIVES

From a purely structural and analytical perspective, there are many ways to provide a seismically upgraded vehicular crossing between Yerba Buena Island and Oakland. However, for public works projects, there are values in addition to structural engineering concerns that must also be addressed. Three key values that Caltrans incorporates in all projects, beginning with the most important, are:

- Public safety
- Public convenience
- Cost-effectiveness

There were two basic alternatives developed to address the issue of seismic safety for the east span of the San Francisco-Oakland Bay Bridge:

- Retrofit the existing bridge
- Replacement

DESIGN CONSIDERATIONS

Seismic Reliability

After careful review of the vulnerabilities of the existing structure, it was determined that the most appropriate and economic retrofit strategy would be to strengthen the foundations (piles and pile cap connections), stiffen the towers, isolate the superstructure and strengthen many superstructure members.

A newly constructed replacement structure would enjoy all of the current research developed for the many long span major structures recently constructed around the world. Without the constraints of modifying an existing structure, the design of a new structure can be uncompromising in the selection of structural configuration and ductile response, the material control would be excellent, and structure response would approximate idealized elastic response.

CONSTRUCTION ISSUES

For the construction issues of duration, traffic disruption, and traffic safety, the retrofit and replacement alternatives are fundamentally different.

The work required to construct either the retrofit alternative or a replacement alternative has a number of differences and similarities in the nature of the construction.

Differences in construction include:

- Safety for traveling public
- Working adjacent to and above traffic lanes
- Construction risk duration of construction
- Closing of traffic lanes
- Yerba Buena Island access and circulation
- Structure dismantling

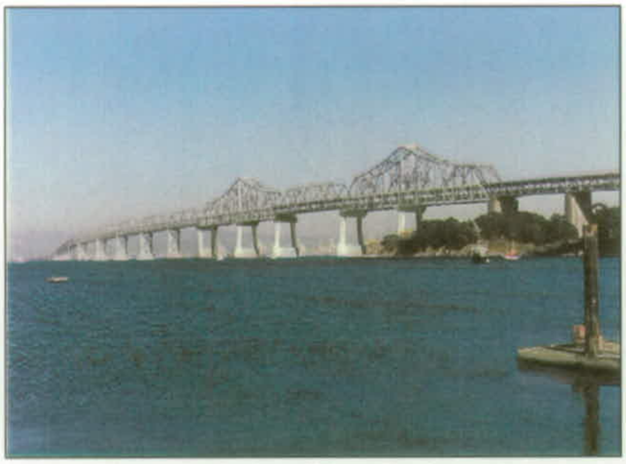


Photo-simulation of Retrofit Alternative
View from Treasure Island

Photo-simulation of Replacement Alternative
View from Treasure Island

Similarities in construction include:

- Scale of work
- In-water construction
- Construction staging area requirements

The Replacement Alternative is superior to the Retrofit Alternative primarily because of the shorter time to construct, less adverse impacts to traffic flow, and the safety advantages realized by separating traffic from the construction zone.

SCHEDULE ISSUES

The comparison of schedules between the replacement and retrofit alternatives can only be reviewed within the context of the current status of the project in order to determine which approach has the least impact on the current project schedule.

Implementing a retrofit alternative at this time would delay seismic safety for eastbound users of the east span of the San Francisco-Oakland Bay Bridge by 1 ½ years and westbound users by 2 ½ years. The construction duration for the retrofit is longer than the duration for the new bridge because the retrofit construction is constrained by the need to provide for public convenience. Daily lane closures allowing access to steel truss members cannot occur during commute periods and much of the day. This substantially lengthens the construction duration for the Retrofit Alternative.

ECONOMIC ANALYSIS

Based on the life-cycle costs and benefits considered in *Retrofit vs. New Bridge – An Economic Analysis for the East Span of the San Francisco-Oakland Bay Bridge, April 1997,* the new bridge (skyway option) would cost about $625 million less than the retrofit option.

CONCLUSIONS

All studies favor construction of a replacement bridge over retrofit for the east span of the San Francisco-Oakland Bay Bridge. The evidence is consistent not only with respect to the crucial question of seismic safety but also with respect to the key values of public and worker safety, public convenience, and cost-effectiveness.

Public Safety

With respect to seismic safety, the Retrofit Alternative is inherently less reliable than a replacement alternative, and reliability is a measure of safety. A new bridge will have a high degree of reliability as it will have fewer and newer elements than a retrofitted structure. A replacement bridge will meet the lifeline performance criteria. Constrained by a 1930s level of material and construction technology, it is impossible to retrofit the existing east span to lifeline standards with any reasonable degree of confidence.

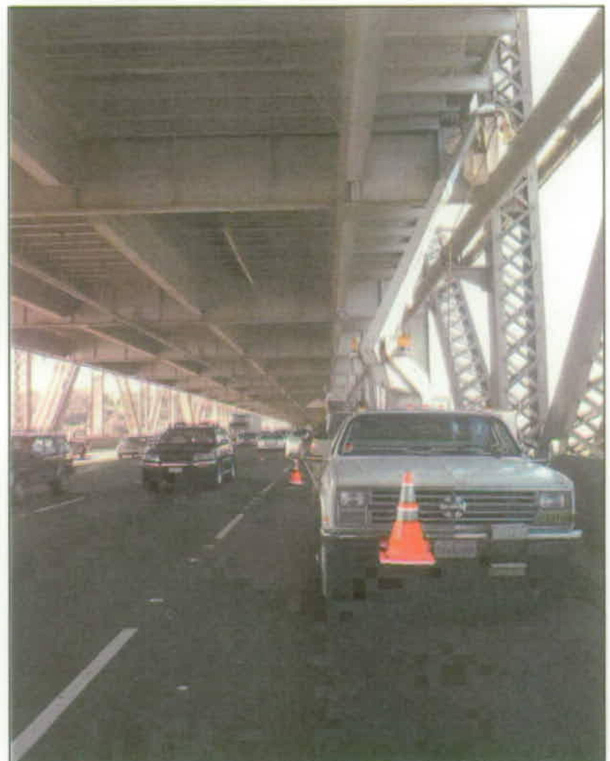
Failure at Pier E9

Seismic safety will also be achieved sooner with the Replacement Alternative. Seismic safety for westbound and eastbound traffic will be achieved 2 ½ years and 1 ½ years sooner, respectively, than for the Retrofit Alternative.

The Retrofit Alternative is less safe for the traveling public and for Caltrans maintenance staff who will maintain the bridge during and after construction. The existing east span structure, which carries 274,000 vehicles per day, is 4 kilometers (two and a half miles) of highly constrained environment, as high as 61 meters (200 feet) above San Francisco Bay, with five lanes of traffic in each direction and no shoulders for emergency parking. Construction for the Retrofit Alternative on the existing bridge would expose public and workers to potential hazards such as:

- Exposure of public and construction workers to installing and removing lane closures
- Construction adjacent to and above traffic lanes
- Construction equipment, maintenance equipment and traffic immediately adjacent to each other

For a replacement alternative, the vast majority of the construction will be away from the existing east span. This separation eliminates conflicts between the construction crews, maintenance crews, and the traveling public.



Truss construction modifications adjacent to traffic

Traffic and Public Convenience

The Retrofit Alternative has a vastly greater adverse impact on public convenience than a replacement alternative both during and after construction. Construction on the steel truss elements above and adjacent to traffic has the greatest impact on the traveling public and is expected to last for the duration of the retrofit construction schedule, approximately six years. Increased traffic control measures, daily closures of multiple lanes, construction equipment and materials in the adjacent traffic lane would all have an impact on the users of the bridge. With most of the construction away from the existing bridge, a replacement alternative will directly affect the traveling public only during the transition of traffic from the existing bridge to the new bridge.

After construction of the Replacement Alternative, two new shoulders in each direction will provide refuge areas accommodating disabled vehicles and routine bridge maintenance activities. The Retrofit Alternative cannot provide roadway shoulder areas.

Cost-Effectiveness

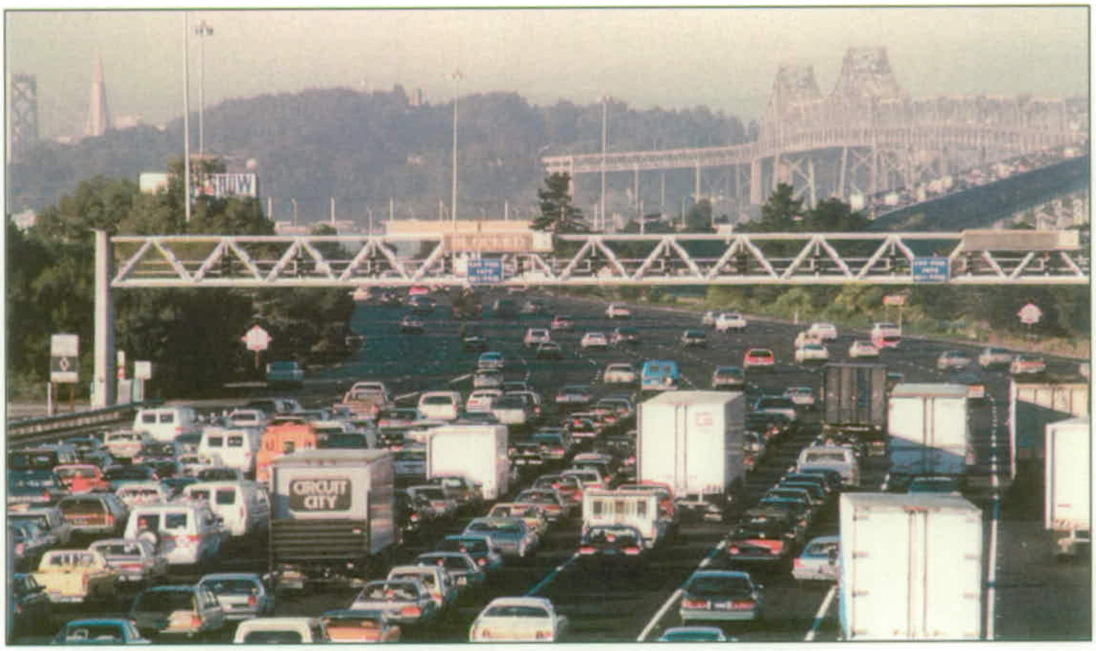
Based on a life-cycle analysis, the Retrofit Alternative is less cost-effective than a replacement structure. Two economic analyses evaluating the costs indicate that, in a life-cycle analysis and including repair after a large earthquake, a replacement alternative (skyway) costs less than a retrofit alternative.

It is important to note that all analyses regarding cost-effectiveness presumed a "base case" replacement structure that would consist of a skyway structure or a skyway/cable-stay structure.

After a decision was made to consider replacement of the bridge, legislation was adopted (Senate Bill 60 of 1997) to provide funding for the project. This legislation provided the Bay Area with the decision making authority to include additional costly amenities in the bridge project (bicycle / pedestrian path, signature span, Transbay Terminal improvements). The Bay Area has included such amenities in the replacement bridge currently under design. The decision to add amenities is independent of the decision to replace or retrofit. Cost-effectiveness, therefore, remains a function of the base case replacement structure.

Regional Preference

Through MTC, the region has identified a locally preferred alternative for a replacement bridge. This alternative is a single tower self-anchored suspension mainspan/skyway viaduct on a northern alignment. The selection of the bridge type, location, and the decision to replace rather than retrofit has been endorsed by an overwhelming majority of technical experts from academia, the professional engineering community, and public agencies within the Bay Area region.



Toll Plaza metering lights – one lane blocked on the bridge

1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is to summarize:

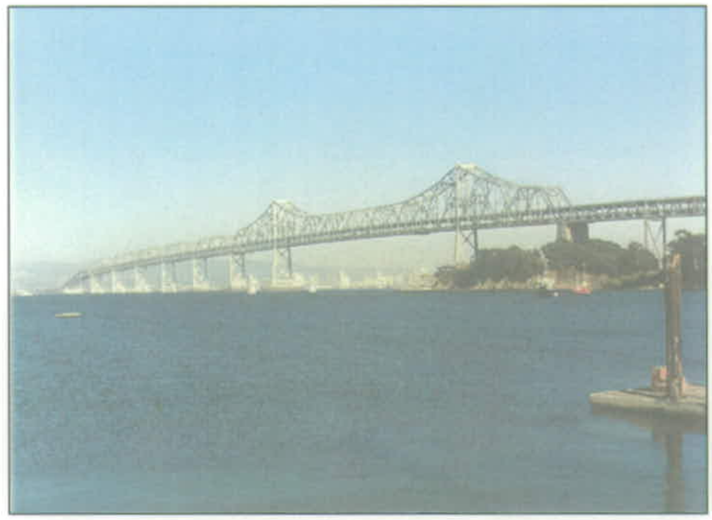
- The studies prepared for the Retrofit Alternative
- Caltrans decision to consider replacement of the east span of the San Francisco-Oakland Bay Bridge (SFOBB) in addition to retrofit
- The identification of replacement as the preferred alternative

1.2 SFOBB East Span Seismic Safety Project

1.2.1 San Francisco-Oakland Bay Bridge East Span

The SFOBB is historically important in the Bay Area and worldwide. Construction of this structure began in 1933 and was completed and opened to traffic in 1936. At the time of its construction, the bridge was the world's longest vehicular bridge, and the Yerba Buena Island (YBI) tunnel, a double-decked structure, was the largest bore tunnel of its time. The foundations for the majority of the East Span piers are supported on 26-meter (85- foot) long Douglas fir timber piles. With the foundations buried about 12 meters (40 feet) into the bay muds, the timber piles extend down to about elevation -37 meters (-120 feet) into the bay mud sediments.

The SFOBB provides regional access between San Francisco, the Peninsula and the East Bay. Currently, approximately 350,000 people in 274,000 vehicles use the bridge each day. As a component of Interstate 80 (I-80), it is also a critical link in the Interstate Defense Highway System. The SFOBB East Span, which carries vehicles between YBI and Oakland, is a double-deck structure 3,697 meters (12,127



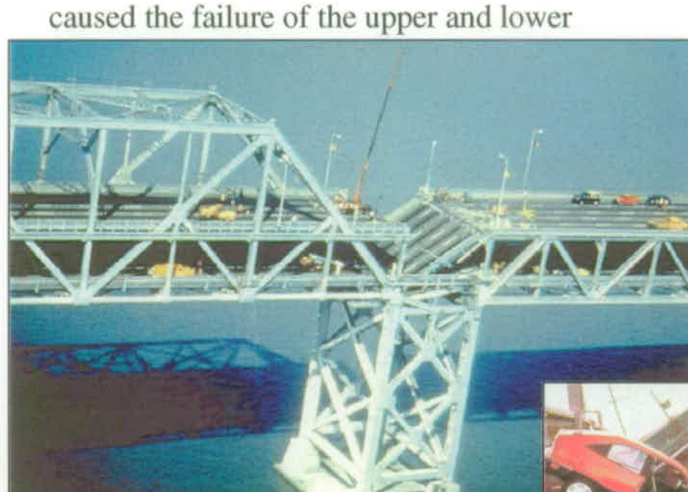
San Francisco-Oakland Bay Bridge – East Span

feet) in length with five traffic lanes in each direction, east- and westbound.

1.2.2 Loma Prieta Earthquake

On October 17, 1989, the Loma Prieta earthquake (magnitude 7.1) struck the San Francisco Bay Area, causing 62 deaths and $5.6 billion in property damage, and leaving 8,000 people homeless. The epicenter of the Loma Prieta earthquake was 96 km (60 miles) away from the San Francisco-Oakland Bay Bridge.

On the SFOBB, the Loma Prieta earthquake caused the failure of the upper and lower



Failure at Pier E-9

decks at Pier E9 (see photo on previous page). A truss broke free from its support causing the upper deck to collapse on to the lower deck. In addition, all 25 mm (1-inch) diameter bolts attaching the north and south fixed shoes to their supports sheared off at each of the Piers E18 through E22. These shear failures allowed the shoes to slip back and forth in the east-west direction. Fortunately, the displacements were not great enough to result in collapse of additional spans.

The East Span was closed for four weeks while the damage was repaired. The closure of the bridge had tremendous impact to commuters who had to be rerouted to other Bay crossings, including other modes of transportation such as ferries or BART.

No analyses have been conducted to quantify the economic impact specific to the closure of the SFOBB. However, the Association of Bay Area Governments (ABAG) did conduct an assessment of the regional macroeconomic impacts of the Loma Prieta Earthquake. ABAG concluded that the maximum loss to the Gross Regional Product was in the range of $181 to $725 million. ABAG noted that San Francisco suffered a significant loss ($73 million) in taxable sales activity, and that "a major portion of the loss in economic activity in San Francisco may have been due to a loss in transportation access" ("Macroeconomic Effects of the Loma Prieta Earthquake," ABAG, 1991).

1.2.3 Project Purpose and Need

The purpose of the East Span Seismic Safety Project is to provide a seismically upgraded "lifeline" vehicular crossing for current and future users between YBI and Oakland. A lifeline connection provides for post-earthquake emergency relief access linking major population centers, emergency relief routes, emergency supply and staging centers, and intermodal links to major distribution centers. The project will upgrade the facility to meet current operational and safety standards to the greatest extent possible. Additionally, a new bridge will not preclude construction of a pedestrian/bicycle path.

The need for the project is based on the following factors:

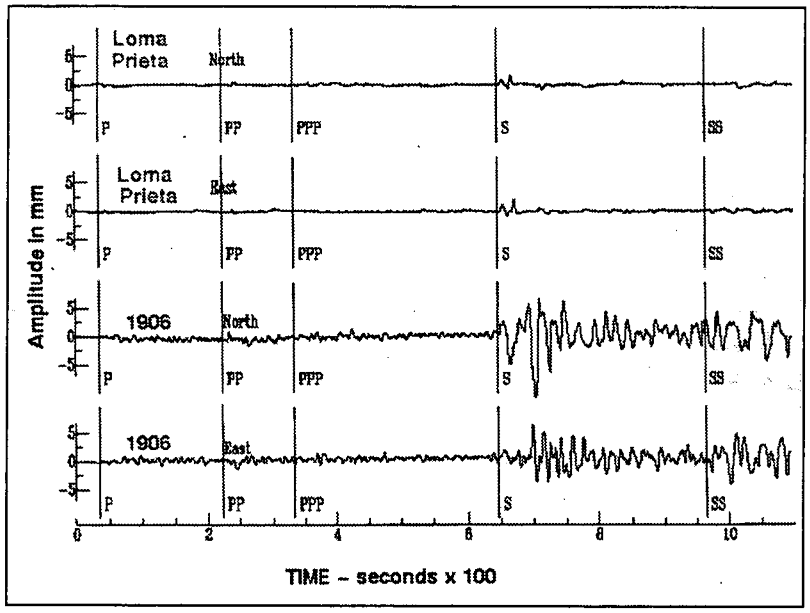
- The existing East Span is not expected to withstand a maximum credible earthquake (MCE)* on the San Andreas Fault (an earthquake of magnitude 8) or Hayward Fault (an earthquake of magnitude 7 1/4).
- The East Span does not provide a lifeline connection for the expected high level of transportation service necessary for emergency response and support for the economic livelihood of the Bay Area following a MCE.
- The existing bridge does not have standard lane widths.
- The existing bridge does not have roadway shoulder areas for disabled or emergency service vehicles.

A MCE on the San Andreas Fault could generate substantially more energy than the Loma Prieta Earthquake. This is due to the potentially greater magnitude of the MCE compared with that of the Loma Prieta Earthquake. For example, the 1906 earthquake (magnitude 8) released 16 times more energy than the Loma Prieta Earthquake. This is shown graphically in seismogram traces of the two earthquakes from seismograph instruments in Gottingen, Germany. This provides a unique comparison of the two events as the same

* A maximum credible earthquake (MCE) was referred to in the DEIS, which reflects a deterministic approach to describing earthquakes. Based on recommendations from the Metropolitan Transportation Commission's (MTC's) Seismic Advisory Board and Engineering Advisory Panel, the earthquake discussions in the FEIS will reflect both a deterministic and probabilistic approach (i.e., describing earthquakes in terms of their return period).

instrument was in operation during both earthquakes.

The proximity of the bridge to the San Andreas and Hayward faults also increases the potential for the epicenter to be nearer the bridge. An epicenter close to the bridge would result in greater seismic forces acting on the bridge.



Comparison of the 1906 and Loma Prieta records at Gottingen, Germany

A MCE on either the San Andreas or Hayward fault would cause heavy damage that would likely be much more widespread than the Loma Prieta earthquake, including the collapse of thousands of buildings, extensive infrastructure damage, and major loss of life. The magnitude of such a natural disaster would necessitate the kind of emergency access provided by a bridge serving as a lifeline connection.

The Hayward fault is located in an area that is more densely populated than the area where the Loma Prieta earthquake hit. According to the United States Geological Survey (USGS), a MCE on the Hayward fault will cause more damage than a MCE on the northern segment of the San Andreas Fault. On the existing SFOBB East Span, a MCE could cause multi-span collapse, potentially resulting in numerous immediate casualties and requiring many months to reopen the bridge or years to build a replacement. As a result, immediate emergency response and more long-term economic recovery would be delayed.

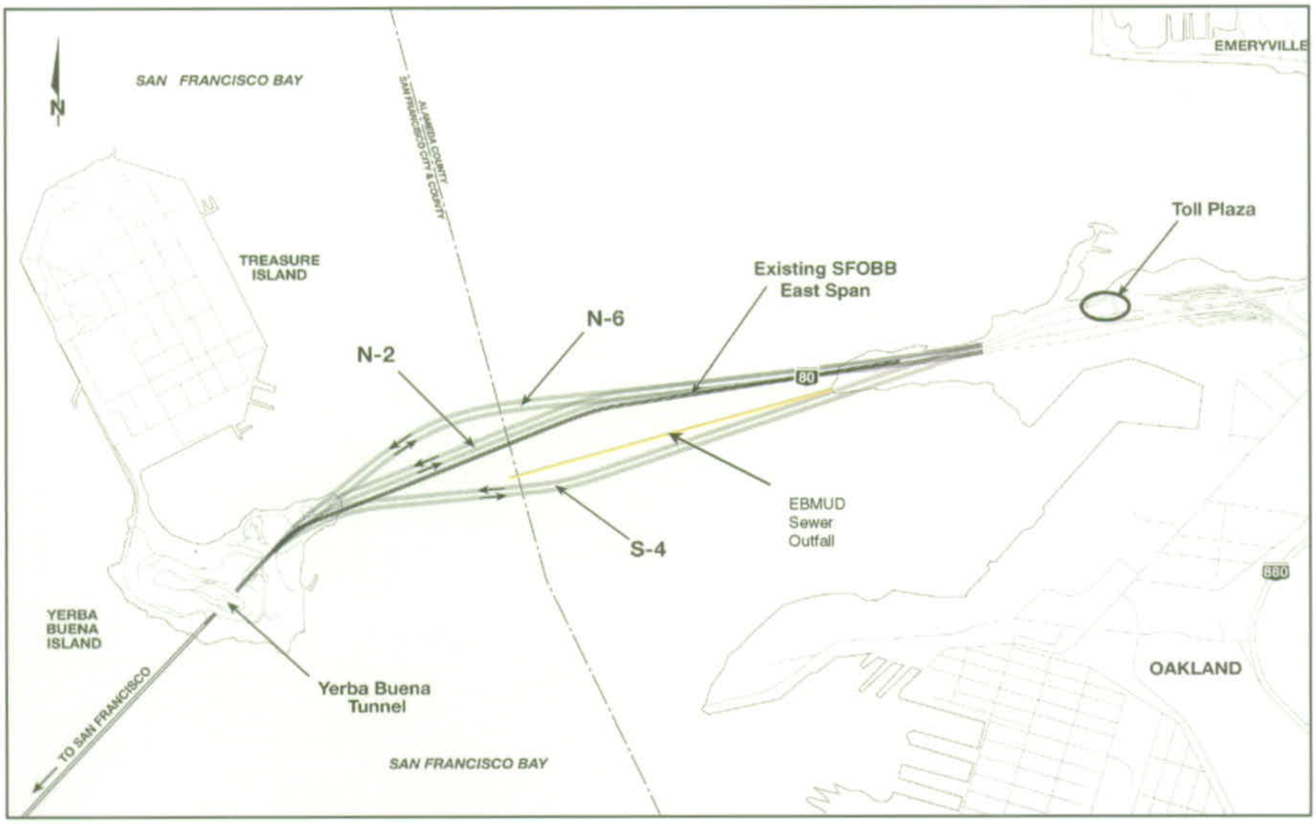
According to a recent report by the USGS, the Bay Area faces a 70 percent probability of an earthquake (magnitude 6.7 or greater) over the next 30 years causing damage equal to or greater than the $20 billion Northridge Earthquake of 1994. The Bay Area faces an 80 percent probability of an earthquake of magnitude 6.0 to 6.7 over the same period. Therefore, it is imperative that the SFOBB East Span Seismic Safety Project be completed as soon as possible.

1.2.4 Project Alternatives

Caltrans has considered and performed engineering studies on a range of possible project alternatives for the SFOBB East Span Seismic Safety Project. The following alternatives were considered in the Draft Environmental Impact Statement:

- No-Build
- Retrofit Existing Structure
- Replacement Alternative N-2
- Replacement Alternative N-6
- Replacement Alternative S-4

<u>No-Build Alternative</u>
The No-Build Alternative would retain the existing SFOBB East Span. The No-Build Alternative assumes that the interim retrofitting of the East Span has been completed as a prior project. The Interim Retrofit Project is currently underway to strengthen bents and columns on the viaduct section on YBI and strengthen piers, bents,



SFOBB East Span Seismic Safety Project -- Replacement Alternatives

and trusses at selected locations on the structure, so that the existing East Span would be able to withstand a moderate earthquake. The Interim Retrofit does not protect the bridge from a catastrophic failure during a large earthquake. The No-Build Alternative was evaluated primarily as a basis for comparison with the other alternatives. The No-Build Alternative does not satisfy the Project purpose and need.

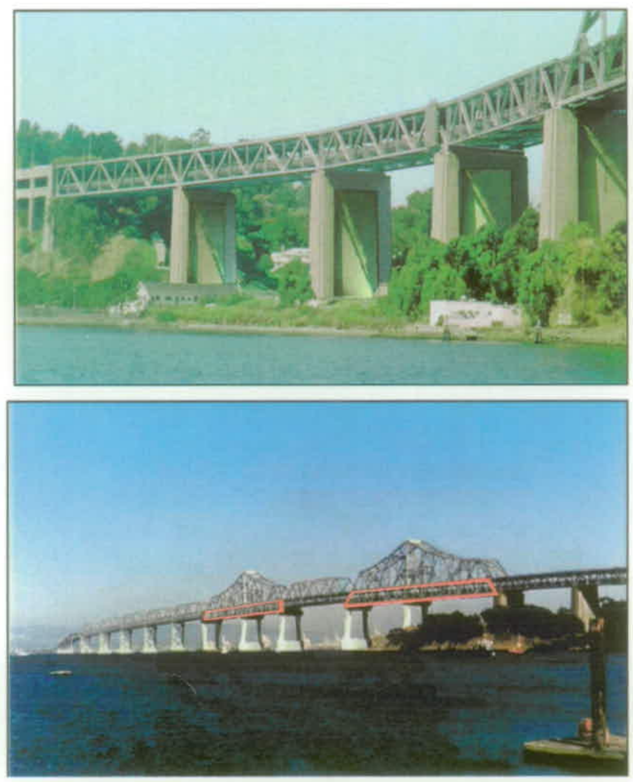


Photo-simulations of Retrofit Existing Structure Alternative

Retrofit Existing Structure Alternative

The Retrofit Existing Structure Alternative would retrofit the existing bridge to withstand a MCE without collapse. The seismic retrofit strategy is based on isolating the superstructure from the substructure (towers, and foundations). This work includes constructing additional large diameter piles and new pile caps around the existing foundations, stiffening the towers, installing isolator bearings at the top of the towers, and strengthening and/or stiffening the superstructure truss members. Two new large deepwater piers would be added to the cantilever span. Although this isolation strategy reduces the level of superstructure modifications, the superstructure would still require significant modifications to strengthen and stiffen the elements of the truss members. An external steel truss to restrict deformation of the cantilever section would extend from the base of the lower deck to the bottom of the upper deck. The external steel truss is highlighted in orange on the photo-simulation on the previous page. The external steel truss would be painted to match the existing bridge.

Even with these modifications, the bridge would still experience substantial damage in the event of a MCE, and therefore not meet the lifeline criteria. This alternative would not provide for improved lane widths and roadway shoulder areas on the existing bridge; therefore, current highway design standards could not be attained. Also, this alternative does not provide for a pedestrian /bicycle facility. Due to these limitations of the Retrofit Existing Structure Alternative, it does not fully satisfy the Project purpose and need.

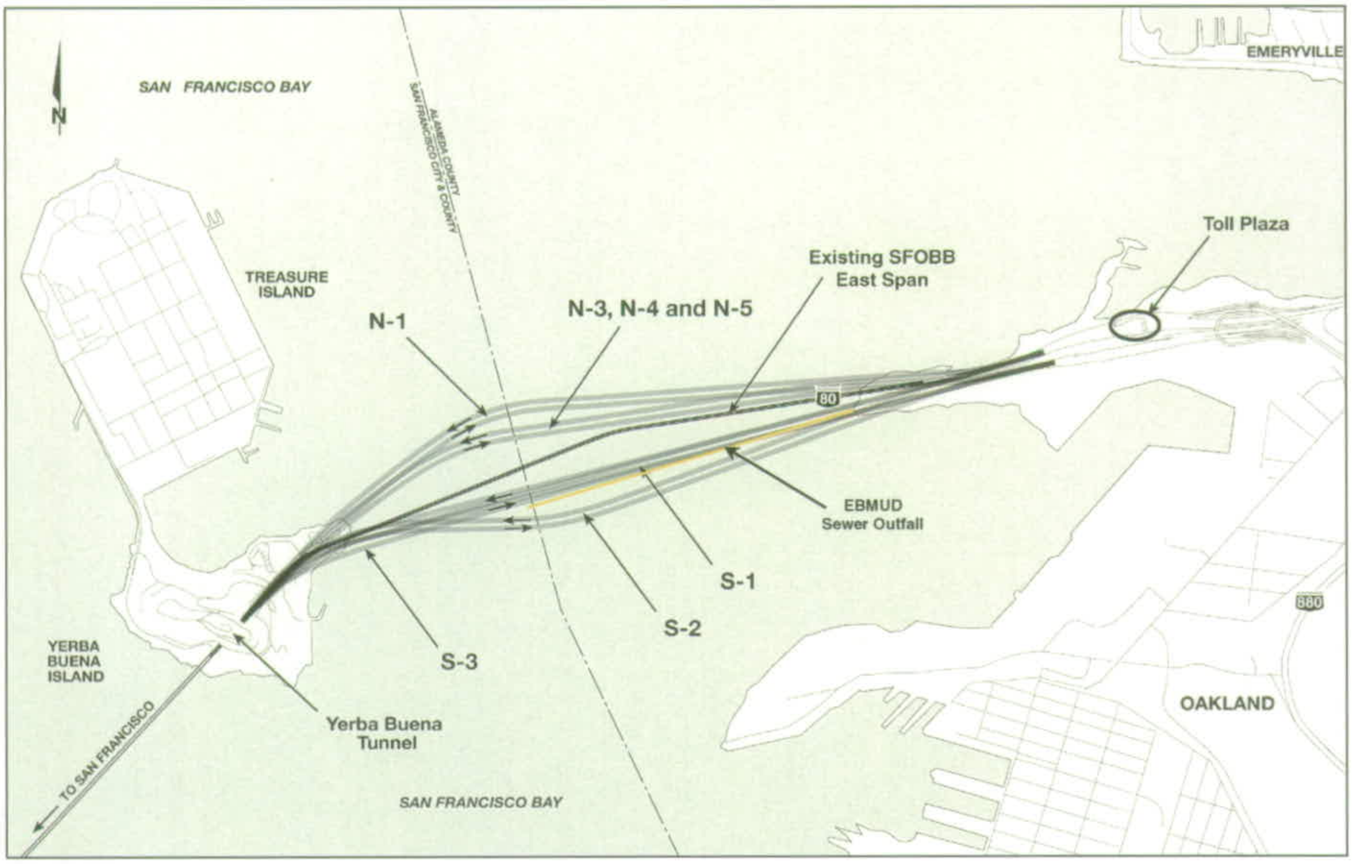
N-2 Alternative

Replacement Alternative N-2 would construct a new bridge (two-side-by-side bridge decks, each deck consisting of five lanes) north of the existing alignment and would dismantle the existing structure. The alignment has been designed to minimize the length of the new bridge by closely following the alignment of the existing East Span. East of the YBI tunnel, the alignment would transition from a double-deck viaduct structure to two parallel structures. The 3,585 meter (11,759 foot) long span would reach the Oakland shore along the northern edge of the existing Oakland Touchdown area and conform to the existing traffic lanes to the west of the SFOBB Toll Plaza. Alternative N-2 would include a pedestrian/bicycle path on the south side of the eastbound structure. The path would be 4.7 meter (15.5 feet) wide and 0.3 meter (1 foot) higher than adjacent lanes. This alternative would meet the Project purpose and need.

N-6 Alternative

Replacement Alternative N-6 is similar to N-2, but the proposed bridge would be aligned north of the existing structure and Replacement Alternative N-2. This alignment has been designed to maximize views to the north of YBI while minimizing intrusion into portions of the Bay where geologic conditions increase the complexity and cost of constructing bridge piers. The overall length of Alternative N-6 is approximately 3,621 meter (11,877 feet). The alignment approaching the Oakland Touchdown area is similar to Replacement Alternative N-2. Alternative N-6 would include a pedestrian/bicycle path on the south side of the eastbound structure. The

Photo-simulation of Replacement Alternative N-6 as viewed from the Oakland Touchdown toward YBI



Alternatives Withdrawn from Further Consideration

path would be 4.7 meters (15.5 feet) wide and 0.3 meters (1 foot) higher than adjacent traffic lanes. This alternative would meet the Project purpose and need.

S-4 Alternative

Replacement Alternative S-4 would be located south of the existing East Span. The alignment would exit the YBI Tunnel on a double–deck viaduct and transition to two parallel structures. The 11,644-foot long span would reach the Oakland shore south of the existing East Span and transition to the existing roadway west of the toll plaza. Alternative S-4 has been developed to avoid offshore conflicts with the alignment of the existing East Bay Municipal Utility District (EBMUD) sewer outfall, which parallels the existing East Span to the south. Alternative S-4 would include a pedestrian/bicycle path on the south side of the eastbound structure. The path would be 4.7 meters (15.5 feet) wide and 0.3 meters (1 foot) higher than adjacent traffic lanes. This alternative would meet the Project purpose and need.

1.2.5 Other Alternatives Considered and Withdrawn

Caltrans considered several other project alternatives that were ultimately withdrawn from further consideration. The alternative alignments and the reasons for withdrawal are identified in the Draft Environmental Impact Statement and are summarized here.

N-1 Alternative

Replacement Alternative N-1 is a 3,685 meter (12,087-foot) long replacement alternative located to the north of Alternative N-6. However, based on geologic data, it was determined that approximately one-half of the N-1 alignment would fall within areas of deep young Bay mud, increasing the complexity, schedule, and cost of constructing the bridge substructure while potentially reducing seismic performance. Therefore, Alternative N-1 was withdrawn from further consideration.

N-3 Alternative

Replacement Alternative N-3 would place the main span tower close to YBI, where geologic conditions are most favorable for the tower footing, thus facilitating the construction schedule by reducing the amount of in-Bay excavation. Alternative N-3 is located to the south of Alternative N-6. However, the tower location would require the roadway horizontal and vertical alignments to be modified to less than optimum configurations, resulting in restricted sight distances, which affect driver response, and therefore safety. Therefore, Alternative N-3 was withdrawn from further consideration.

N-4 Alternative

Replacement Alternative N-4, a modification of the N-3 alignment, provides for a 180-meter (591-foot) tangent (straight) roadway section at the YBI tunnel approach on the westbound alignment. This alternative was designed to satisfy design standards by preventing westbound traffic from entering the tunnel portal on a curve. However, because of the deep water location of the main span tower, resulting in increased project cost and lengthened construction schedule, Alternative N-4 was withdrawn from further consideration.

N-5 Alternative

Replacement Alternative N-5, a modification of Alternative N-3, consists of a larger curve radius for the westbound alignment entering the YBI tunnel portal, reducing or eliminating sight distance concerns. However, based on the desire to place a tangent roadway section at the westbound alignment approach to the YBI tunnel portal and the need to place and maintain the main span tower as close to YBI as possible, Alternative N-5 was withdrawn from further consideration.

S-1 Alternative

Replacement Alternative S-1 was defined as the most direct alignment between YBI and the Oakland Touchdown. However, this alignment would not meet superelevation design standards for curves at the YBI tunnel approach, requiring a mandatory design exception and affecting roadway safety. Furthermore, this alignment would create significant conflicts with the EBMUD sewer outfall. Therefore, Alternative S-1 was withdrawn from further consideration.

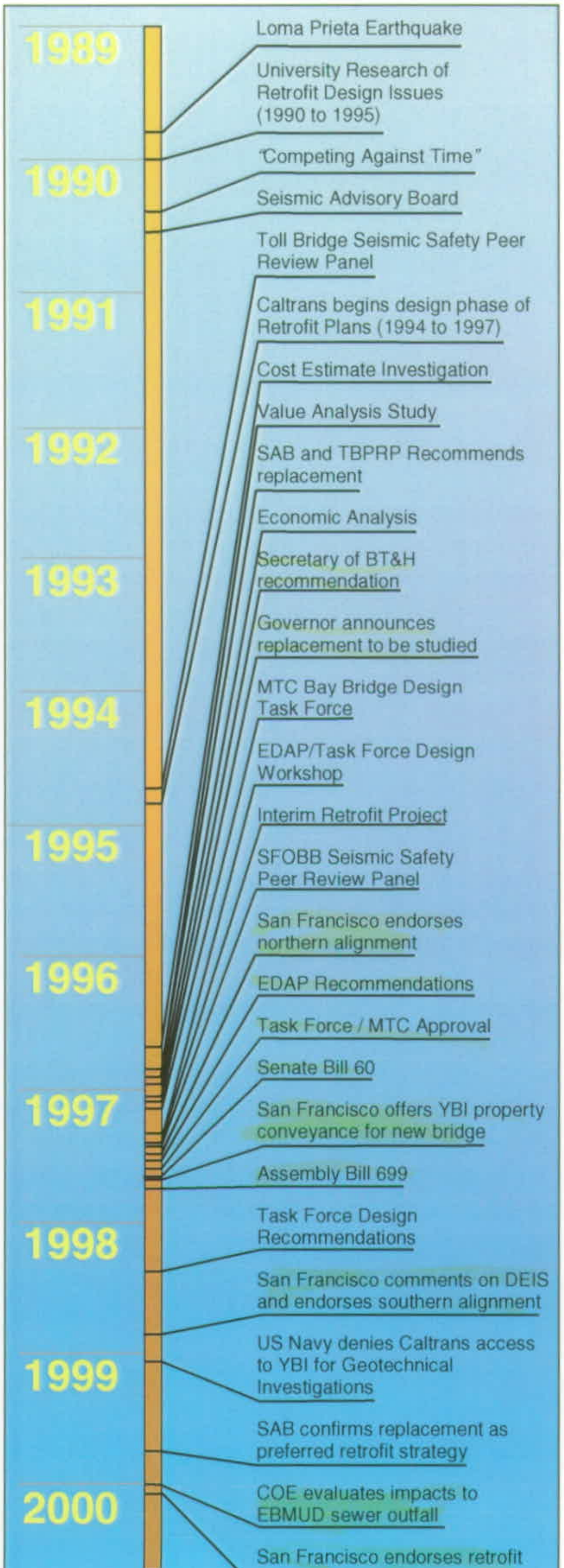
S-2 Alternative

Replacement Alternative S-2 provides broader radius curves than the S-1 alternative at the YBI Tunnel approaches, avoiding the need for design exceptions. Furthermore, this alignment would avoid offshore conflicts with the EBMUD sewer outfall. However, construction staging to maintain five lanes of traffic in each direction would require construction of temporary detour structures out to the cantilever section of the existing East Span. Further investigation indicated that the tie-in of the temporary detour structures to the cantilever section would be complex and potentially could compromise structural integrity of the existing structure. Therefore, Alternative S-2 was withdrawn from further consideration.

S-3 Alternative

Replacement Alternative S-3 is a refinement of S-1, which would also eliminate the need for design exceptions for superelevation of roadway curves. However, this alignment would require construction of detour structures similar to those described for Alternative S-2, raising concerns for the structural integrity of the existing East Span cantilever section. Therefore, Alternative S-3 was withdrawn from further consideration.

2.0 PROJECT HISTORY



There is a long history in the decision to replace the east span of the San Francisco-Oakland Bay Bridge rather than retrofit. The decision has been based on careful study and analysis. This section summarizes the key decision points and activities that led to the alternative that best serves public safety.

October 17, 1989
Loma Prieta Earthquake

On October 17, 1989, the Loma Prieta Earthquake (magnitude 7.1) struck the San Francisco Bay Area, causing 62 deaths and $5.6 billion in property damage and leaving 8,000 people homeless. The epicenter of the Loma Prieta Earthquake was 60 miles away from the San Francisco-Oakland Bay Bridge.

On the SFOBB, the Loma Prieta Earthquake caused significant damage at a number of locations including the failure of the upper and lower decks at Pier E9 (see photo above). A larger or longer duration earthquake would likely have resulted in a multispan collapse of the east span.

The east span was closed for four weeks while the damage was repaired. The closure of the bridge had tremendous impact to commuters who had to be rerouted to other bay crossings, including other modes of transportation such as ferries or BART. Many decided to avoid discretionary trips into San Francisco.

1990 - 1995
University Research of Seismic Retrofit Design Issues

Constructed in the 1930s with literally hundreds of thousands of individual structural elements, the east span was immediately recognized to be an extremely complex and difficult bridge to assess for retrofit strategies. Research projects were started soon after the Loma Prieta Earthquake to better understand the vulnerabilities of the east span and to develop retrofit strategies for construction.

The State entered into various contracts with the University of California at Berkeley (UCB) to conduct research and prepare reports on the seismic retrofit of the State-owned toll bridges. Professor Abolhassan Astaneh-Asl, a Professor of Civil Engineering at UCB, participated in this research together with other UCB professors and students.

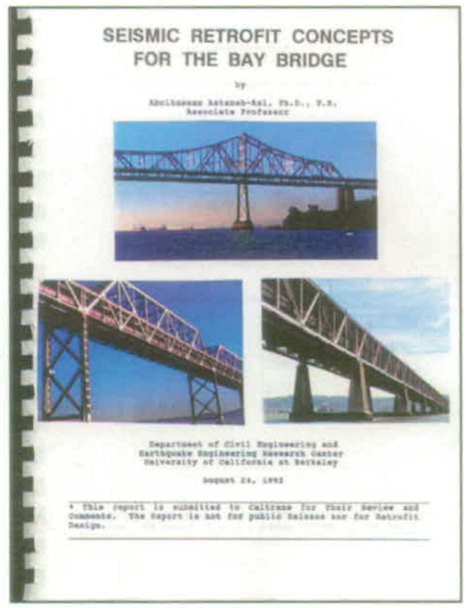
During the period of these contracts, Professor Astaneh conducted several research efforts in laboratory testing of structural steel elements. Professor Astaneh's research focused on the east span, but its intended use was to offer general insight into the challenge of seismically retrofitting large steel bridges like those which were to be retrofitted throughout California as part of the toll bridge retrofit program. Only a portion of the contracted for reports were produced, and many of the reports that were produced were in draft form and were never finalized.

The research contracts with UCB were not contracts for production of contract Plans, Specifications and Estimates (PS&E). This was understood by the UCB staff as reflected by the following statement which appeared on the cover of the report titled *Seismic Retrofit Concepts for the Bay Bridge*.

"The report is not for public release nor for retrofit design."

This report was one of the reports submitted in draft and never finalized.

Additional reports were prepared for a variety of tests performed by Professor Astaneh. A sampling of his reports are listed in Appendix E.


SEISMIC RETROFIT CONCEPTS
FOR THE BAY BRIDGE

by

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August 24, 1992

* This report is submitted to Caltrans for Their Review and Comments. The Report is not for public Release nor for Retrofit Design.

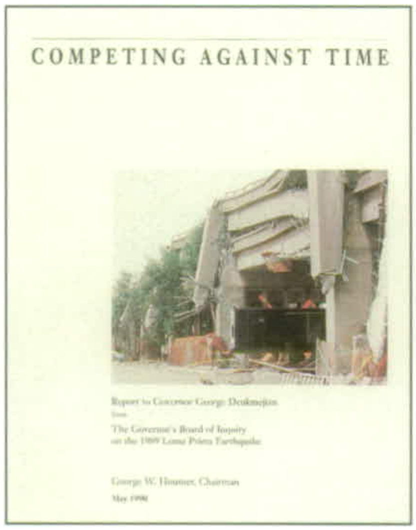
These reports were limited in scope and were intended to focus only on bridge members. The reports provided insight for development of retrofit strategies for elements of the bridge. However, none of the reports studied bridge design or foundation design.

May 31, 1990
"Competing Against Time"
A Report by the Governor's Board of Inquiry

On November 6, 1989, then-Governor George Deukmejian created a Board of Inquiry (Governor's Board) to investigate the collapse of the Cypress Structure of Interstate 880 and spans of the San Francisco-Oakland Bay Bridge. The Governor's Board was made up of eleven experts in the fields of civil, structural, and seismic earthquake engineering and design, and earthquake science. The Governor's Board was chaired by Dr. George Housner of the California Institute of Technology.

The Governor's Board made the following eight recommendations to the Governor:

1. Affirm the policy that seismic safety shall be a paramount concern in the design and construction of transportation structures
2. Establish that earthquake safety is a priority for all public and private buildings and facilities within the State
3. Direct the Seismic Safety Commission to review and advise the Governor and Legislature periodically on State agencies' actions in response to the recommendations of this Board of Inquiry



4. Prepare a plan, including schedule and resource requirements, to meet the transportation seismic performance policy and goals established by the Governor
5. Form a permanent Earthquake Advisory Board of external experts to advise Caltrans on seismic safety policies, standards, and technical practices
6. Ensure that Caltrans' seismic design policies and construction practices meet the seismic safety policy and goals established by the Governor
7. Recommendations for specific structures
8. Recommendations for other agencies and independent districts that are responsible for transportation systems

Per Recommendation 5, the formation of a permanent Earthquake Advisory Board of external experts was established in the summer of 1990 and is known as the Caltrans Seismic Advisory Board.

Summer 1990
Formation of the
Caltrans Seismic Advisory Board

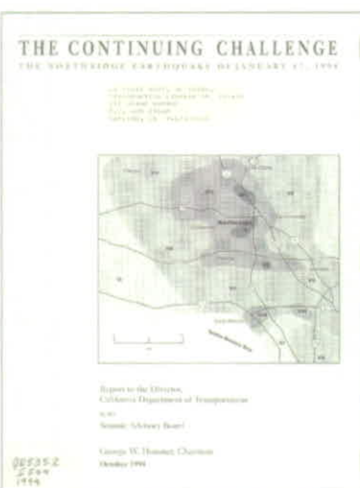
In response to the Governor's Executive Order D-86-90, the Seismic Advisory Board (SAB) was formed. The SAB advises Caltrans on seismic safety policies, standards, and technical practices. The SAB consists of preeminent experts in seismology, geotechnical engineering, and structural engineering from the earthquake engineering community and academia. The members of the SAB at that time were:

- Joseph Penzien, Chair SAB, Professor Emeritus, University of California, Berkeley, one of the pioneering researchers in modern bridge seismic analysis and design ground motions
- Bruce A. Bolt, Professor Emeritus, University of California, Berkeley, world-renowned seismologist, Mr. Bolt is credited with alerting Caltrans to the near-field velocity pulse (i.e. seismic "fling")
- John F. Hall, Professor, California Institute of Technology, leader in the field of earthquake engineering
- Alexander C. Scordelis, Professor Emeritus, University of California, Berkeley, pioneering researcher in structural bridge analysis
- Nicholas F. Forell, Founding Partner, Forell / Elsesser Engineers, Inc, Building Seismic Safety Council delegate and

past president of the Applied Technology Council. With Mr. Forrell's passing in February 1998, he was replaced by:

F. Robert Preece, President, Preece, Goudie & Issa, San Francisco, respected practicing structural engineer in California

- Joseph P. Nicoletti, structural engineer, URS Consultants, San Francisco, a leader in structural engineering in California
- I. M. Idriss, Professor of Civil and Environmental Engineering, University of California, Davis, world-renowned expert on seismic site response
- Frieder Seible, Professor of Structural Engineering, University of California, San Diego, expert in finite element analysis and structural element testing



In January 1994, the status of the SAB was reported as follows in a report to the Director of Transportation entitled *The Continuing Challenge, The Northridge Earthquake of January 17, 1994.*

"The California Department of Transportation established a board of eight leading experts in the field of seismic engineering and design. Caltrans Bridge Earthquake Engineering staff and management meet with the SAB quarterly to obtain their approval of new criteria and solicit their advice on future developments. Four of the eight board members were also members of the Governor's Board of Inquiry and one is the chairman of the Engineering Criteria Review Board for the Bay Conservation and Development Commission. Another member is the chair of the Seismic Research Advisory Panel."

Noted in this report, the SAB identified a lack of progress on the State-owned toll bridges stating,

"Although the size and complexity of the toll bridges makes progress slower, their importance puts a premium on completion before they are damaged in an earthquake."

The SAB continues today in its role as advisors for the replacement of the San Francisco-Oakland Bay Bridge as well as other seismic policy issues on projects throughout California.

1994
Caltrans Toll Bridge Seismic Safety Peer Review Panel

In response to the SAB finding that the State-owned toll bridges were an important element of the transportation system and therefore carry great importance to the State, Caltrans formed a Toll Bridge Peer Review Panel (TBPRP). The mission of the TBPRP was to review and guide the retrofit strategies under development for the State-owned toll bridges. The panel was comprised of experts from the fields of seismology, major bridge design, and construction.

The panel members and a brief summary of their credentials are as follows:

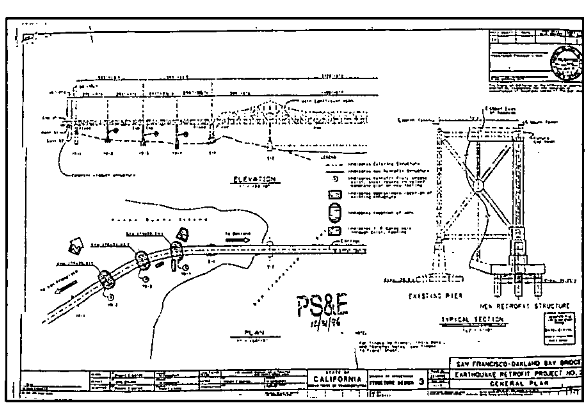
Mr. Charles Seim (Panel Chair) is a world renowned bridge engineer currently working for TY Lin International. As a Senior Principal and the Senior Bridge Engineer of the firm, he manages the design of major bridge structures, conducts structural investigations and writes engineering reports. Prior to his work with TY Lin, Mr. Seim worked as a supervising bridge engineer with Caltrans where he was in charge of the California Toll Bridge Maintenance Unit that includes the maintenance of the San Francisco-Oakland Bay Bridge. Mr. Seim is the engineer of record for the seismic retrofit of the mainspan of the Golden Gate Bridge.

Dr. I.M. Idriss is an internationally recognized expert on-site response to seismic motions. He is a Professor of Civil and Environmental Engineering at the University of California at Davis (UCD). Dr. Idriss recently received an award from the University of California for outstanding service and contributions to the engineering community. Dr. Idriss' membership on this panel is but one example of his continuing service to the community.

Mr. Jerry Fox is an expert bridge designer. Before retiring, Mr. Fox led the bridge group at HNTB, a major bridge design firm. At HNTB he designed a variety of cable-supported bridges including long span steel and concrete bridges. Mr. Fox remains active on several bridge committees and panels guiding others with his internationally recognized expertise for designing large bridges. He is of the highest caliber of large bridge engineers.

Late 1994 - 1996
Caltrans Begins Design Phase of SFOBB East Span Retrofit PS&E

Once possible retrofit design strategies were determined, Caltrans began production of the plans, specifications and estimates (PS&E) for a retrofit construction project. Caltrans design engineers met with the Seismic Advisory Board on a quarterly basis as the design and plans progressed. The purpose of these meetings was to confirm that the proposed design was appropriate for the conditions.

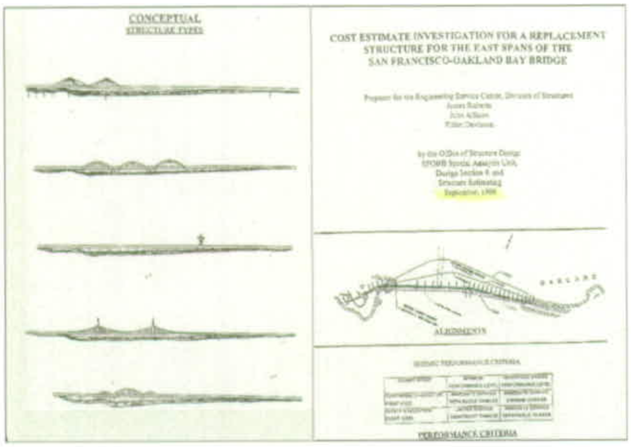


As development of PS&E progressed it became clear to the Department that the retrofit would be extremely costly due to its exceptional complexity. The retrofit project was broken into a series of ten contracts totaling over $900 million in construction costs. By late 1996, the PS&E packages were developed to levels of completion ranging from 65% to 95% completion before it was determined that a replacement alternative was the best retrofit strategy for the east span of the San Francisco-Oakland Bay Bridge. The retrofit strategy for the east span is further described in *Section 4.0, Retrofit Alternatives*.

September 1996
Cost Estimate Investigation for a Replacement Structure for the East Span of the San Francisco-Oakland Bay Bridge

With the estimated cost to retrofit the existing east span having escalated to over $900 million, then-Caltrans Director James Van Loben Sels questioned the cost-effectiveness of retrofitting the existing bridge and requested that a cost study be prepared for a replacement alternative for comparison purposes.

To assess the cost implications of a replacement structure, the Caltrans Office of Structure Design, SFOBB Special Analysis Unit, Design Section 9, and the Structure Estimating Unit prepared a study of replacement alternatives as a seismic retrofit measure.

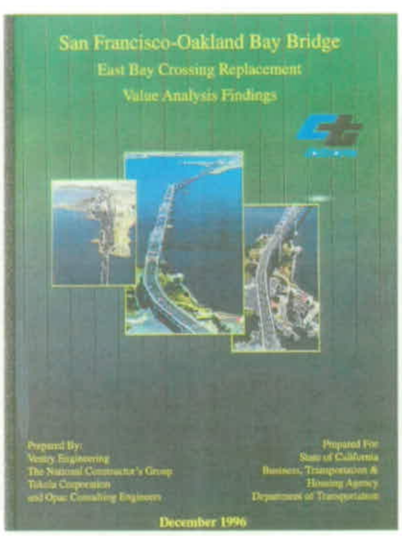


Five alignments for replacement bridges were reviewed including four northern alignments and one southern alignment. Seven bridge types were studied including variations of concrete and steel viaducts, and concrete and steel cable-stayed structures.

The preliminary design resulted in replacement costs ranging from $900 million to $1.4 billion. The cost for each replacement alternative is directly related to structure type, transportation capacity, and alignment. The selected seismic performance criteria were also noted as a significant contributing factor in the cost of a replacement structure.

December 1996
Value Analysis Study

Upon completion of the cost estimate study for a replacement alternative, the Caltrans Director requested an independent assessment of the staff recommendation to replace the existing east span rather than retrofit.



To assess staff recommendations, Ventry Engineering was contracted to perform a value analysis (VA) of all alternatives including retrofit and replacement alternatives. The Value Engineering Team was led by William F. Ventry, P.E., C.V.S. Mr. Ventry is a Certified Value Specialist (CVS).

A team of technical experts covering the areas of structures, geotechnical, highway, construction, environmental, and value engineering reviewed the alternatives. The following firms made up the Value Engineering Team:

- Ventry Engineering
- OPAC Consulting
- National Constructors Group
- Tokola Corporation

The Ventry Engineering report summarizes the results of a VA study of the east span for the San Francisco-Oakland Bay Bridge conducted for Caltrans. The study compared alternatives that would provide acceptable earthquake resistance for the east span, ranging from retrofitting the existing bridge to construction of replacement structures with varying designs and locations. Below are quotes from the VA study, followed by a brief summary of some of its conclusions.

> *"The Value Analysis studies lead to a clear conclusion that bridge replacement is a better option than bridge retrofit. This is true for all issues of the project that were studied. These issues, classified here as*
> *1) cost,*
> *2) performance,*
> *3) maintenance,*
> *4) environment, and*
> *5) construction,*
> *are discussed [in the report]. Replacement is the better option for each of these issues - retrofit has no advantages discernable under value*

analysis. The discussion below is one-sided in favor of replacement because that reflects the findings of the Value Analysis studies."

The Value Analysis concluded that:

- A replacement bridge is less costly in all cost comparisons (construction cost, maintenance cost, life cycle cost, travel cost, post-earthquake damage repair cost).
- A replacement bridge will perform better structurally and as a transportation link. Its seismic performance is also better.
- A replacement bridge can be built to reduce future maintenance requirements.
- A replacement bridge provides an opportunity to remove existing features or avoid new features that contribute to environmental impacts, and to add new features that would reduce environmental impacts.
- A replacement bridge can be constructed with fewer traffic disruptions, with greater work crew efficiency and with fewer construction risks such as contract delays. It can probably be built faster.
- Retrofitting has inherent uncertainties. It is prone to design detail problems, delay and added cost, which cannot be reasonably measured or evaluated.

December 10, 1996
Recommendations by the Caltrans Seismic Advisory Board and Seismic Safety Peer Review Panel

The SAB and TBPRP were briefed on the retrofit project on a quarterly basis. As the design progressed, the SAB and TBPRP became concerned regarding the cost and extreme measures required for the retrofit project. The SAB and the TBPRP wrote to then-Caltrans Director James van Loben Sels concerning their positions on whether the east span of the San Francisco-Oakland Bay Bridge should be retrofitted or replaced. The following are quotes from that letter:

"Both the SAB, in its charge to address and advise Caltrans on seismic policy, and the [TB]PRP, in its mission to review seismic safety issues regarding all toll bridge retrofit designs, support replacement of the East Bay spans of the San Francisco-Oakland Bay Bridge rather than the retrofit of the existing structure. Without considering political and legal issues, we have based this position on technical evidence which clearly favors the construction of a replacement bridge over retrofit of the old bridge. The evidence is consistent not only with respect to the crucial question of seismic safety but also with respect to reliability, constructibility, traffic maintenance, structure maintenance, initial costs, life cycle costs, and environmental concerns."

"It is our opinion that Caltrans' engineers are employing state-of-the-art technology and recent research results in the retrofit design for the existing bridge to ensure safety (no collapse) during a maximum expected earthquake for this location; but the expected performance envisions the occurrence of a major traffic interruption following the earthquake. A new bridge could however be designed with much greater reliability to respond favorably to a major earthquake of this type. The design of a new structure would be uncompromising in the selection of structural configuration and ductile response, the material control would be excellent, and the complete structure would respond essentially elastically to the strong ground motions. Therefore, the bridge would need very little, if any, repair after a major earthquake. The design for the retrofit of the old bridge is compromised by restraints imposed by

the existing structure and by the need to minimize traffic interruptions. Work to date shows that it is nearly impossible and certainly expensive to retrofit the old bridge to the same level of seismic performance as a new structure."

"In view of the above statements and in the interest of public safety and economy, the members of the SAB and the [TB]PRP strongly recommend a replacement structure for the East Bay spans of the San Francisco-Oakland Bay Bridge rather than the seismic retrofit of the old structure. All members of the SAB and [TB]PRP stand ready to assist in the decision process on the above matter and to help in convincing the general public and elected officials that a replacement bridge is the correct long-term choice in view of the permanent high-level seismic hazard in the San Francisco Bay region."

December 17, 1996
Replacement Study for the East Span of the SFOBB Seismic Safety Project
A probabilistic economic analysis was prepared by Dr. Brian Maroney of Caltrans to assist in the decision making process of retrofit versus replacement.

The alternatives were evaluated in terms of probable outcome and cost. To facilitate comparison of alternatives, probable dollars were used as a measure of effectiveness. This essentially established an economic analysis comparing retrofit and replacement of the east span.

It was recognized that dollar value does not always allow for complete evaluation in what is fundamentally a safety upgrade project.


REPLACEMENT STUDY FOR THE EAST SPANS OF THE SAN FRANCISCO - OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECT

Engineering Service Center

Prepared by Brian Maroney

December 17th, 1996

Some outcomes are unacceptable regardless of economy. Therefore, an allowance was given to evaluate outcome as well as cost.

The following items were considered in developing the economic analysis:
- Loss of life
- Structure collapse
- Probability and magnitude of earthquakes
- Earthquake event before and after upgrade
- Structure condition
- Foundation condition
- Maintenance costs
- Traffic volumes
- Historic value
- Legal issues

The analysis supported a decision to replace the east span of the San Francisco-Oakland Bay Bridge with a new structure.

The analysis included the assessment of an "enhanced" retrofit project. This enhanced retrofit project would provide a higher level of performance during a large earthquake than the current retrofit design, which is designed to a level of "no collapse". However, the enhanced retrofit project still does not meet the performance criteria for a lifeline standard.

A replacement alternative was supported due to the high cost of construction for the Retrofit Alternative. This is consistent with State policy. In a June July? 12, 1996 letter, the State of California, Department of General Services established a policy, based in part on Proposition 152, that dictates consideration of replacement as an alternative when the retrofit costs exceed 75 percent of replacement costs. At the time of the economic analysis report, the capital cost for retrofit was $915 million compared to a cost for replacement of $1.17 billion viaduct structure. Construction costs for the Retrofit Alternative represented 78% of replacement costs. When considering lifecycle costs on a 50-year basis, the percentage of retrofit to replacement costs increased to 89%.

January 10, 1997
Secretary of Business, Transportation and Housing Recommends Replacement
Based on the research and analysis of retrofit alternatives and on the testimony of world-renowned experts on all aspects of bridge and seismic design, then-Secretary of Business, Transportation and Housing Dean Dunphy signed a recommendation to consider replacement of the east span of the San Francisco-Oakland Bay Bridge as a project alternative. The following is the *Summary of Recommendation* from the Secretary's recommendation to the Governor.

> *"The California Department of Transportation (Caltrans) has extensively analyzed and the Seismic Advisory Board thoroughly reviewed seismic retrofit alternatives for the structures of the San Francisco-Oakland Bay Bridge (SFOBB). While retrofit of the western span is an effective treatment, replacement of the eastern spans of the bridge from the Oakland shore to the tunnel at Yerba Buena Island appears more desirable than retrofitting the existing structure. A new eastern structure, coupled with enhanced retrofit of the western span, provides:*
>
> - *greater seismic safety, reliability, constructibility, and maintenance of traffic flow;*
> - *significantly lower long term maintenance and life cycle costs than retrofit of the existing spans;*
> - *a lifeline connection between San Francisco, the east bay and the I-80 corridor to the east providing higher post earthquake transportation service for emergency response and continued livelihood of the Bay Area; and*
> - *a structure which meets current traffic safety standards to Yerba Buena Island.*
>
> *It is recommended that the necessary studies proceed leading to a timely decision, recognizing that the existing structure is vulnerable, because the potential benefits of a new structure far outweigh the risk associated with the additional 2 years a new bridge will take to complete. If this recommendation is approved, then Caltrans will:*
>
> - *Proceed with concurrent design of a new structure for the east bay spans of the SFOBB.*
> - *Complete the retrofit design of the east bay spans as insurance in the event the replacement alternative proves unacceptable.*
> - *Expedite an interim retrofit for the east bay spans to avoid collapse in the less than maximum but more likely seismic events.*
> - *Proceed with environmental studies that do not preclude either the retrofit or replacement alternative. The environmental document will be segmented and FHWA will be pursued as the lead agency.*
> - *Proceed with the retrofit of the west bay spans of the SFOBB to lifeline standards."*

February 1997
Governor's Press Release
In a press release, then- Governor Pete Wilson announced his acceptance of the recommendation from the Secretary of Business, Transportation and Housing to consider replacement of the east span of the San Francisco-Oakland Bay Bridge as an alternative for the project.

The release noted that the option to retrofit the existing east span of the Bay Bridge was *"a monumental engineering challenge"*. The complexity of the structure coupled with the large number of bridge members provides too many opportunities for failures in a major quake. A new bridge can be built to current design standards that incorporates the latest technological advances in the science of seismic, structural and materials engineering.

Dr. Joseph Penzien, professor emeritus of Structural Engineering at the University of California, Berkeley, and Vice Chairman of the Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake stated,

> *"Thanks to the considerable research that has been done so far the knowledge of the seismic forces that could affect the bridge and how the structure would respond have expanded exponentially. The members of the Seismic Advisory Board agree with Caltrans' decision to pursue a new bridge."*

Following the Governor's announcement, the Metropolitan Transportation Commission (MTC), the regional transportation planning agency for the Bay Area, established a process with Caltrans to achieve regional consensus on alignment, design and bridge amenities.

The MTC is the transportation planning, coordinating and financing agency for the nine-county San Francisco Bay Area. Created by the State Legislature in 1970 (California Government Code § 66500 et seq.), MTC functions as both the regional transportation planning agency – a state designation – and for federal purposes, as the region's metropolitan planning organization (MPO). As such, MTC is responsible for the Regional Transportation Plan, a comprehensive blueprint for the development of mass transit, highway, airport, seaport, railroad, bicycle and pedestrian facilities. The Commission also screens requests from local agencies for state and federal grants for transportation projects to determine their compatibility with the plan.

The Commission consists of 19 commissioners representing the cities and counties in the nine-county Bay Area as well as certain state and federal interests. Federal representation includes the Department of Transportation and the Department of Housing and Urban Development. Two members represent regional agencies -- the Association of Bay Area Governments (ABAG) and the Bay Conservation and Development Commission (BCDC).

Early 1997
The MTC Bay Bridge Design Task Force
MTC organized the Bay Bridge Design Task Force (Task Force) in early 1997 to consider replacement bridge alternatives. The Task Force mandate was to develop a consensus recommendation for a new east span of the SFOBB and recommend any additional features that might be included in the design of the replacement bridge. The Task Force is composed of seven MTC commissioners with two representatives each from Contra Costa, San Francisco, and Alameda counties, and one representative from BCDC. One of the San Francisco members was appointed by the Mayor of San Francisco while the other was appointed by the San Francisco Board of Supervisors.

MTC Engineering and Design Advisory Panel (all members not shown)

The MTC Task Force formed an Engineering and Design Advisory Panel (EDAP) to advise the Task Force on issues of cost, engineering feasibility, design factors, and seismic safety. The EDAP is comprised of technical experts in structural, geotechnical, seismic and civil engineering, and architecture. The original 33 members of EDAP are listed in Appendix H of this report. EDAP deliberations included meetings and workshops open to the public for presentation of design concepts from interested parties.

Beginning with the first formal public meeting on March 27, 1997, the Task Force began the process to consider different types of replacement bridge structures and alignment issues.

May 1997
EDAP / Task Force Design Workshop
The EDAP and Task Force held a three-day design workshop to identify and consider the technical and aesthetic opportunities for a new east span. A wide range of cable supported structures were submitted by members of the public and engineering community, including well known engineering firms and agencies such as:

- Caltrans
- Gerwick/Sverdrup/DMJM
- Lin Tung-Yen China, Inc.
- OPAC Consulting Engineers
- Parsons Brinckerhoff
- TYL International
- URS Greiner

Bridge designs submitted by other companies and individuals included:

- Astaneh-Black
- Coman Feher
- DCM Studios
- Garrett Green
- Michael Longo
- Zhong-Lin-Hsue

The submission by Professors Astaneh and Black of the University of California, Berkeley (UCB) consisted of a combination single-tower cable-supported mainspan and skyway structure connecting to the Oakland shore. The atypical design of the cable-stayed portion of the structure incorporated an inclined tower supporting a curved deck. The Astaneh-Black design was proposed on a northern alignment and featured a connection between differing bridge types (cable-stay and skyway structures). These features are consistent with the current proposed design for the Replacement Alternative, yet Professor Astaneh has faulted the current proposed design due to the existence of these features.

A UCB press release (www.urel.berkeley .edu/urel_1/CampusNews/PressReleases/ releases/bridge.html) announcing the Astaneh-Black design stated,

> *"Astaneh was leader of the team that studied the seismic vulnerability of the Bay Bridge's eastern span. The team's findings eventually led to the decision to tear it down and build a new segment between Yerba Buena Island and Oakland."*

This statement appears on its face to be supportive of replacement as opposed to retrofit of the existing bridge.

The Astaneh-Black design was atypical in that the supporting main tower was inclined. All other submissions used supporting structural towers that were vertical. Due to concerns regarding the seismic reliability of the design, the Astaneh-Black submission was not selected.

Spring 1997
Interim Retrofit Project
Due to the political and environmental uncertainties associated with a replacement alternative, Caltrans proceeded with an interim retrofit project to provide protection to the east span against a smaller, more probable earthquake. The project was implemented as insurance for the short term to buy back a portion of the risk during the time required to environmentally approve, design, and construct a replacement bridge. The interim retrofit project will not protect the east span from collapse and catastrophic failure during a large earthquake.

Nearly all of the bridge segments of the east span from the Yerba Buena Island tunnel to Pier E23 near the Oakland shore have received some retrofit improvement. The work focused on stiffening the tower and superstructure elements and strengthening the connections at the towers.

The towers were strengthened by installing additional steel plates, anchor bolts, diagonals, and replacing selected rivets with high strength steel bolts. The superstructure work included replacing rivets, upgrading vertical posts, and installing steel plates.

The contract was let out to construction on May 6, 1998, with construction estimated at $19 million.

Spring 1997
SFOBB Seismic Safety Peer Review Panel
As the development of retrofit strategies progressed for the State-owned toll bridges, it soon became apparent that each bridge represented a unique challenge. To address the challenges of the east span of the San Francisco-Oakland Bay and to assist the design team in designing a retrofit strategy, Caltrans commissioned an independent panel, the Seismic Safety Peer Review Panel (SSPRP), which possesses the expertise to address every major seismic issue that the team would face. The panel is comprised of world-renowned experts in the fields of seismology and geotechnical site response, deep-water foundation design and construction, structural analysis, and major bridge design.

Two of the panel members were part of the original Toll Bridge Peer Review Panel. The other panel members and a brief summary of their credentials are as follows:

Mr. Joseph Nicoletti (Chair) is an outstanding and well-recognized structural engineer. Because of his expertise he sits on the Seismic Advisory Board that was established following the 1989 Loma Prieta Earthquake under the guidance of the Governor of California to continuously advise the California Department of Transportation on issues of transportation seismic safety policy. Mr. Nicoletti is a past Chair of the Engineering Criteria Review Board for the Bay Conservation and Development Commission and continues to hold a seat on the board. It is because of his broad range of knowledge and perspective that he was asked to be chair of the SSPRP.

Professor Ben Gerwick is a professor emeritus at the University of California at Berkeley (UCB) in the Department of Civil Engineering. He built his internationally recognized expertise in offshore foundation design and construction through his engineering and construction business. Of special interest is his knowledge of specific San Francisco Bay geology and past foundation construction successes and failures. Professor Gerwick also has tremendous experience in offshore construction as is documented in his textbook on that subject.

Dr. Frieder Seible is a professor of Structural engineering at the University of California at San Diego (UCSD) and a principal of SEQAD, an engineering consulting firm. Professor Seible is an expert in analysis including finite element methods and structural element testing. He is internationally recognized for his contributions to bridge engineering. Professor Seible has co-authored a reference book on bridge seismic design and retrofit currently in use by practicing engineers. Dr. Seible also serves on the Seismic Advisory Board.

Dr. I.M. Idriss and Mr. Jerry Fox were on the Toll Bridge Peer Review Panel and their credentials are summarized in the discussion on the TBPRP. This carry-over of panel members provided an important and necessary communication and experience link back to the original peer review panel. The SSPRP meets bi-monthly with the Caltrans East Span Seismic Safety Project design team to review design issues and strategies.

July 21, 1997
San Francisco Endorses Northern Alignment Over Southern Alignment
In a letter addressed to the Chair of the Task Force and dated July 21, 1997 (copy of letter attached in Appendix A), Mayor Willie L. Brown, Jr. of San Francisco endorsed the proposed northern alignment stating,

> *"The arguments of a southern alignment versus a northern alignment have to be weighed with the impact each alignment has on either Yerba Buena Island or the Port of Oakland. It is my feeling that the economic development opportunities to the Port of Oakland outweigh the economic opportunities to San Francisco at Yerba Buena Island. ... Even though it will cost more money to build a signature bridge, I am willing to support the efforts of the majority of the task force to support the northern alignment."*

July 23, 1997
Engineering and Design Advisory Panel (EDAP) Recommends Replacement for a New Bridge
After five months of review, discussion and deliberation, the EDAP put forward to the Task Force seventeen recommendations addressing issues related to finance, design process, planning, and bridge design, including replacement rather than retrofit of the existing bridge.

With regard to the planning for the San Francisco-Oakland Bay Bridge East San Seismic Safety project, the EDAP recommended in part,

> *"The existing eastern span of the Bay Bridge should not be retrofitted, but replaced with a new structure."*

> *"The new eastern span and existing western span should be designed to provide post-earthquake lifeline service."*

July 30, 1997
Task Force / MTC Endorses EDAP Recommendations
The Task Force approved a set of seventeen finance, design, and planning recommendations for the new eastern span, based largely on the analysis and advice of EDAP.

Many of the recommendations approved by the Task Force refer to proposed features of the new eastern span, including the number of lanes (five in each direction), the alignment (north of the existing alignment), and other design elements (e.g. two parallel

Signing of SB60 into Law – Photo-simulation in backdrop is of the self-anchored suspension bridge on a northern alignment. Pictured from L to R: Assembly Woman Carole Migden, Mayor Willie Brown, then-Governor Pete Wilson, then-Senate Pro Tem Bill Lockyear, then-Senator Quentin Kopp. (Photo Source: AP/Wide World Photos)

separated decks rather than a double-decked structure). The seven representatives on the MTC Task Force that adopted the seventeen recommendations including replacement over retrofit were:

City and County of San Francisco

- San Francisco Mayoral Appointee -- Jon Rubin
- San Francisco Board of Supervisors Appointee -- Tom Hsieh

Contra Costa County

- Cities of Contra Costa County – Council Member Sharon Brown,
- Contra Costa County – Supervisor Mark DeSaulnier

Alameda County

- Alameda County -- Supervisor Mary King, Chair
- City of Oakland -- then-Mayor Elihu Harris

Bay Conservation and Development Commission

- Angelo Siracusa

Following the action by the Task Force later that afternoon, the full Metropolitan Transportation Commission met and endorsed the seventeen recommendations approved by the Task Force.

August 1997
Senate Bill 60

In August 1997, then-Governor Pete Wilson signed into State law Senate Bill 60 (SB 60). SB 60 provided a funding package for a replacement east span bridge that includes increasing the tolls for all State-owned toll bridges in the Bay Area and identified MTC as the regional agency responsible for representing the Bay Area in making bridge recommendations. In part, the law states,

> *"The department [Caltrans] has also identified the east span of the San Francisco-Oakland Bay Bridge as needing to be replaced. That replacement span will be safer, stronger, longer lasting, and more cost efficient to maintain than completing a seismic retrofit for the current span."*

SB 60 also gave the MTC authority to fund, at its discretion, three additional features, or amenities, for a replacement east span including a more distinctive "signature" bridge structure, a pedestrian/ bicycle path, and a new Transbay Transit Terminal in San Francisco. The authority to fund these amenities is constrained by the amount of revenue that could be generated by a two-year extension of the bridge toll increase.

In response to Task Force recommendations and the mandates of SB 60, Caltrans initiated preliminary engineering studies as requested by the Task Force and EDAP. These studies were used to determine the seismic performance, cost, and aesthetics of the bridge types recommended by the Task Force and the cost and feasibility of including design amenities such as "signature" bridge structures and a pedestrian/bicycle path. The EDAP reviewed the results of the studies in a series of public meetings and made specific recommendations to the Task Force.

September 5, 1997

San Francisco Offers Conveyance of Property to Caltrans for Replacement Bridge

San Francisco Requests Governors Support for AB-699

In mid-1997, San Francisco sought approval of special legislation (AB699) which was designed to facilitate San Francisco's development efforts for former Naval Station Treasure Island. In September 1997, two letters were received by the State from San Francisco regarding land use issues on Yerba Buena Island.

In his letter dated September 5, 1997 (copy of letter attached in Appendix A) to then-Caltrans Director James Van Loben Sels, Mayor Willie Brown offered to convey any property needed on YBI for the East Span Seismic Safety Project to the State at no cost to the State. This offer included a broad swath of land approximately 100 meters (328 feet) in width.

In a separate letter also dated September 5, 1997 to then-Governor Pete Wilson, Mayor Willie Brown urged the Governor to sign AB-699 stating,

> *"I have spoken with Jim Van Loben Sels regarding his concerns about access to the existing and proposed eastern span of the San Francisco-Oakland Bay Bridge. I am enclosing a letter that I have sent to Mr. Van Loben Sels that addresses his concerns."*

September 1997
Assembly Bill 699

In September 1997, AB699 was passed into State law providing for a Treasure Island Development Authority (TIDA) to oversee the conversion of the U.S. Navy facility on Yerba Buena and Treasure Islands. The City and County of San Francisco was given authority to designate the TIDA as the redevelopment agency pursuant to the Community Redevelopment Law for redeveloping Naval Station Treasure Island.

With respect to the future safety and transportation needs of the Bay Area region, the law states,

> *"The Trust Property shall remain subject to any requirements of the Department of Transportation for future rights-of-way, easements, or material for the construction, location, realignment, expansion, or maintenance of bridges, highways, or other transportation facilities without compensation, except as ..."*

The law further states that Caltrans would compensate the TIDA for:

1. Any property taken that was originally acquired by the TIDA for valuable consideration.
2. Any improvements, betterments, or structures taken that have been placed by the TIDA.
3. Holders of a lease, franchise, permit or license to use or occupy a portion of the property that is taken.

June 24, 1998
Task Force Design Recommendations

Following extensive public comment, the Task Force forwarded a second set of

Task Force Members: Jon Rubin (San Francisco Mayor Appointee), Tom Hsieh (San Francisco Board of Supervisors Appointee), Angelo Siracusa (BCDC), Council Member Sharon Brown (East Bay Cities), Supervisor Mary King (Chair, Alameda County), Supervisor Mark DeSaulnier (Contra Costa County), (not shown: then-Oakland Mayor Elihu Harris)

recommendations to MTC that complemented and provided additional detail. The Task Force recommended that the replacement structure be a concrete skyway structure on a northern alignment with an asymmetrical self-anchored suspension main span supported by a single steel tower. A 4.7 meter (15.5-foot) wide pedestrian/bicycle path 0.3 meter (1 foot) higher than the traffic lanes located on the south side of the eastbound structure was also recommended by the Task Force. The Task Force recommendations were adopted by the MTC on June 24, 1998.

The MTC recommendations are considered advisory and represent locally preferred options. Caltrans and the FHWA have considered and performed preliminary engineering on a range of possible project alternatives in accordance with NEPA requirements and in consultation with permitting and regulatory agencies. Five alternatives (No-Build, Retrofit Existing Structure, two northern replacement alternatives and one southern replacement alternative) were considered in the Draft EIS for the East Span Seismic Safety Project.

November 23, 1998 (Mayor letter also sent in June 98 too)
San Francisco Comments on SFOBB East Span Seismic Safety Project DEIS
San Francisco Mayor Brown sent a letter to Caltrans that commented on the Draft Environmental Impact Statement on the East Span Seismic Safety Project (Appendix A). In that letter, the San Francisco reversed the earlier endorsement of a northern alignment, and instead, submitted an economic analysis supporting a modified version of the southern alignment known as the "S-1 Modified" alignment. Caltrans will respond to the comments raised by San Francisco as part of the Final Environmental Impact Statement (FEIS).

In December 1998, Caltrans identified Alternative N-6 as the preferred alternative following circulation of the Draft EIS and consideration of public and agency comments on the document.

Fall 1998
U.S. Navy Denies Caltrans' Access to Yerba Buena Island for Geotechnical Investigations
The U.S. Navy denied Caltrans' request to perform geotechnical investigations on U.S. Navy property at Yerba Buena Island. On July 28, 1999, Governor Gray Davis sent a letter to Richard Danzig, Secretary of the U.S. Navy (see Appendix D), on *"a matter of great public concern and safety"*. The

letter requested that the U.S. Navy grant permission to Caltrans to conduct geotechnical drilling on Yerba Buena Island. Subsequent to the letter, the U.S. Navy granted permission to conduct geotechnical drilling investigations on Yerba Buena Island.

In a letter dated October 26, 1999, Governor Davis requested assistance from Secretary of Transportation, Rodney Slater, to expedite completion of the federal environmental review process (see Appendix D).

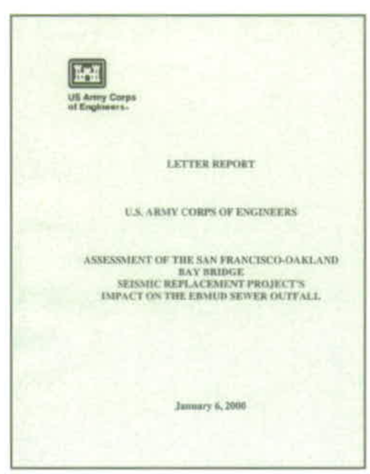
September 9, 1999
Letter to Senator Dianne Feinstein from the Seismic Advisory Board
The SAB wrote to Senator Dianne Feinstein, reemphasizing its position on whether the east span of the San Francisco-Oakland Bay Bridge should be retrofitted or replaced. The following are quotes from that letter which is included in Appendix C:

> *"... All of the above retrofit measures, while theoretically feasible, would result in a 60-year-old bridge structure having significant uncertainties in its seismic performance at a cost which would nearly equal that of a new bridge at this site. Furthermore, retrofitting the existing bridge would result in significant traffic interruptions and delays over a period of 4 to 5 years necessitated by lane closures required during retrofit construction."*

> *"Since a new bridge designed and built using current state-of-the-art seismic design concepts and details would be much more reliable in responding to higher seismic performance levels than would the retrofitted bridge, the SAB and the Seismic Safety Peer Review Panel for the Toll Bridge Retrofit Designs strongly recommended to Caltrans that it consider replacement rather than retrofit. An independent value engineering analysis concurred with this recommendation. The 37-member Engineering and Design Advisory Panel appointed by the Metropolitan Transportation Commission also endorsed replacement rather than retrofit."*

> *"We would like to re-emphasize that the SAB still fully supports the decision to go forward with the planned replacement rather than retrofit of the existing bridge, since retrofit solution would not result in the same high level of seismic reliability and performance as the new bridge."*

January 2000
COE evaluates southern alignment impact on EBMUD sewer outfall
At this time, San Francisco and U.S. Navy were supporting a southern alignment above the East Bay Municipal Utility District (EBMUD) sewer outfall. Caltrans had maintained that such an alignment was impractical due to the conflict with the sewer outfall as it presented significant design and construction challenges which led to major increases in cost and serious risks to schedule. The U.S. Army Corps of Engineers (COE) was requested by the National Economic Council (NEC), an


US Army Corps of Engineers

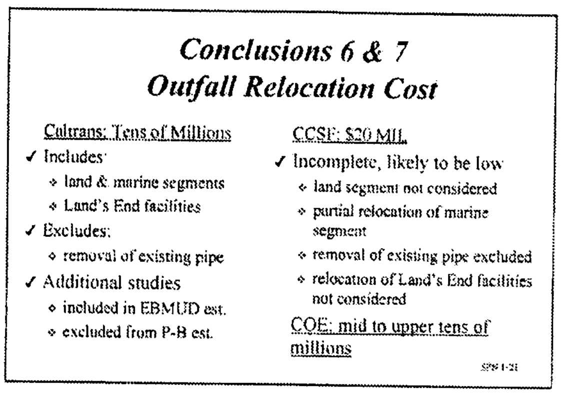
LETTER REPORT

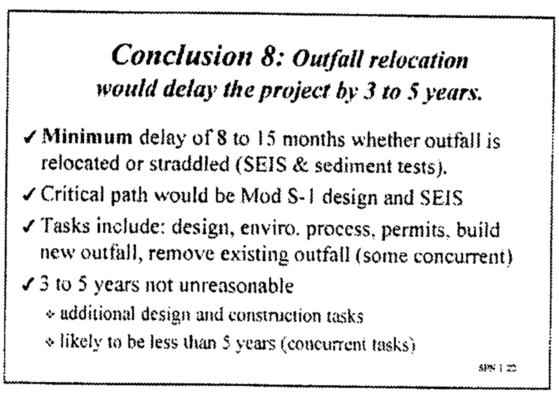
U.S. ARMY CORPS OF ENGINEERS

ASSESSMENT OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE SEISMIC REPLACEMENT PROJECT'S IMPACT ON THE EBMUD SEWER OUTFALL

January 6, 2000

office within the Executive Branch of the Federal Government located in the White House, to perform an independent evaluation of the issues surrounding the San Francisco "S-1 Modified alignment." The evaluation was undertaken in an effort to resolve federal agency concerns so that a unified federal position could be established with respect to the project. The evaluation was completed on January 6, 2000. On the key issues of cost and schedule impacts, the COE conclusions are summarized in their presentation slides (shown below).





The COE summarized its findings as follows:

> *"... the COE's assessment confirms that building the new SFOBB over the outfall would delay the schedule by a* ***minimum*** *of 8 to 15 months, increase construction risks, and increase project costs by tens of millions of dollars. Relocating the outfall would decrease risks associated with construction of the Modified S-1 alignment, but would significantly increase project costs and delay the initial construction of the new bridge by a* ***minimum*** *of 8 to 15 months."*

The COE also states that the Caltrans' delay estimate of 3 to 5 years is not unreasonable. However, the delay would likely be less than 5 years.

January 2000
San Francisco Advocates Retrofit over Replacement

After the COE findings were announced regarding the EBMUD sewer outfall issue, U.S. Navy and San Francisco representatives were quoted in the local newspapers as advocating a retrofit alternative for the east span of the San Francisco-Oakland Bay Bridge (see Appendix J). The U.S. Navy and San Francisco perceive a retrofit alternative as having less impact on San Francisco plans for redevelopment of Yerba Buena Island and less impact on an existing historic district, also on Yerba Buena Island. Caltrans has prepared a report entitled *Land Use Issues Associated with the SFOBB East Span Seismic Safety Project and the Naval Station Treasure Island Draft Reuse Plan, January 2000.* This report provides an overview of San Francisco's proposed development on the eastern side of Yerba Buena Island as outlined in San Francisco's *Naval Station Treasure Island Draft Reuse Plan (July 1996)* in relation to the proposed alternatives for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project.

Professor Abolhassan Astaneh-Asl, a professor of civil engineering at the University of California, Berkeley, has provided technical assistance to San Francisco in its support for a retrofit alternative.

East span superstructure from within the cantilever section looking east.
Note the number of pieces. Each connection and member is an opportunity for failure.
Some members have multiple failure mechanisms.

3.0 EXISTING CONDITIONS

This section describes the seismic environment of the Bay Area, the physical characteristics of the existing bridge, and geology of the project site.

3.1 Seismicity

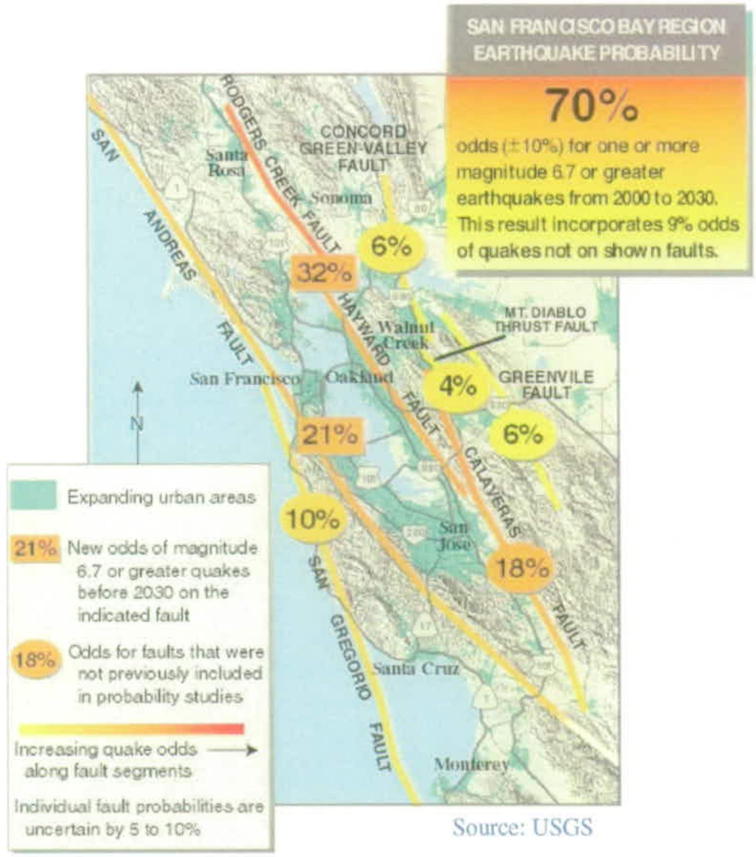
The Loma Prieta earthquake, magnitude 7.1, is the largest seismic event in the Bay Area since the earthquake of 1906. On the SFOBB, the Loma Prieta earthquake caused the failure of the upper and lower decks at Pier E9 (see photo above). A larger magnitude or longer duration earthquake would likely have resulted in a multispan collapse of the east span. The Loma Prieta earthquake, with an epicenter 96 kilometers (km) (60 miles) away from the bridge, demonstrated that despite the Bay Bridge's behemoth stature, it is vulnerable to damage during strong quakes.

In a recent draft report prepared for the U.S. Geological Survey (USGS) entitled *Earthquake Probabilities in the San Francisco Bay Region: 2000 to 2030 - A Summary of Findings* (http://quake.wr.usgs.gov/), it is stated:

> *"The San Francisco Bay region sits astride a dangerous "earthquake machine", the tectonic boundary between the Pacific and North American Plates. The region has experienced major and destructive earthquakes in 1838, 1868, 1906, and 1989, and future large earthquakes are a certainty. The ability to prepare for large earthquakes is critical to saving lives and reducing damage to property and infrastructure."*

Fault Locations in the Bay Area (Map Source: USGS)

On the basis of research conducted since the 1989 Loma Prieta earthquake, the USGS concludes that there is a 70% probability of at least one magnitude 6.7 or greater quake, capable of causing widespread damage, striking the San Francisco Bay region before 2030. Major quakes may occur in any part and at any time of this rapidly growing region. This emphasizes the urgency for all communities in the Bay Area to continue preparing for earthquakes.



Source: USGS

The San Francisco-Oakland Bay Bridge is located between the Hayward and San Andreas Faults, with the Hayward Fault located just eight kilometers (five miles) to the east of the project site. Seismic demands predicted in future large Bay Area earthquakes from one of these faults are expected to exceed Loma Prieta rock motions by a factor of 5 (0.067g => 0.5g). Such base mat rock motions are expected to strain the complex soils above the rock and surrounding the bridge foundations to the levels well beyond their capacity to transmit accelerations, leading to significant inelastic strains in the soil.

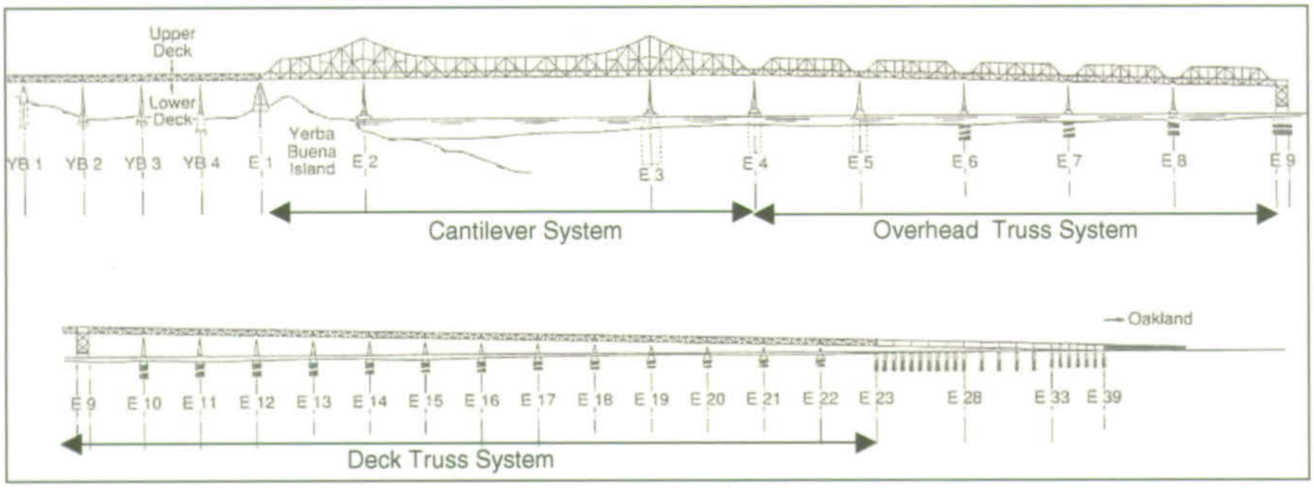
Due to rock motions generating forces that exceed the structural capacity of the surrounding soils, there will be instability around the bridge foundations. With the foundations actually "floating" in the soils of the bay, this instability results in permanent displacement of the soils, literally displacing the foundations of the bridge that are not founded on bedrock.

3.2 East Span Structure

Completed in 1936, the east span structure was a marvel of its time. The cantilever section of the bridge was the longest and heaviest cantilever structure in the United States. In a November 26, 1936 article on the construction of the San Francisco-Oakland Bay Bridge, Engineering News-Record noted that:

> *"…the East Bay Crossing would itself rank among the major bridges in the world. Despite the fact that it is overshadowed by the more spectacular West Bay suspension spans, the cantilever presented the greater difficulties in design, fabrication and erection."*

Construction of the Cantilever Section



Pier Locations on the East Span Structure

Within the bay, the majority of the existing east span structural system is comprised of three distinct type of structures to accommodate the varying conditions of the bay. For purposes of this report, the bridge sections are described as follows:

- A cantilever system (Piers E1-E4) is used over the navigation channel
- An overhead truss system (Piers E4-E9) is employed for the deeper water
- A deck truss system (Piers E9–E23) is used for the shallow water conditions

Within each of the three systems, the two basic elements of the bridge are the superstructure and substructure. Simply stated, the superstructure includes the bridge deck and steel truss, and the substructure includes the towers and foundations. The figure above shows the location of the bridge types by pier numbers.

3.2.1 Superstructure

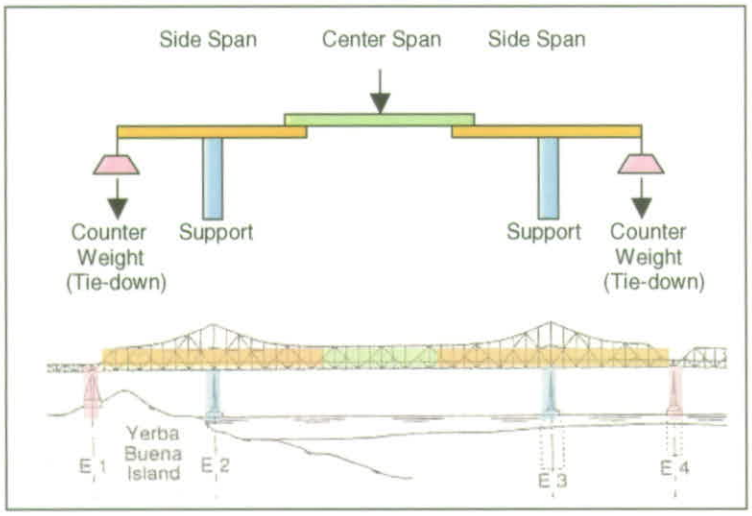
The basic component of the superstructure is a steel truss. Consistent with the material technology of the 1930s, the truss members are built up from steel plates, angles and lattice members. These elements were connected together using steel rivets.

Truss members on the east span

To address corrosion from the saltwater environment of the bay, the steel components of the bridge are regularly painted. Until 1968, lead paint was commonly used to maintain the bridge. This has resulted in many layers of lead paint on the steel elements and is a potential environmental hazard when disturbed. The average thickness of the lead paint is nearly one millimeter (33 mils) with some areas as thick as 5 mm (200 mils).

The center span of the cantilever section (Piers E2 to E3) spans a length of 427 meters (1,400 feet) across the navigation channel. The superstructure of the cantilever section is comprised of three sections, two cantilever side spans and a center span truss. The principle of the cantilever is shown in the figure on the following page.

Cantilever section on the east span



Principle of the Cantilever Span

The five long overhead trusses (Piers E4 to E9) east of the cantilever section each span 154 meters (504 feet). The long spans were selected to reduce the number of foundations in the deeper waters of the bay.

As the bridge approaches the Oakland shore, the superstructure changes to a series of fourteen 89-meter (288-foot) spans (Piers E9 to E23) constructed as a steel deck truss. The shallower waters of the bay and a lower roadway profile lent themselves to the shorter spans and somewhat smaller but greater number of foundations.

3.2.2 Substructure

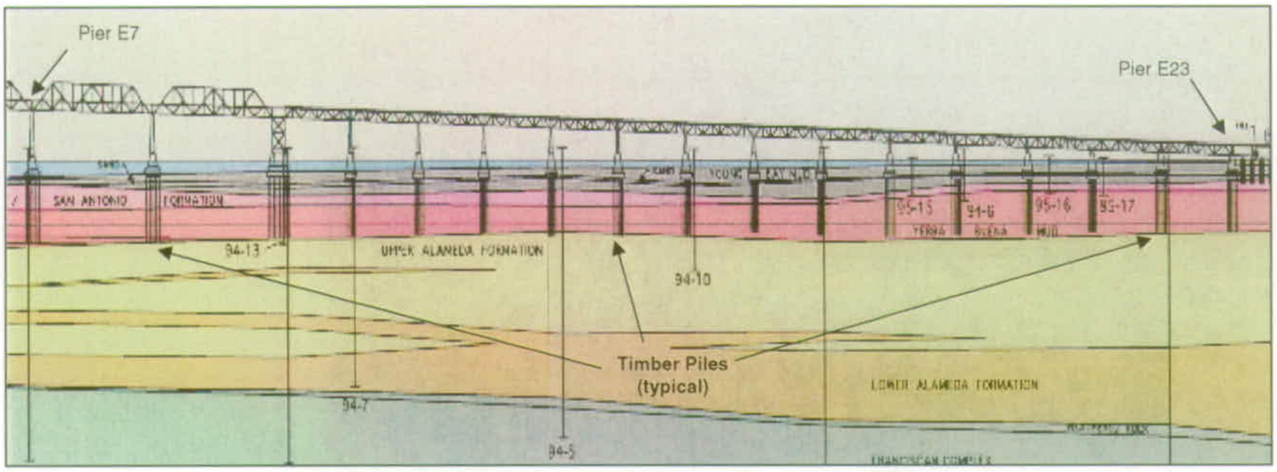
The substructure is comprised of two elements, the tower and the foundation. Except for Piers E3, E4 and E5, which are founded on sunken caissons, the foundations are supported by timber piles. The only in-water foundation extending to bedrock is at Pier E2. East of Yerba Buena Island, the bedrock slopes steeply to a depth of nearly 91 meters (300 feet) below the water at Pier E3. From there, the bedrock continues to slope downward to approximately 134 meters (440 feet) below the water at the Oakland shore.

Towers for Piers E2 to E16 are comprised of a steel truss. Piers E2 to E9 use a double-braced truss as shown in the figure on the following page, while Piers E10 to E16 use a single-braced truss. The overhead truss as shown in the figure is located from Pier E4 to E9. The tower members are built-up from steel plates, angles and lattice members. These elements were connected together using steel rivets. Similar to the superstructure, decades of maintenance have resulted in a build-up of lead contaminated paint on the steel elements of the tower. At Piers E17 to E23, the superstructure is supported on marginally reinforced concrete pedestals.

The foundations of the cantilever section include two center supports (Piers E2 and E3) and two counterweights (Piers E1 and E4) which tie down the ends of the cantilever spans.

Pier E1 is on land and founded on bedrock at Yerba Buena Island, and Pier E4 is founded on a sunken caisson. As the tie-down piers for the cantilever section, each of these piers carries tension loads of over 7 million pounds. The connections of Piers E1 and E4 to the superstructure are critical because they serve as the tie-downs for the cantilever section. If either connection were severed, the cantilever span would fall into San Francisco Bay. In general, connections are one of the most vulnerable elements of a bridge during a major earthquake. With the cantilever section, failure of one of these connections would be catastrophic.

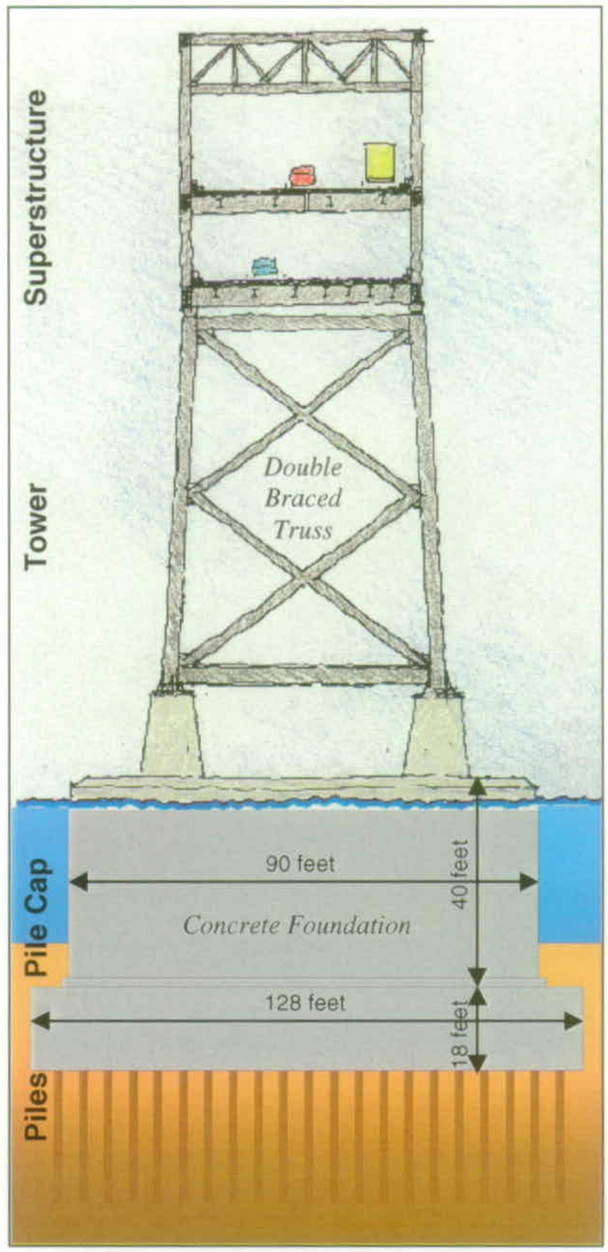
As noted earlier, Pier E2 reaches bedrock about 14 meters (45 feet) below the water. Pier E3 is founded on a sunken caisson and is the deepest foundation on the entire San Francisco-Oakland Bay Bridge, including foundations for the west span towers. Sunk to a depth of 72 meters (235 feet), this foundation was the deepest in the world at



Timber piles extend to the Upper Alameda Formation

the time of construction. Although sunk to this great depth, the foundation at Pier E3 does not reach bedrock and the bottom of the caisson is suspended nearly 21 meters (70 feet) above the bedrock.

With shorter spans and less weight to support, the foundations for the overhead and deck truss sections (Piers E6 to E23) are of a different design. These foundations are supported by 457 mm (18-inch) diameter tapered Douglas fir timber piles. The 26-meter (85-foot) long piles are embedded 1.8 meters (6 feet) into the concrete pile cap and extend down to the Upper Alameda Formation at elevation -36 meters (-120 feet) (see figure above). The timber piles were installed by means of an open cofferdam sunk to elevation -12 meters (-40 feet) and constructed of concrete. Much larger than required to actually support the bridge, the cofferdams were left in place, filled with tremie concrete, and incorporated into the pile cap. About four stories in height, the footprint of these massive concrete foundations is generally larger than a basketball court with Piers E6 to E8 covering an area 30% larger than a basketball court. The concrete foundations for Piers E6 to E8, the majority of which is beneath the water surface, measures 27.4 meters (90 feet) long by 14.6 meters (48 feet) wide by 12.2 meters (40 feet) deep.



Bridge Typical Section – Piers E6 to E8

There is also a pile cap that is 39 meters (128 feet) long by 20.7 meters (68 feet) wide by 5.5 meters (18 feet) deep. The foundations for the other piers were similarly constructed and are slightly smaller, but similarly massive, in dimensions.

As a result, the mass of these existing concrete foundations is considerable. This existing mass of concrete at the top of the piles places substantial loading in the structure during an earthquake. *Section 5.0, Design Considerations* includes additional information regarding the vulnerabilities of the existing structure.

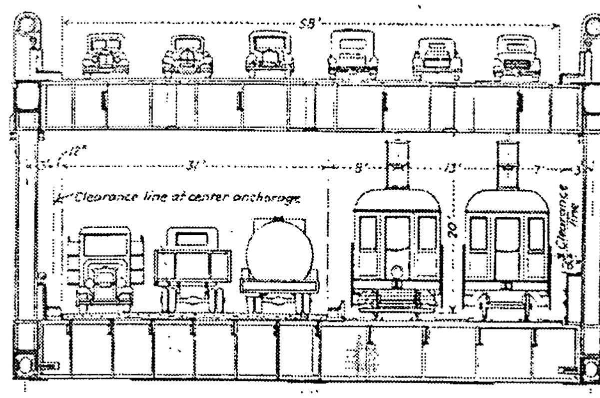
3.2.3 Roadway Geometry

3.2.3.1 Roadway Section

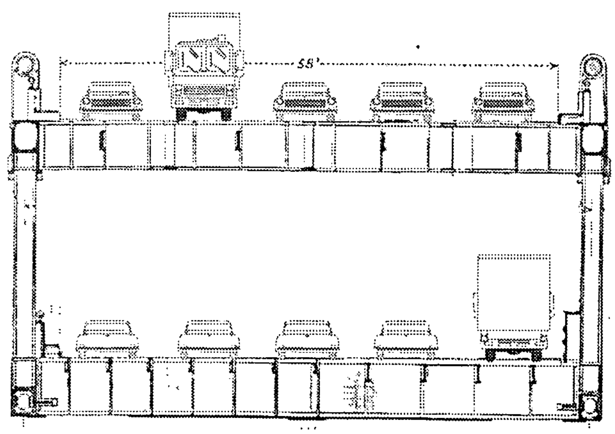
The original roadway section, designed under criteria of the 1930s, was developed to accommodate six lanes of auto traffic on the upper deck, and three lanes of truck traffic and two tracks of rail on the lower deck. It should be noted that although lane configurations were somewhat similar to the current lane configuration, truck loading in the 1930s was significantly less.

The bridge was reconfigured in the late 1950s to provide five lanes of vehicular traffic in both the eastbound and westbound directions. By current standards, there are several non-standard features of the existing bridge as follows:

- The total available roadway width for the existing bridge is 17.7 meters (58 feet). The existing bridge has five traffic lanes with non-standard lane widths of 3.53 meters (11 feet-7 inches) and no shoulders. The existing roadway cross-section has no provisions for breakdowns or accidents resulting in a loss of traffic lane(s) and congestion after each incident on the bridge.



Original roadway cross section

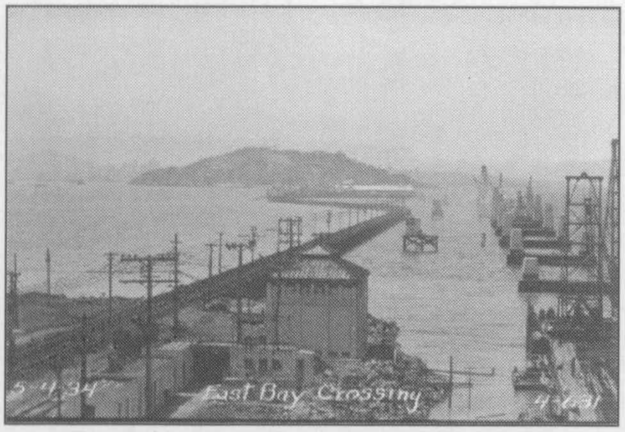


Current roadway cross section

- Clearances - the vertical clearance east of the tunnel is 4.9 meters (16 feet) on the existing east span bridge compared to the 5.1-meter (16.7-foot) standard.
- There is no horizontal clearance between the travel lanes and the bridge rail on the existing east span bridge. Standard horizontal clearance is 1.2 meters (4 feet).

3.2.3.2 Alignment

Beginning at the Oakland Touchdown, the existing alignment climbs nearly 60 meters (200 feet) above the bay to meet the elevation of the Yerba Buena Island tunnel. The alignment was constructed on a combined tangent and curvilinear alignment to avoid direct impacts to the Key System



Foundation construction near the Key System pier

ferry terminal pier, which existed at that time.

The bridge has a maximum grade of 2.7% which extends for a length of 1,700 meters (5,576 feet) between Piers E7 and E28. There are several non-standard elements of the existing bridge alignment. The most notable non-standard elements are as follows:

- Horizontal Alignment - The lower deck of the existing east span approaching the East Shore has a non-standard tangent (straight) roadway length between two curves; 19.2 meters (63 feet) compared to the current 177-meter (580-foot) standard.
- Vertical Alignment - The constraint of the existing east span upper deck roadway meeting the existing Yerba Buena Island tunnel entrance requires the bridge connection to have a series of vertical alignment changes that would not occur on a typical roadway.
- Superelevation - Curved roadways are designed to bank, or superelevate, to provide safe and comfortable driving conditions. The existing east span has a non-standard superelevation rate near the tunnel portal of 5 percent compared to the standard 8 percent superelevation.
- Stopping Sight Distance - The existing east span has non-standard stopping sight distance around a curve. According to current standards, the stopping sight distance on the existing east span can only accommodate a 60 kph (38 mph) design speed.

3.3 Geology

This section includes a brief description of the geologic formations in the vicinity of the existing SFOBB and proposed replacement alternatives. A cross-section is included at the end of this section.

- Young Bay Mud – The Young Bay Mud (Bay Mud) is the most recent of the sedimentary deposits in the bay and it primarily comprises the seafloor bottom. The Bay Mud generally consists of very soft silty clay and clayey silt with lenses of loose fine silty sand, clayey sand, and sand. It is slightly organic to organic. Shells have been found and range from a trace to thick beds with fine sand.

- Merritt, Posey, San Antonio Formation – Underlying the Bay Mud are relatively thin and discontinuous lenses of sand, silty sand, silty clay, and clay of the Merritt, Posey, and San Antonio Formations. These units are generally medium dense to dense sands and firm to stiff clays.

- Yerba Buena Mud – The Yerba Buena Mud, also referred to as Old Bay Mud, underlies the Posey/Merritt/ San Antonio Formation. The Yerba Buena Mud consists of soft to stiff clay and silty clay of marine origin with discontinuous interbeds of sand and shells.

- Alameda Formation – The Alameda Formation lies beneath the Yerba Buena Mud and consists of two distinct lithologic units: an upper marine member and a lower non-marine member. The upper member consists of clay and silt and stiff to very stiff, silty clay with a few scattered discontinuous lenses of medium dense sand. The lower member consists of interbedded dense to very dense sand, gravel, sandy silt, and clayey silt with some hard silty clay lenses.

- Franciscan Complex – Bedrock underlies the Alameda Formation and is identified as the Franciscan Complex. This formation outcrops at Yerba Buena Island and influences much of the relief of the San Francisco Bay Area. It consists of dark gray, moderately to slightly weathered, soft, intensely fractured shale and siltstone and sandy siltstone interbedded with light gray, slightly weathered to fresh, moderately hard, moderately to slightly fractured sandstone.

The geologic cross-section was developed by Caltrans as part of the seismic retrofit program. This cross-section is drawn along the existing alignment. The cross-section shows the topographic profile of the seafloor, as well as the geologic formations along the existing alignment. Bedrock slopes steeply from the east side of Yerba Buena Island to elevation -91 meters (-300 feet) and then slopes more gently to elevation -134 meters (-440 feet) as it approaches the Oakland Touchdown. The Yerba Buena Mud is thickest, approximately 36.5 meters (120 feet) thick, in the vicinity of the cantilever section of the bridge between the two largest piers of the east span, Piers E-2 and E-3.

Extensive additional geologic exploration was conducted for the design of the self-anchored suspension bridge on the northern alignment.

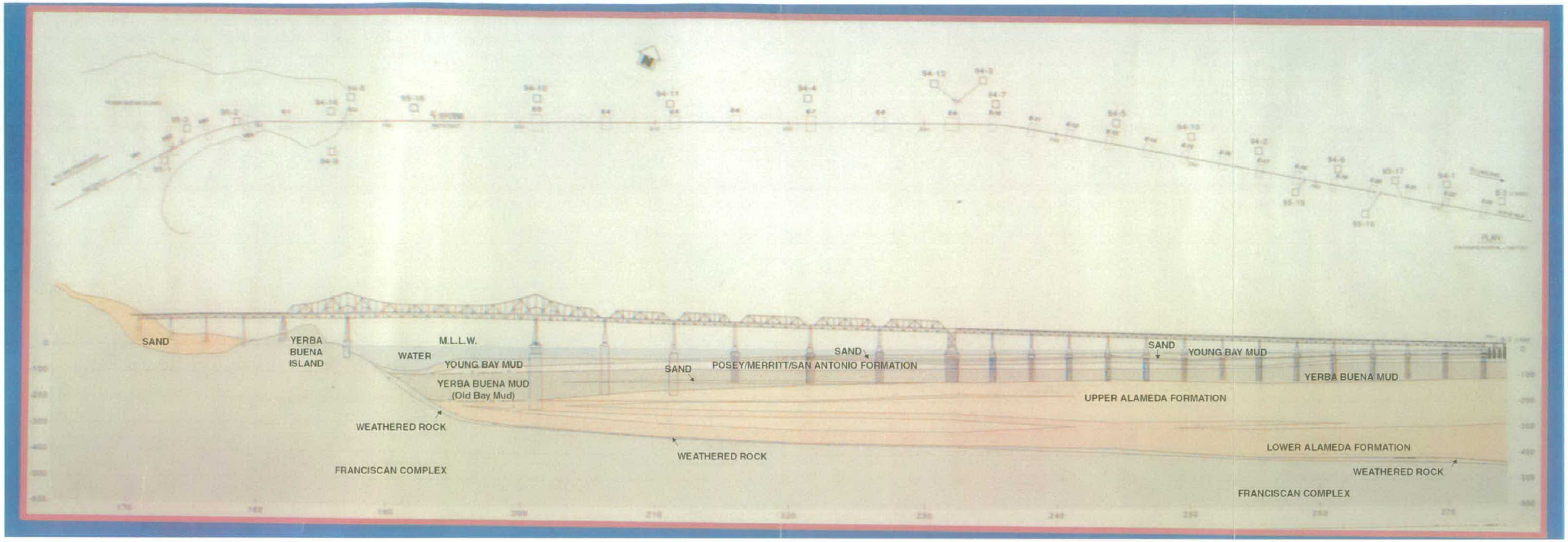
3.4 Lifeline Route

Caltrans has statutory responsibility for the development of the transportation element of State emergency response efforts. Designation of lifeline routes is part of this responsibility.

A lifeline route is a route on the State Highway System that is deemed so critical to emergency response/life saving activities of a region or the State that it must remain open immediately following a major earthquake, or for which pre-planning for detour and/or expeditious repair and reopening can guarantee movement. The focus is on highly critical routes that allow for the immediate movement of emergency equipment and supplies into or through a region.

Inclusion of the San Francisco-Oakland Bay Bridge as a lifeline route and upgrading it to meet that standard significantly improves response time between two major urban centers with emergency response infrastructure.

Due to the constraints of a 1930s level of materials and construction technology of the existing east span, the Retrofit Alternative cannot be designed to meet lifeline performance criteria with any reasonable degree of confidence. It was designed to meet the lesser criterion of "no collapse".



Geologic Profiles of San Francisco – Oakland Bay Bridge East Span

4.0 ALTERNATIVES

From a purely structural and analytical perspective, there are many ways to provide a seismically upgraded vehicular crossing between Yerba Buena Island and Oakland. However, for public works projects, there are values in addition to structural engineering concerns that must also be addressed. Three key values that Caltrans incorporates in all projects, beginning with the most important, are:

- Public safety
- Public convenience
- Cost-effectiveness

Public safety considerations include conformance with design and performance standards, safety during construction for the public and construction workers, as well as

Comparison Matrix – Retrofit vs. Replacement

	ISSUE	RETROFIT	REPLACEMENT
Public Safety	**Seismic Performance and Damage After Major Seismic Event**	Moderate to major damage. Weeks to months of repair. Performance not as reliable as new bridge. Normal traffic may never be allowed back on bridge. Replacement may be necessary, at a time when entire region will need emergency funding. Post-earthquake recovery to region impaired.	Minor to moderate damage. Operational within hours (at reduced speeds). Normal service restored within weeks to months once deck joints are repaired. Post-earthquake recovery to region enhanced. Seismic Advisory Board (a panel of outside experts from academia and the private sector) and two independent Value Analysis studies concluded that bridge should be replaced and not retrofitted.
	Time to Achieve Seismic Safety	Seismic safety not achieved until all retrofit work is completed; approximately six years after start of construction.	Seismic safety achieved for westbound traffic 3 ½ years after start of construction, eastbound 4 ½ years after start of construction.
	Lifeline Connection	No. Would NOT provide safe route for emergency equipment and supplies.	Yes. Would provide safe route for emergency equipment and supplies.
	Construction Exposure	Significant construction above and adjacent to traffic lanes, highly constrained construction zone next to traffic.	Vast majority of construction is away from the existing traffic. Some construction exposure during the tie-ins for the detour routes.
Public Convenience	**Bicycle / Pedestrian Path**	None.	4.7 meter (15.5 foot) wide pedestrian/bike path elevated 0.3 meters (1 foot) above the roadway.
	Traffic During Construction	Many lane closures but not during commute hours; scheduled during the day, evening and nights. This does affect construction duration. Some lane closures almost every day for various construction activities.	Minimal impact. New bridge constructed adjacent to existing bridge, then traffic switch. Traffic switch will involve nighttime traffic controls.
	Traffic After Construction	Bridge will continue to operate as it does today.	The replacement will operate significantly better due to existence of standard lanes, 2 shoulders in each direction providing a refuge area for disabled vehicles and emergency vehicle access. Overall bridge operation will be enhanced.
Cost-Effectiveness	**Life Expectancy**	50 years	150 years
	Design / Construction Cost	$1.085 billion (escalated to 2002 at 3%/yr)	$1.5 billion (escalated to 2002 at 3%/yr)
	Life Cycle Maintenance	Bridge will need to be redecked in about 20 years. Continuous painting of entire structure. Over time, increased traffic will cause spreading of commute hours and affect maintenance work windows.	Modern structure, mostly concrete; steel portion will have a modern paint system requiring minimal maintenance and painting.

maintenance and inspection access safety issues. The existing east span is a highly constrained environment with no shoulders and non-standard lane widths. The structure needs continuous maintenance with daily lane closures to provide access for maintenance personnel.

Public convenience is a key consideration during the design, construction and maintenance of a project. Measures are incorporated into all projects to reduce impacts to traffic during all phases of construction. With 274,000 vehicle per day crossing the SFOBB, it is a critical transportation link in the Bay Area and construction activities can have a dramatic and adverse effect on already difficult commute traffic conditions.

Cost-effectiveness speaks to the value the project provides to the public. This is often evaluated on a life-cycle basis. For the East Span Seismic Safety Project, cost-effectiveness is not just a measure of the cheapest alternative, but includes an evaluation of seismic safety, future maintenance, anticipated accident reduction, and post-earthquake repair costs.

There were two basic alternatives developed to address the issue of seismic safety for the east span of the San Francisco-Oakland Bay Bridge:

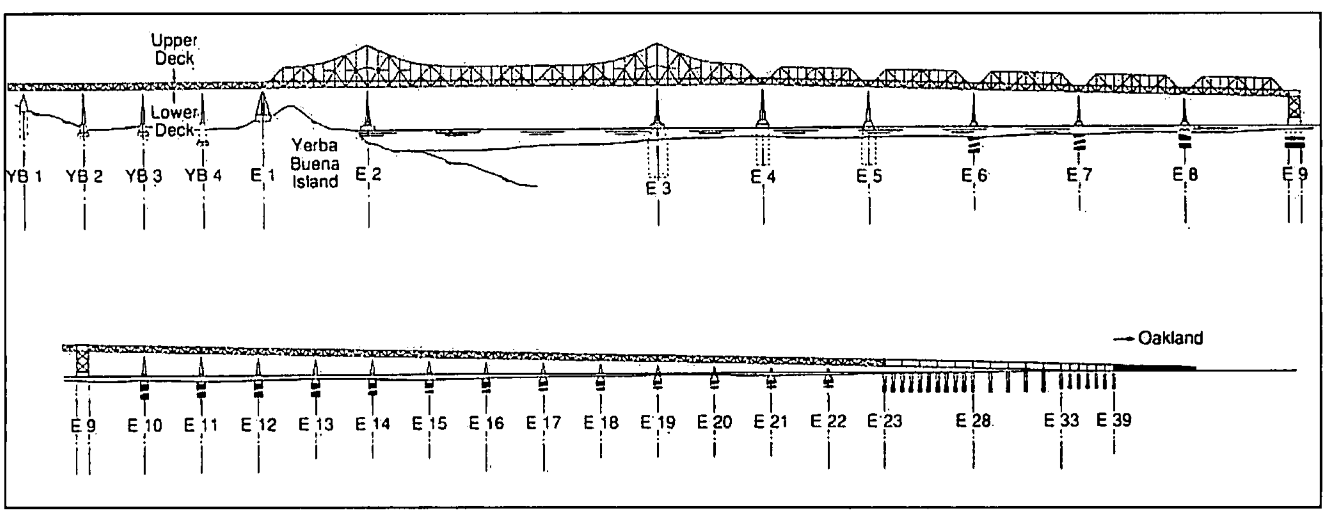
- Retrofit the existing bridge
- Replacement

This section describes the basic elements of these two alternatives. The figure below indicates pier locations referenced in the descriptions.

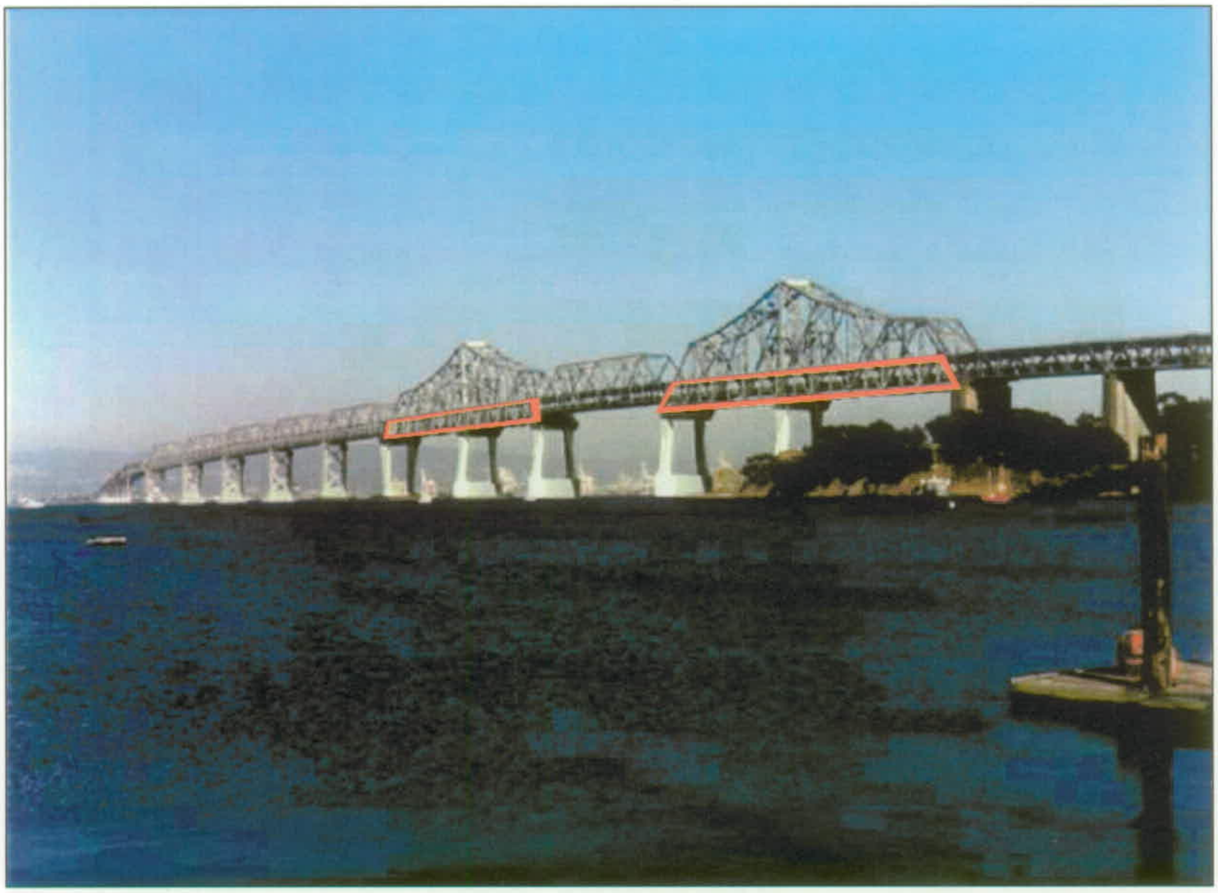
4.1 Retrofit Existing Bridge

It is impossible to retrofit the existing east span to a lifeline standard with a reasonable degree of confidence. The existing bridge is comprised of millions of steel elements (plates, rivets, angles). Each member and connection is an opportunity for failure. The design of the retrofit is compromised by the constraints imposed by the existing structure that was constructed to a 1930s level of materials and construction technology, and understanding of seismic design.

Early retrofit designs included significant modifications to the truss systems of the superstructure. As the designs developed, it became apparent that the required above-deck construction would have severe impacts on traffic and public safety. With no shoulders on the east span, construction zones would be highly constrained and work windows and lane closures would be limited to periods of the day with lower traffic



East Span pier locations by pier numbers



Cantilever with external steel truss

volumes. The issues of public and worker safety and traffic maintenance are further expanded in *Section 6.0, Construction Issues*.

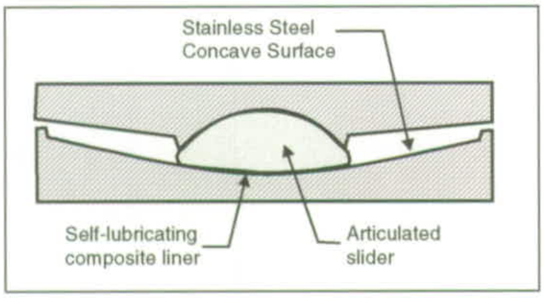
To reduce impacts to the public, the basic approach to retrofitting the existing bridge would be to change the input motions and reduce the seismic forces to the superstructure. This would be accomplished by isolating the superstructure and reducing the horizontal components of the ground motion. Isolation bearings would be used to allow movement between the substructure and superstructure. However, the amount of displacement must be managed so that the superstructure would not unseat from the towers.

Fundamental to this isolation strategy is that there is no damage or instability below the point of isolation. This would require that the existing towers be strengthened and stiffened against a strong earthquake. It is also necessary to reduce the displacement at the top of the towers. While superstructure modifications are reduced, many members of the superstructure above and adjacent to traffic lanes would still require significant modification to enhance performance. A external steel truss (highlighted in orange) as shown in the figure above would still be required for the cantilever section. Due to the massive size of the existing concrete pile caps, the foundations also need to be retrofitted to reduce displacement. The timber piles of the existing bridge are vulnerable to snapping from the pile cap if displacement is not adequately controlled. While the existing bridge system is comprised of several distinct elements, the following provides a general description of the modifications required to retrofit the existing bridge.

Further explanation of the issues leading to this retrofit design can be found in *Section 5 Design Considerations* of this report.

4.1.1 Superstructure

To reduce seismic forces to the superstructure, isolation bearings would be installed between the towers and the steel truss superstructure. The design needs to manage displacements of approximately 1.2 meters (4 feet) at the top of the towers.



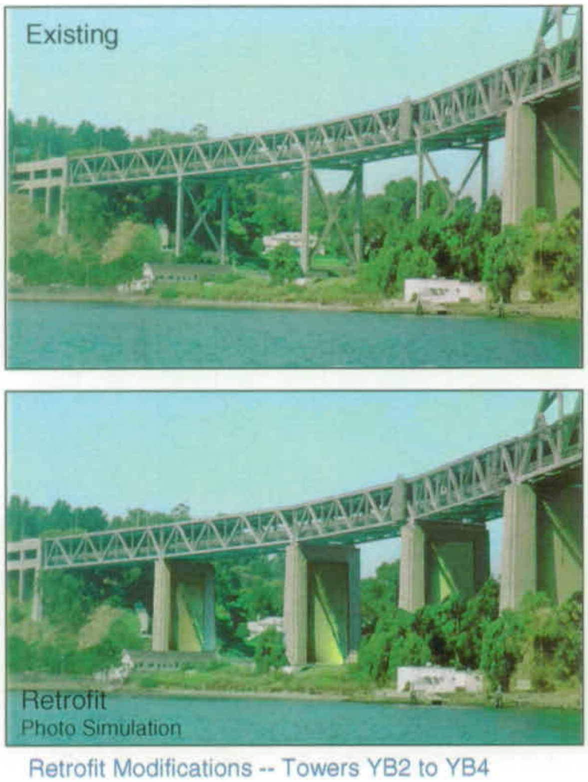
Pendulum Isolation Bearing

Even with these modifications reducing seismic demand in the superstructure, resulting forces would still require strengthening and stiffening many of the truss elements adjacent to and above traffic lanes to withstand buckling during a large earthquake. This would involve the addition of millions of pounds of new structural steel elements. Cross members of the truss would be strengthened or stiffened by adding steel plates, replacing rivets with high strength steel bolts, and replacing angles and lattice members.

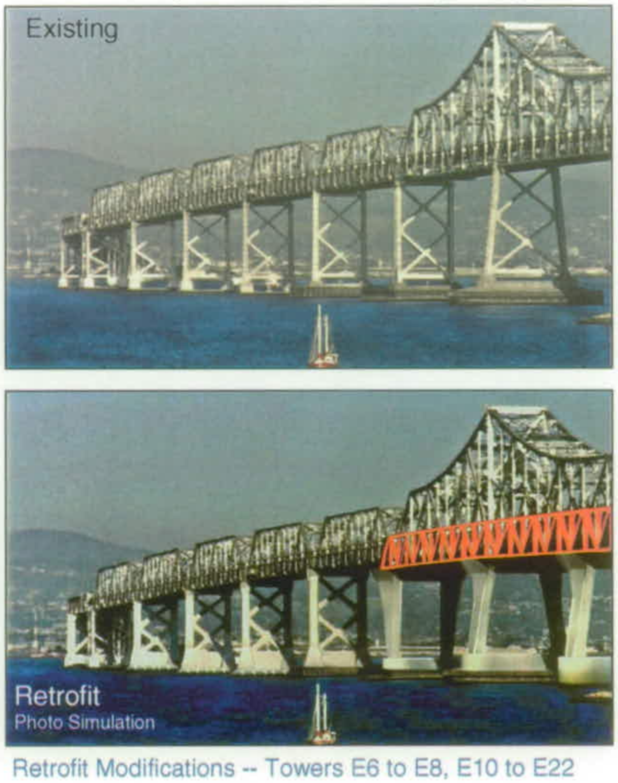
A external steel truss (external edge truss) was anticipated to strengthen portions of the cantilever section. These frames would extend from the top roadway deck to the lower roadway deck and as highlighted in orange on the photo simulation below. In addition to the external steel truss, elements of the cantilever truss at the top would be removed to further isolate each of the cantilever segments from each other. The result is a simply supported structure allowing for the connections at the tie-down piers to be released.

4.1.2 Towers

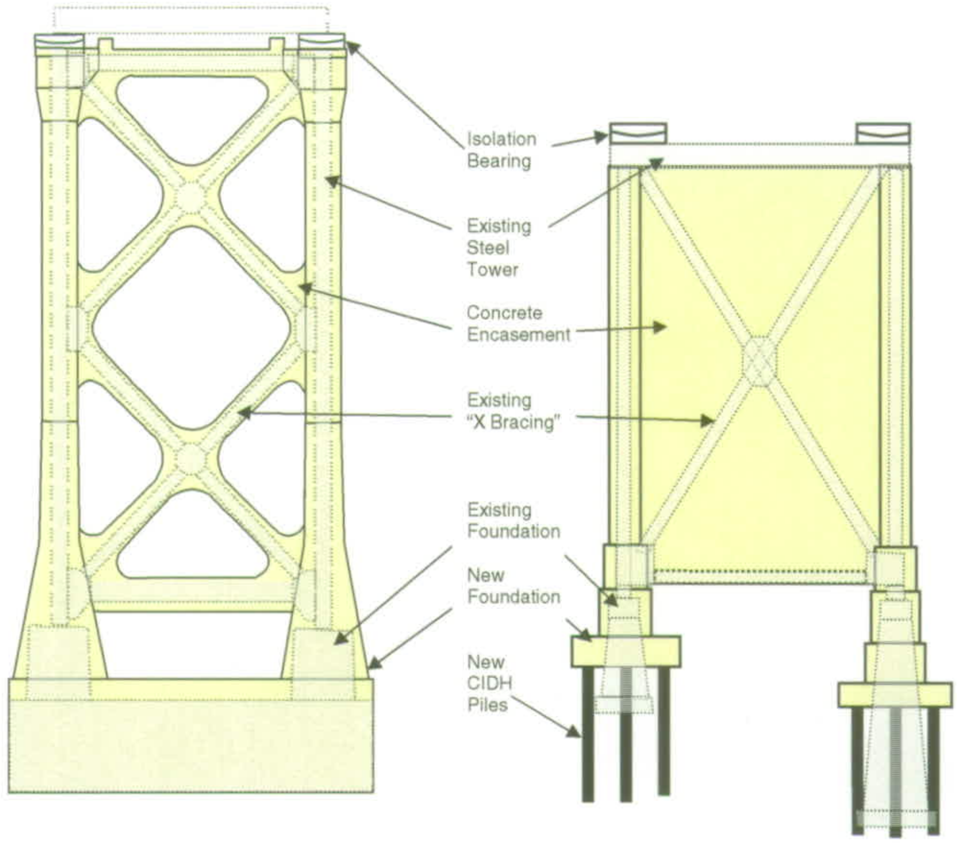
As noted earlier, tower strengthening and stiffening are required to ensure no damage or instability would occur during a large



Retrofit Modifications -- Towers YB2 to YB4



Retrofit Modifications -- Towers E6 to E8, E10 to E22 earthquake and to reduce displacements at the top of the tower to manageable levels. Tower strengthening would be accomplished by encasing the tower members in reinforced concrete. The concrete encasement strategy was chosen after comparisons with the structural steel modification alternative. The biggest advantages were to provide increased stiffness needed with isolation, eliminate lead paint removal associated with steel modifications, avoid structural solutions for which little physical testing exists, and eliminate future painting and maintenance costs.



Pier E5 – Proposed retrofit for the tower (typical)

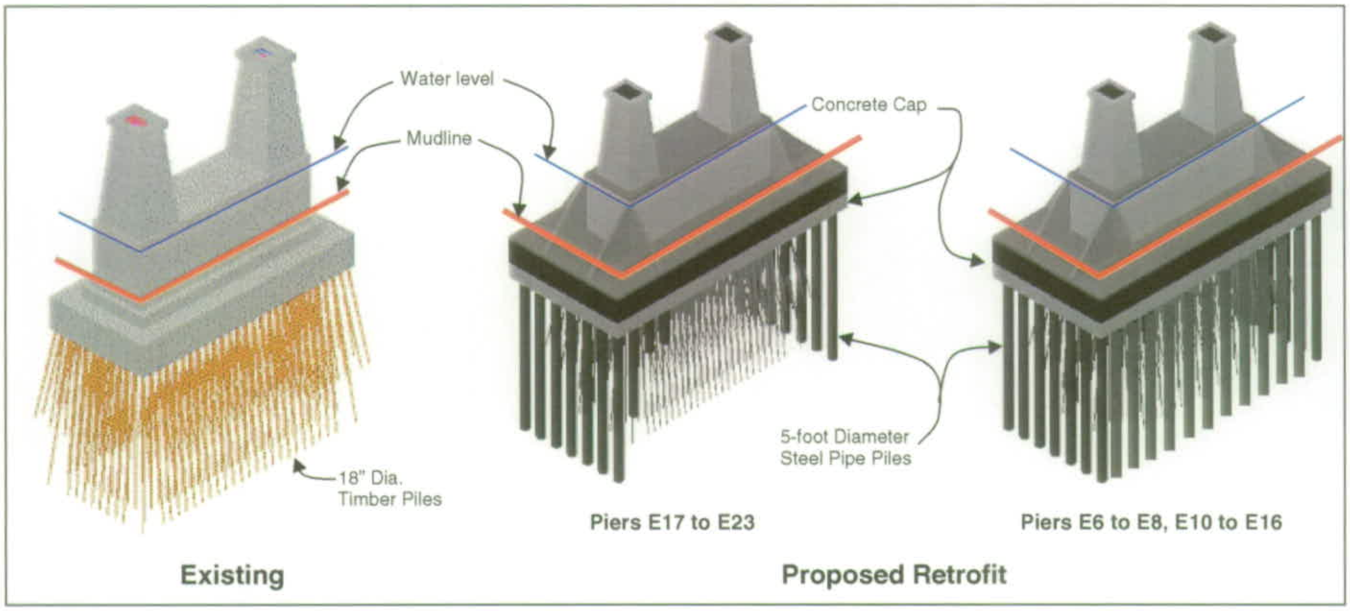
Pier YB4 – Proposed retrofit for the tower and foundation

The steel towers at Piers YB2, 3 and 4 would be completely encased in concrete. The full concrete encasement would give the appearance of solid concrete piers. For the towers at Piers E6 to E8, and E10 to E22, the steel members would be encased in reinforced concrete maintaining a similar but bulkier cross bracing members.

These towers can be retrofit with steel. The "X-bracing" shown in the images above would undergo significant modification or replacement. This would require placing the tower in a condition vulnerable to instability, which leads to buckling and collapse. Temporary bracing could be carefully installed and monitored to prevent this unstable condition while modifying the tower bracing. The tower retrofit strategy utilizing concrete does not carry the burden and additional risk resulting from the temporarily braced state. This simple reality forces the concrete retrofit at the towers to be recognized as superior to the steel retrofit of the towers by valuing safety to the travelling public.

The tower retrofits would include a large ledge, or table, at the top on which large isolator bearings, up to ten feet in diameter, can be installed. The double-tower at YB3 would be locked by the concrete encasement. Thermal expansion currently permitted by the double-tower would be absorbed by the isolator bearings.

The concrete encasement approach for the towers greatly increases stiffness and strength, is more cost-effective than a steel



solution, and avoids the environmental hazard associated with lead paint removal. These retrofit modifications would not add significantly to the dead load on the pier foundations.

4.1.3 Foundations

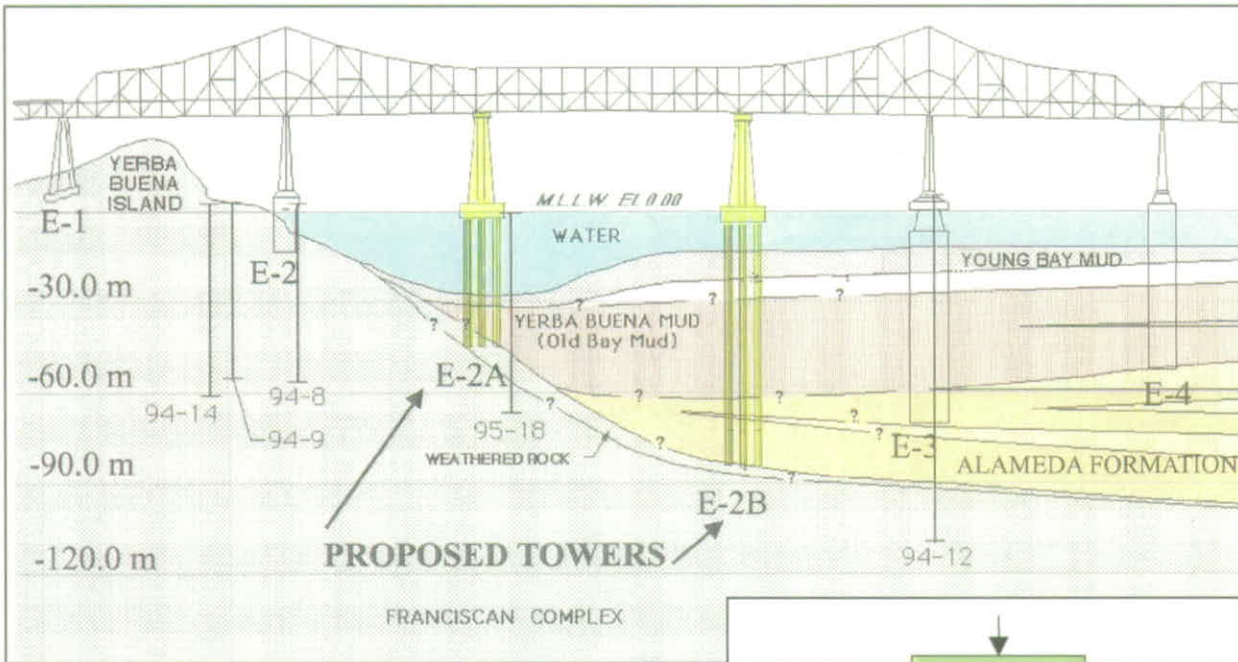
The existing foundations are inadequate to withstand a large earthquake. The large mass of existing concrete at the top of the existing timber piles combined with ground motion accelerations of a large earthquake would cause forces and displacements severe enough to snap the foundations off the piles. Except for Pier E9, all of the foundations would need to be strengthened to reduce and manage the displacement of the foundations.

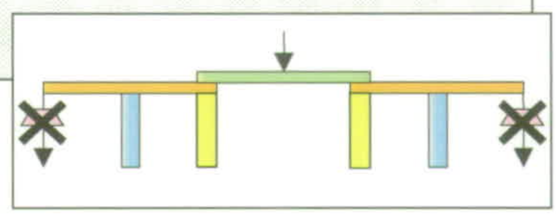
At Piers YB2 to YB4, the foundation would use cast-in-drilled hole concrete piles surrounding the existing spread footing foundation. The new pile cap would enclose the existing footings.

The existing timber pile foundations from piers E6 to E16 would be strengthened and stiffened by installing a total of 44 large capacity 1.5-meter (5-foot) diameter cast-in-steel shell pipe piles around each existing pier footing. A reinforced and prestressed concrete pile cap would fix the top of the new piles and surround the existing pier to strengthen it and connect it to the new piles.

The existing timber pile foundations from piers E17 to E23 would be strengthened and stiffened by installing a total of 36 large capacity 1.5-meter (5-foot) diameter steel pipe piles at the north and south ends of each existing pier footing. A reinforced and prestressed concrete pile cap would fix the top of the new piles and surround the existing pier to strengthen it and connect it to the new piles. The existing timber piles would continue to support the dead load (weight of the bridge) and live load (traffic) while the new piles would primarily provide resistance to expected large-scale seismic forces.

As shown in the figure above, the majority of the foundation is below both the water line and the mudline. The depth to the bottom of the foundations varies but is typically 12 meters (40 feet) below the water surface extending as much as 9 meters (30 feet) into the bay mud. Cofferdams would be required to construct the retrofitted foundations for these piers.

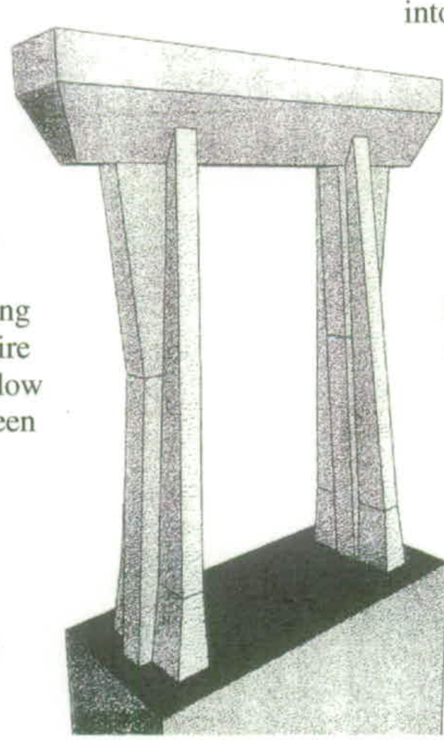




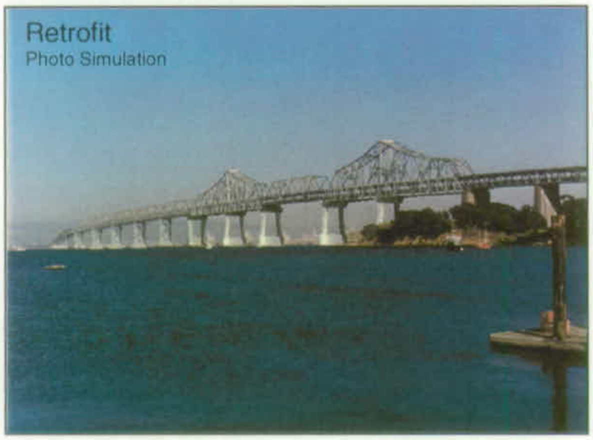
4.1.4 Cantilever Section

The cantilever section of the bridge requires a significantly different approach. As described in *Section 2.1.2 Existing Conditions – Substructure*, the cantilever section is vulnerable to a catastrophic failure should one of the tie-down connections at Piers E1 or E4 fail.

The displacements caused by the seismic forces estimated for a large earthquake would sever the connections at the tie-downs, Piers E1 and E4. To manage the displacements, an isolation system would be constructed. However, isolating the superstructure would require severing the connections to allow a freedom of movement between the tower and superstructure. The cantilever section, which requires these connections to remain stable, would be converted to a simply supported structure by adding two new piers. These new piers, E2A and E2B, would be required between Piers E2 and E3 to support the now decoupled cantilever section (see figure above). Without these additional supports, the disconnected cantilever section would fall into the bay. The towers for Piers E2A and E2B would be constructed of concrete and would be nearly 61 meters (200 feet) tall.



The tall concrete towers would be designed to be flexible in a large earthquake. This would isolate the superstructure and manage the displacement. With this approach, the towers of the adjacent Piers E2, E3, and E4 would also need to be reconstructed to behave in a similar fashion. A rendering of the concrete towers is shown to the left.

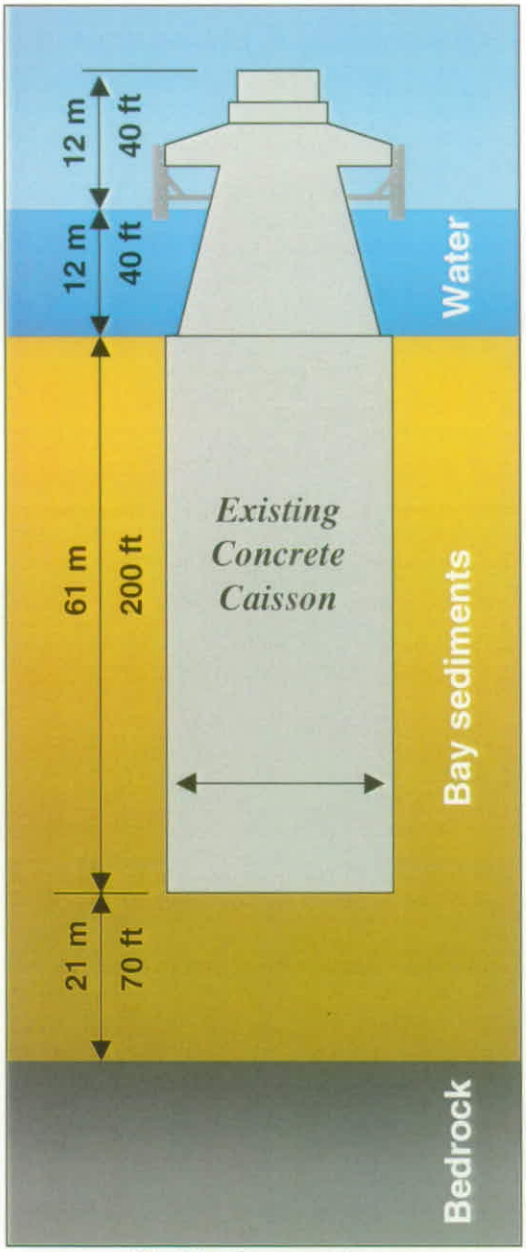


These piers would be rebuilt in a similar shape as Piers E2A and E2B. A comparison of the existing and the retrofitted bridge is shown above.

The large diameter steel pipe piles for the new piers would need to extend deep into the bay to found these large piers on competent material (Franciscan Complex). For Pier E2B, this distance is nearly 91 meters (300 feet) below the waterline.

Even with these retrofit modifications, it is anticipated that there would be permanent displacement of Pier E3 after a large earthquake. This is due to a combination of physical constraints:

- Pier E3 is a massive concrete structure standing nearly twenty stories below the water with a foot print 41.1 meters (135 feet) by 24.4 meters (80 feet).



Pier E3 – Concrete caisson

- Pier E3 is not founded on bedrock and is suspended 21 meters (70 feet) above bedrock.
- The peak accelerations predicted for a large earthquake would generate forces that exceed the capacity of the surrounding soils causing failure and permanent displacement of the soils, literally and permanently moving the pier.

Photo simulation of the Replacement Alternative N-6 as viewed from Yerba Buena Island

4.2 Proposed Replacement Alternative

The identified bridge type for the replacement structure for the east spans of the San Francisco-Oakland Bay Bridge is a combination asymmetric single-tower, self-anchored suspension main span segment near Yerba Buena Island with a skyway connecting to the Oakland shore on an alignment north of the existing bridge. As outlined in *Section 1.2.5 Introduction, Regional Preferences* of this report, the identification of this structure type went through a rigorous public and technical review. {PRIVATE "TYPE=PICT;ALT=Dot"}This design was also recommended as the locally preferred option. Ultimately, the design was endorsed by the legislatively authorized agency to achieve regional consensus, the Metropolitan Transportation Commission (MTC).

4.2.1 Features

Features of this Replacement Alternative include:

- The new bridge will meet lifeline standards and be able to withstand a Maximum Credible Earthquake on the Hayward or San Andreas Fault with manageable structural damage.
- The new bridge will be constructed while traffic continues to use the existing bridge. This will allow construction to occur unimpeded from high traffic volumes on the existing bridge.
- The Replacement Alternative will construct a new bridge north of the existing bridge and would then dismantle the existing bridge.
- {PRIVATE "TYPE=PICT;ALT=Dot"} The east span will consist of two side-by-side roadway decks, each with five traffic lanes plus 3-meter (10-foot) shoulders on both sides.

- The east span will open views to both eastbound and westbound motorists.
- Emergency shoulders will ease traffic congestion by providing pullout areas for disabled vehicles.
- {PRIVATE "TYPE=PICT;ALT=Dot"} The span will include a 4.7-meter (15.5-foot) wide bicycle/pedestrian path on the south side of the eastbound deck, raised 1 foot above the roadway.
- {PRIVATE "TYPE=PICT;ALT=Dot"} The two decks will transition to a double-deck structure at the Yerba Buena Island tunnel.

4.2.2 Alignment

A replacement alternative following a northern alignment is described below beginning at the YBI tunnel portal and moving east to the Oakland shore. A figure of the alignment for Replacement Alternative N-6 can be found on page 1-4.

Replacement Alternative N-6 begins at the eastern portal of the YBI Tunnel. Part of the existing YBI East Viaduct would be retrofitted, modified, and partially demolished. The new bridge begins at Bent 48, approximately 300 meters (1000 feet) east of the tunnel portal, with a transition structure (see figure below) separating the double-decked lanes into two parallel structures. "Outrigger" supports would be used to support the upper deck as the lower deck transitions out from below and parallel to the upper deck. The parallel structures curve, enter a tangent or straight section over the existing navigation channel, curve, and then align on tangent toward the Oakland Touchdown. The parallel structures reach the Oakland shore along the northern edge of the existing Oakland Touchdown area and conform to the existing traffic lanes to the west of the toll plaza.

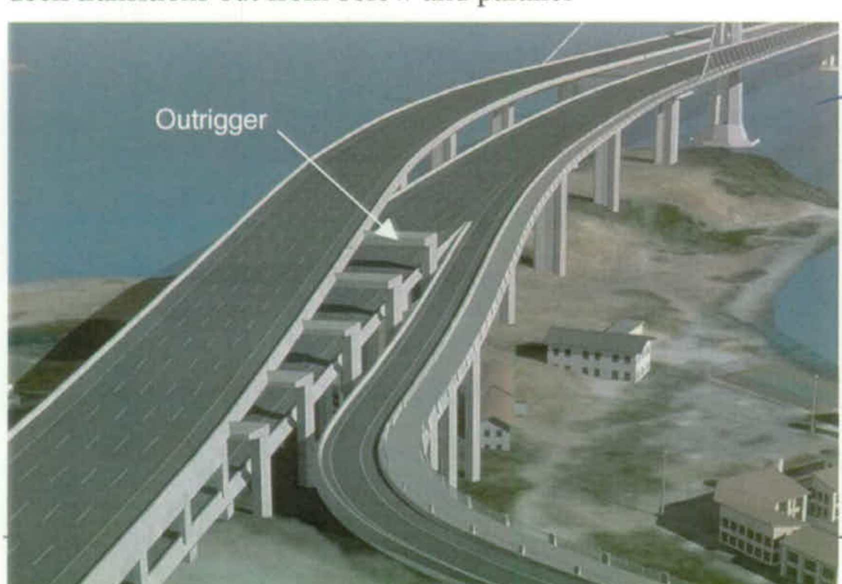


Photo-simulation of the transition structure looking east

Replacement Alternative N-6 consists of two parallel structures each supported by 21 piers over water and 21 bents set on YBI and the Oakland Touchdown area. The structures would each be 25.1 meters (82 feet) wide and typically separated by 15 meters (50 feet). The typical roadway section for each bridge deck consists of five lanes, each 3.6 meters (12 feet) wide, left and right shoulders, each 3 meters (10 feet) wide and traffic barriers. A 4.7-meter (15.5-foot) pedestrian/bicycle path would be located on the south side of the eastbound deck, 0.3 meter (1 foot) above the roadway elevation.

The height of the bridge, including the transition structure and the parallel structures, would vary in elevation from 50-55 meters (164-180 feet) above the water at the east viaduct to 5-10 meters (16-33 feet) above water at the Oakland Touchdown.

4.2.3 Mainspan Structure

A single-tower, self-anchored suspension bridge is unusually well suited aesthetically to the site given the proximity of the suspension spans of the Golden Gate Bridge and west spans of the SFOBB. The spans of the structure are asymmetric with a 180-meter (590-foot) span west of the main tower and a 385-meter

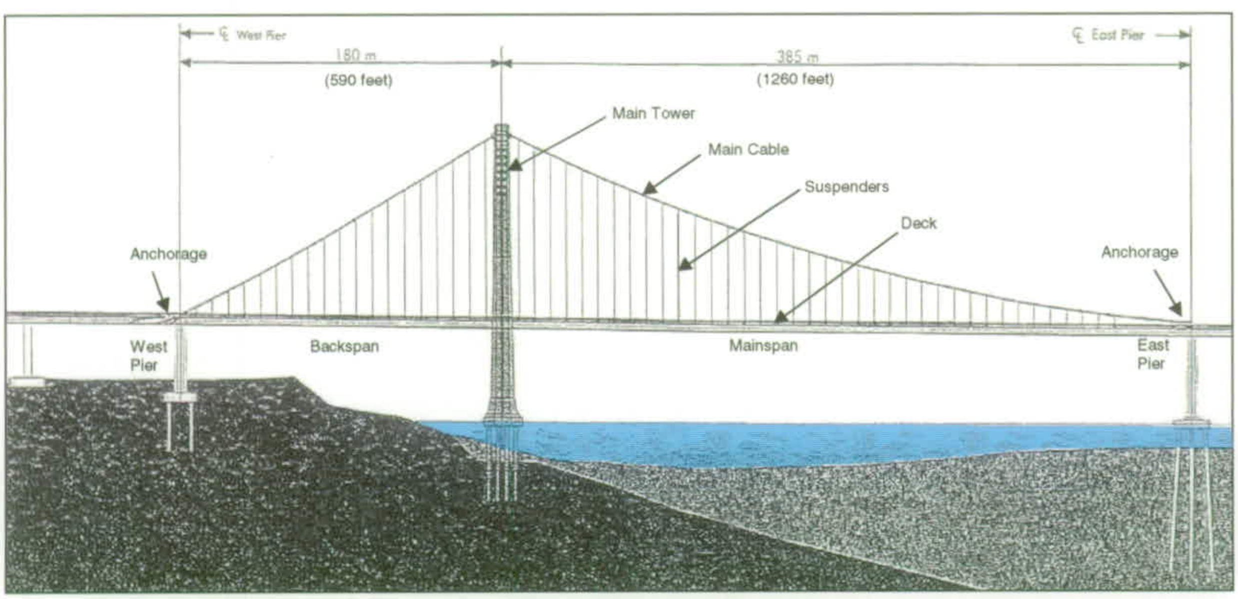
Photo simulation of Replacement Alternative as viewed from Treasure Island

(1260-foot) span east of the tower.

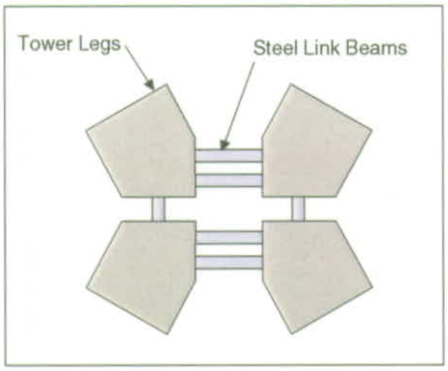
The high bedrock profile on Yerba Buena Island to the west and the soft soil to the east limit the bridge types that can be considered at the project site. The weight of the suspension bridge is principally carried by the main tower which is founded on bedrock. As seen in the figure below, the longer eastern half (mainspan) rests lightly on the east pier delivering small dead and live loads and placing little demand on this foundation located in deep young bay muds.

Connected at the top of the tower, the main cable is anchored at each end directly into the superstructure, placing the superstructure in compression. The deck is supported by suspenders connected to the main cable.

The main tower is visually and functionally striking. It is made of four slender steel vertical legs connected together by steel link beams. The link beams provide damping (energy dissipation) and are the basis of the tower's excellent seismic behavior. This damping absorbs energy while the vertical tower legs remain elastic and undamaged. The links act as fuses for the tower, allowing damage in tower elements that are easily repaired and replaced while protecting the



Asymmetric Self-Anchored Suspension Bridge four vertical tower legs that support the bridge. These tower links behave much like the fuses on a residential electrical system where potential damage from an overload of the system is absorbed by the fuse and the system remains protected.

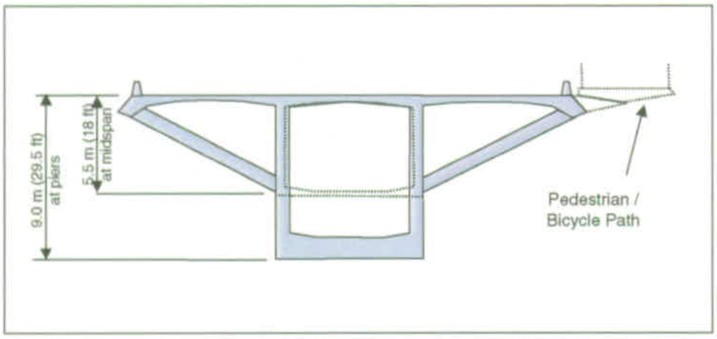


Typical Cross Section – Main Tower

The main tower will be founded on bedrock just east of Yerba Buena Island. The bedrock is about 10 meters (33 feet) below the water surface and slopes steeply in an easterly direction.

4.2.4 Skyway Structure

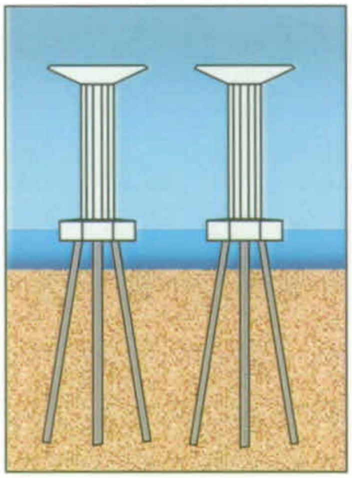
The majority of the skyway structure will be comprised of a variable depth (haunched) concrete superstructure with 160-meter (525-foot) spans supported on single column piers. The depths of the girder varying from 5.5 meters (18.0 feet) to 9.0 meters (29.5 feet).



Cross-section of haunched concrete box

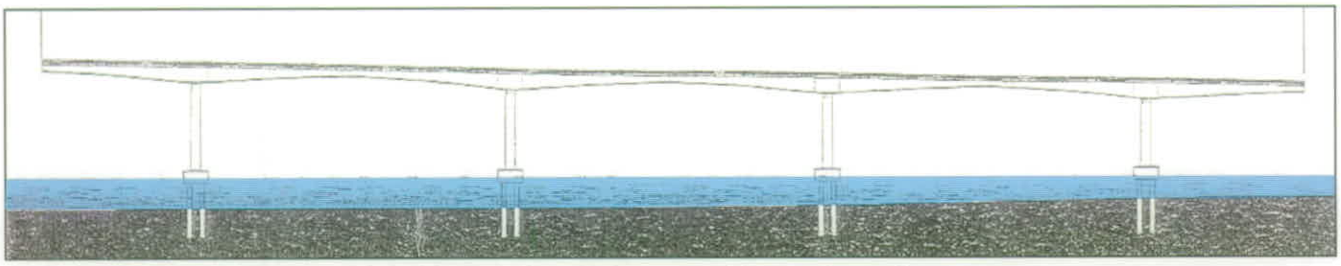
As the skyway structure approaches the Oakland shore, the spans become progressively shorter in length. This assures that the girder depth is proportional to the pier height and span length. Shortening the spans as the bridge approaches the water surface near the Oakland Touchdown keeps the ratio of length to width of the space beneath the bridge and between piers reasonably constant, maintaining a visual continuity. When the spans are short enough to require girder depths less than 4.5 meters (14.8 feet), the girder changes from variable depth to a constant depth, tapering down to 3.0 meters (10 feet) at the Oakland Touchdown

The concrete structure will use post-tensioned members, which are prestressed in both the longitudinal and transverse directions. For the variable depth sections, vertical post-tensioning will be used to control shear stresses in the girder web.


Section of Skyway

The skyway structure will be arranged in frames (groups) of three or four piers. Hinges near the midspan and between the frames will allow longitudinal expansion and contraction due to creep, shrinkage and temperature. Internal steel beams at the hinges will provide shear transfer and control deflections at the ends of the frame.

Seismic loading is the most significant criterion controlling the design of the skyway structure foundations. The extreme variation in pier height, 50 meters (165 feet) for the west-most piers and 10 meters (33 feet) for the east-most piers, water depth, and soil properties required careful



Typical frame for haunched concrete girders on Skyway Structure

consideration of the impact of the foundation configuration on the seismic response characteristics of the skyway structure. The foundations will be designed to respond essentially elastically for a large earthquake. Another concern is the potential for permanent offset at the pilecap level after a large earthquake. Battered piles will be used to manage and control the potential displacement of the foundations after a large earthquake.

The foundation will also be designed to resist loads due to shrinkage, creep, and temperature. These loadings are critical for the proposed concrete superstructure, especially for frames with short piers near the Oakland Touchdown.

Steel pipe piles will be used due to their strength and ductility. For the longer 160-meter (525-foot) spans, the piles will be driven to the Lower Alameda Formation extending more than a 100 meters (328 feet) below the water. Several different types of analyses were performed to select the appropriate pile size and penetration depths including:

- Linear Elastic Response Spectrum Analysis
- Pushover Analysis
- Inelastic Time History Analysis

5.0 DESIGN CONSIDERATIONS

5.1 Seismic Reliability

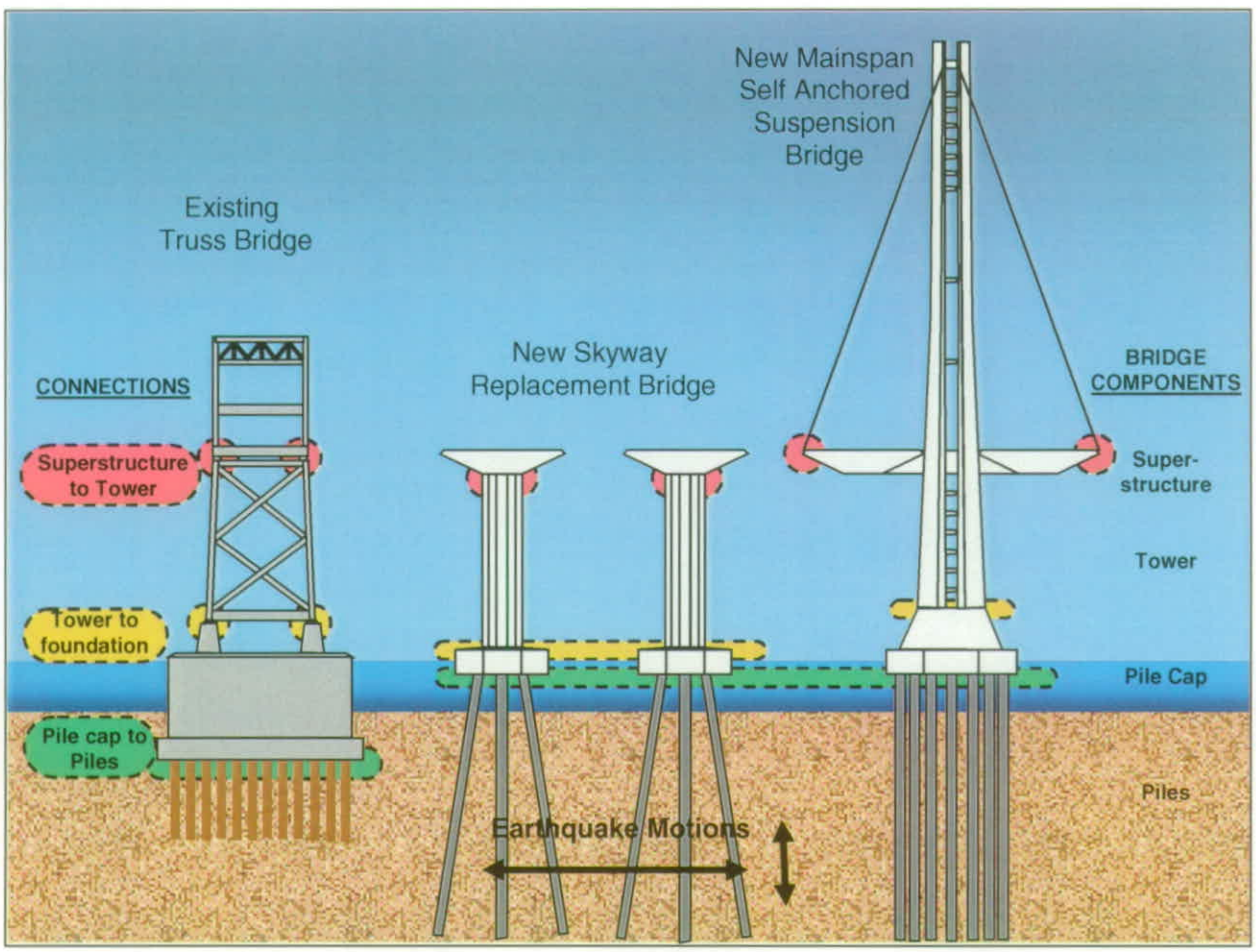
For purposes of this report, a bridge can be broken into three basic components and three points of connection. These components and connections are noted as follows and shown in the figure below. The connection points are color-coded to identify the locations on the respective bridge cross-sections.

Bridge Components
- Superstructure
- Tower
- Foundations (pile cap and piles)

Bridge Connection Points
- Tower to superstructure (red zone)
- Foundation to tower (yellow zone)
- Pile cap to piles (green zone)

In part, how well a structure performs or how reliable a structure is during an earthquake is dependent upon how these connection points and components are designed and constructed as well as the number of components. Each element of the structure (e.g. the foundations, tower, superstructure) and each connection are potential failure points in the structure. These elements can be designed to be very strong to resist the forces of an earthquake or designed to accept and manage damage.

The design for the retrofit of the existing bridge is compromised by constraints imposed by an existing structure built to a 1930s level of materials and construction technology and understanding of seismic design. Also, traffic levels have significantly increased and the in-situ



geology presents many challenges. A new bridge can be designed with much greater reliability to respond more favorably to a major earthquake than a retrofitted bridge. Simply stated, a replacement structure will have a higher degree of reliability as it will have fewer and newer elements than a retrofitted bridge.

Assessing seismic reliability is a complex process involving many technical disciplines. For the SFOBB East Span Seismic Safety Project, experts from academia, public agencies and private engineering firms have been brought together to evaluate the many complexities of the retrofit and replacement alternatives. The technical fields represented include:

- Seismology
- Geology
- Geotechnical Engineering
- Bridge Engineering and Design -- Steel and Concrete
- Construction Engineering
- Construction Specifications Engineering
- Cost Estimating

Retrofit Alternative

In order to develop a strategy for the Retrofit Alternative, the vulnerabilities of the existing east span structure must be reviewed. Analysis of the existing structure indicates that there is risk of catastrophic failure during a maximum credible earthquake. Referencing the figure on the previous page, the potential modes of failure are:

- Large seismic loadings at the top of piers which could exceed the capacity of the bearings and unseat the superstructure (red zone).
- Analysis shows that the pier would fail in flexure because of insufficient reinforcement (tower).
- Flexural and shear overload on the existing timber piles. The piles would break in a strong earthquake that would release the pier laterally and possibly remove the vertical support (green zone).
- Large numbers of elements and connections each of which provides an opportunity for failure.

After careful review of the vulnerabilities of the existing structure, it was determined that the most appropriate and economic retrofit strategy would be to strengthen the foundations (piles and pile cap connections), stiffen the towers, isolate the superstructure and strengthen many superstructure members.

Although isolating the superstructure would require substantial modifications of the towers to provide for the isolation bearings, reducing the input motions to the

Cantilever truss member and elements on the East Span superstructure members was identified as key to reducing superstructure modifications. The superstructure would still require strengthening the connections and stiffening and/or strengthening many truss members adjacent to and above traffic lanes.

Replacement

Without the constraints of modifying an existing structure, the design of a new structure can be uncompromising in the selection of structural configuration and ductile response, the material control would be excellent, and structure response would approximate idealized elastic response.

A replacement alternative would also avoid the many years of traffic impacts that would be part of the Retrofit Alternative.

Many bridge types were considered for a replacement structure. Common to all was the use of a viaduct structure, steel or concrete, to span the mud flats near the Oakland shore. Several bridge types were developed to cross the navigation channel including:

- A viaduct
- Several variations of a cable-stayed structure
- Several variations of a self-anchored suspension bridge

As noted earlier, a new structure will be designed to meet the established design criterion of a lifeline standard.

In his letter to the MTC Bay Bridge Design Task Force dated 20 June 1998, Professor Asteneh writes,

> *"In the literature, there is almost no information about this so-called self-anchored suspension bridge system. Only Niels J. Gimsing, one of the most prominent bridge engineers of the world and Professor at Technical University at Denmark, has a short paragraph on self-anchored suspension bridges in his book: "Cable Supported Bridges". He considers this system inferior to other bridge systems."*

Professor Astaneh uses this reference to Professor Gimsing's text as evidence to support Astaneh's contention that the stability and reliability of the proposed self-anchored suspension bridge are in question. However, the "inferiority" discussed by Professor Gimsing is a reference to additional cost associated with construction issues involved in a self-anchored suspension bridge.

Unlike a gravity-anchored suspension bridge which can use the supporting cables in the construction of the superstructure, a self-anchored suspension bridge must provide a separate temporary supporting system for the construction of the deck.

Professor Gimsing does not state any concerns with the stability and reliability of a self-anchored suspension bridge. An appropriately designed self-anchored suspension bridge is as reliable and safe as any suspension bridge.

The self-anchored suspension bridge discussion from Professor Gimsing's book is included in Appendix I.

5.2 Roadway Design

Design standards are applied to bridge and roadway projects to provide a safe public facility. The SFOBB East Span, constructed in the 1930s, does not meet some of the current mandatory and advisory design standards. Features of the existing bridge that do not meet current standards and how they are addressed with a replacement alternative are addressed in this section.

Retrofit Alternative
Roadway Cross-Section -- The existing bridge has non-standard lane widths. The total available roadway width in each direction on the existing bridge is 17.7 meters (58 feet). The existing section consists of five lanes and no shoulders. For a five-lane roadway, current highway design standards dictate an 24.4-meter (80-foot) roadbed providing for five 3.6-meter (twelve-foot) lanes and two 3.0-meter (10-foot) shoulders. The existing roadway cross section provides no provisions for breakdowns or accidents resulting in a loss of traffic lane(s) and resulting congestion after any vehicle stall or accident on the bridge.

Any retrofit alternative would leave the existing roadway cross section, and its associated operational constraints, in place.

Existing EB roadway (top) and photo-simulation of EB roadway for a replacement alternative (bottom)

Roadway Geometry -- There are several non-standard elements of the existing bridge. The Retrofit Alternative would not provide for any opportunity to upgrade the roadway geometry to current design standards. The most notable non-standard elements of the existing bridge geometry are identified in *Section 2.1.3 Existing Condition, Roadway Geometry.*

Replacement Alternative
Roadway Cross-Section -- A replacement alternative will bring the roadway cross-section up to current standard with full width shoulders providing a safe refuge area for disabled vehicles and incident response.

Roadway Geometry -- All of the non-standard geometric features on the existing bridge will be eliminated by the new bridge which will be designed to meet current state and federal standards for roadway geometry.

5.3 Bridge Traffic Operations

There are several operational reasons for metering traffic entering the bridge including maximizing vehicle through-put, traffic safety, incident response and driver comfort in a constrained environment. The density of vehicles on a congested bridge is much higher than on a bridge with free flowing traffic conditions. The rate of traffic entering the bridge is controlled so vehicles on the bridge can keep moving at a speed optimal for maximizing vehicle through-put.

Westbound traffic entering the bridge is controlled by a metering light system located just west of the toll plaza. The rate of the vehicle metering is dependent on the volume of high-occupancy vehicles (HOVs), which bypass the metering lights, entering the bridge. As the number of HOVs

Metering lights on for the morning commute – lane blocked

increase the metering lights slow down, reducing the rate of entry for non-HOV vehicles. Additionally, when an accident or stalled vehicle occurs on the bridge, the rate of vehicles metered onto the bridge is decreased to match the available capacity.

Eastbound traffic is geometrically metered at the west approach in San Francisco. Prior to entering the bridge in downtown San Francisco, Route 80 though-traffic is constrained to three lanes, effectively metering Route 80 eastbound traffic. Ramp traffic from the Financial and South of

Eastbound traffic during commute hours

Market districts are metered in effect as one lane enters the bridge at Essex and First Streets. These ramps enter the bridge into their own lanes. The impact of these geometric meters are reflected in the congestion on Route 80 west of the bridge approach, which often extends well past 9th Street, and on the ramp approaches in San Francisco on First, Second, Essex, Folsom, and Harrison Streets, as well as others.

Retrofit Alternative

The Retrofit Alternative does not allow any upgrades to the existing roadway cross section and would not provide for any operational improvements.

While rate of entry is controlled under normal operating conditions, minor traffic incidents can have significant operational impacts on the bridge. In the event of a breakdown or accident, traffic capacity is instantly reduced by 20% due to lane blockage. There is further reduction in capacity due to traffic changing lanes to avoid an incident causing a general slowdown of traffic in the adjacent lanes. During the critical and high volume traffic conditions of the peak hour commute, reductions in capacity for even short periods can cause severe congestion and lengthy delays on the bridge and the approaches.

Replacement Alternative

With respect to traffic operations, the most significant element of a replacement alternative is the inclusion of shoulders to reduce congestion impacts of disabled vehicles and other incidents. Having pullout areas will allow traffic to flow relatively unencumbered as well as provide for emergency access lanes for incident response. This benefit will be significant and will be recognized even though no geometric modifications are being made to the west span of the San Francisco-Oakland Bay Bridge.

5.4 Pedestrian / Bicycle Facilities

In response to regional desires, the Metropolitan Transportation Commission (MTC), per the authority provided in SB 60, directed Caltrans to include a pedestrian/ bicycle facility with a replacement alternative. The facility includes a 4.7-meter (15.5-foot) wide pathway accommodating both pedestrian and bicycle traffic.

Computer-simulation of proposed pedestrian/bicycle path

It should be noted that there is an ongoing investigation to include a pedestrian/ bicycle path on the existing west span to close the gap in ABAG's Bay Trail plan between Oakland and San Francisco. MTC and Caltrans are in the process of developing costs and structural analysis for constructing a pedestrian / bicycle path on the existing west span.

ABAG Bay Trails – Map 5

Retrofit Alternative

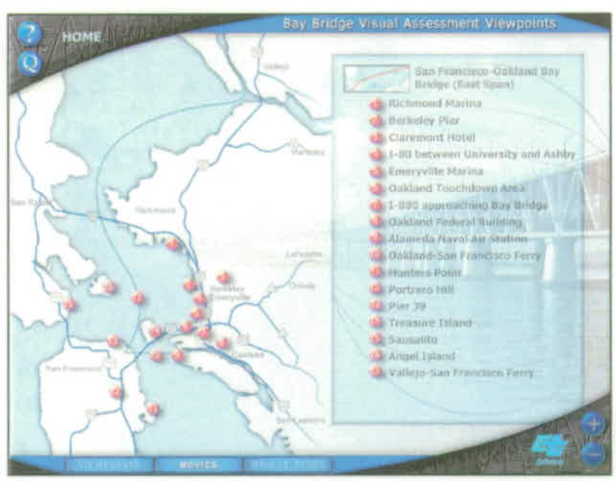
The Retrofit Alternative does not include provisions for a pedestrian / bicycle path.

Replacement Alternative

The Replacement Alternative provides a pedestrian/bicycle path on the east span as prescribed by the MTC.

5.5 Aesthetics

Aesthetics has long been an issue for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. The SFOBB is located in the middle of the San Francisco Bay and the east span of the SFOBB is visible from nearly every city bordering the



Map from the Visual Assessment CD-ROM

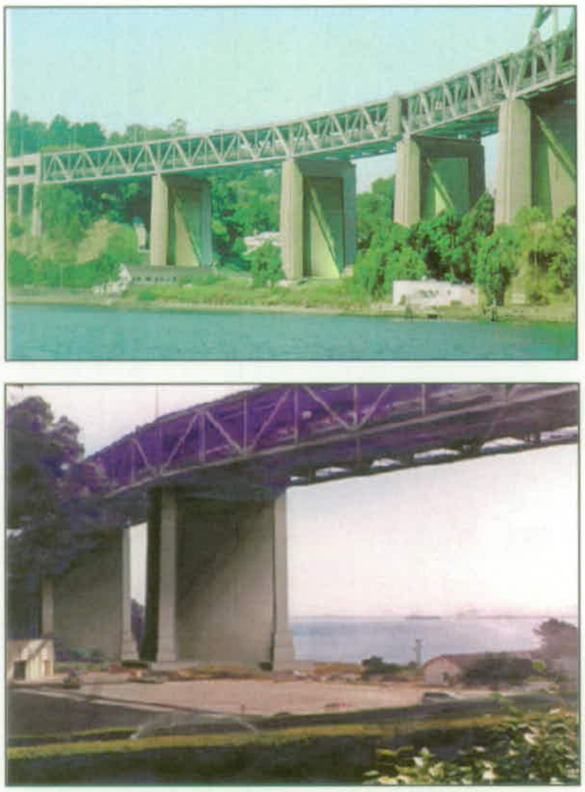
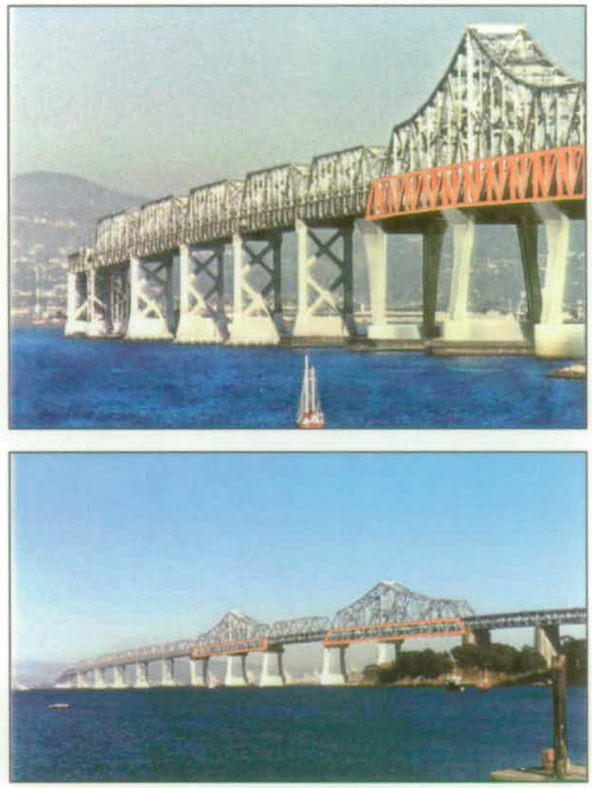


Photo simulations of towers encased in concrete on Yerba Buena Island



Cantilever with two new support towers (external steel truss outlined in orange)

central part of the bay. Photo-simulations were prepared for all of the locations shown in the figure on the previous page and included in the Visual Assessment Report for the project.

Retrofit Alternative

The Retrofit Alternative would require extensive modification of the foundations, piers, and superstructure of the existing east span. These modifications would have an impact on the visual character of the bridge as well as its surroundings.

The braced steel towers on Yerba Buena Island would be completely encased and filled in with concrete resulting in a loss of openness as shown in the photo-simulation above.

Two new towers would be added to support the cantilever section. The members of the steel towers for most of the remaining piers would be encased in concrete, resulting in bulkier vertical and bracing members (see photo-simulation, top right). These piers would also require large concrete tables at the tops of the towers to accommodate the large isolation bearings.

The superstructure modifications include strengthening by adding steel plates and replacing many of the angle and lattice elements. The most visible superstructure modification would be the addition of the external steel truss around the end spans of the cantilever section. Highlighted in orange on the photo-simulation, the external steel truss would reduce views from the lower deck and light entering the lower deck.

Replacement Alternative

The replacement structure selected by the Bay Area representatives, a combination self-anchored suspension/skyway structure,

Replacement Alternative

reflects the values of aesthetics in this highly visible setting.

The replacement structure bridge type was selected for its aesthetic features as well as for seismic reliability. Taken into context with its surroundings, the self-anchored suspension portion of the new east span reflects the forms of the SFOBB west spans and the Golden Gate Bridge, but with 21st century technology of materials and knowledge of seismic design.

6.0 CONSTRUCTION ISSUES

The primary construction issues are duration, traffic disruption, and traffic safety. With respect to these issues, the retrofit and replacement alternatives are fundamentally different. The Replacement Alternative is superior to the Retrofit Alternative primarily because of the shorter time to construct, less adverse impacts to traffic flow, and the safety advantages realized by separating traffic from the construction zone.

This section addresses the construction differences and similarities between the two alternatives.

Table 6-1, *Comparison of Construction Issues* summarizes the similarities and differences in construction issues.

6.1 Differences Between Construction Of Alternatives

There are pronounced differences in construction of the retrofit and replacement alternatives. These differences are in the areas of:

- Construction duration
- Traffic interruptions
- Work above and adjacent to traffic lanes
- Traffic access and circulation on Yerba Buena Island
- Dismantling structures

The construction differences are discussed in the following paragraphs by topic and alternative.

6.1.1 Construction Duration

<u>Retrofit Alternative</u>

Retrofitting the existing structure is estimated to require approximately 6 years to complete. The construction consists of in-water activity, substructure and superstructure modifications. The bridge would gain in seismic strength as the project progresses but would not reach full capability until the project is complete. While retrofitting the superstructure is taking place, construction would be scheduled to avoid affecting traffic during the commute periods. When traffic convenience is assigned a higher priority over construction access, the work requires more time to complete. Because there is a 70% probability of a magnitude 6.7 or greater quake striking the Bay before 2030, every additional month to complete the project puts this vital transportation link and the people using it at higher risk.

<u>Replacement Alternative</u>

The replacement structure is estimated to require approximately 4 ½ years to construct and an additional year to complete the dismantling of the existing bridge. Westbound traffic will be directed onto the new structure and a temporary detour structure on YBI about 3 ½ years after start of construction. Approximately 4 ½ years after start of construction, the eastbound traffic will be directed onto the new structure. Dismantling of the existing bridge and temporary detours will begin once eastbound traffic is directed onto the new bridge.

Table 6-1 Comparison of Construction Issues

ISSUE			ALTERNATIVE	
			Retrofit	**Replace**
Construction Differences	**Duration**	Completion	6 years to retrofit structure.	4 ½ years plus one year to dismantle existing bridge.
		Westbound Traffic	6 years through construction zone. Work in low use hours.	3 ½ years to reroute to new structure. Several months of traffic exposure to work zone while detours are constructed.
		Eastbound Traffic	6 years through construction zone.	4 ½ years to reroute to new structure. Several months of traffic exposure to work zone while detours are constructed.
	Traffic Interruptions		Some work would require that the lanes on the existing bridge be closed. This work would be scheduled during periods of the day with lower traffic volumes.	The new bridge will be constructed while traffic uses the existing bridge. Detours will be constructed to facilitate traffic at both ends of the bridge.
	Public Safety		Higher traffic exposure to work zone. Some work will occur above and adjacent to traffic.	Bridge construction occurs away from the existing bridge and traffic.
	YBI Traffic Access and Circulation		Ramp access unchanged. No detouring around work.	Change of ramp access. Temporary road closures and detouring of island traffic.
Construction Similarities	**Scale of Work**		Large equipment, labor intensive.	Similar to Retrofit
	In-Water Construction	Barge-Based Work	Pile driving, dredge, cofferdams, concrete, materials delivery.	Similar to Retrofit
		Marine Access and Navigation	Marine traffic diverted to navigation channel. Barges, mooring, trestles, and pile driving.	Similar to Retrofit
		Materials and Worker Access	Boat, barge, bridge, trestle, temp docks.	Similar to Retrofit
		Dredging	Access for barge, excavate cofferdam.	Similar to Retrofit
		Substructure Construction	Piers, driven piles, caissons, fenders.	Similar to Retrofit
	Construction Staging Area	Yerba Buena Island	Uses all space available on east end of YBI. Laydown area in parade grounds, pier with vessel mooring.	Similar to Retrofit
		Oakland Touchdown	Access from surface streets, access to shore has environmental restrictions.	Similar to Retrofit

6.1.2 Traffic Interruptions

The retrofit and replacement alternatives are remarkably different when considering the effects on traffic. The Replacement Alternative provides a higher level of traffic mobility because traffic would be separated from the work zone. By comparison, the Retrofit Alternative requires motorists to pass within feet of the construction zone through the entire 4-kilometer (2 ½ mile) long project. This condition would persist for the much of the nearly 6 year duration estimated to construct the Retrofit Alternative.

The SFOBB carries Interstate 80 traffic and is the primary vehicular link between the San Francisco Peninsula and the East Bay. The westbound approaches are congested during the morning commute period, and the eastbound approaches are congested during the evening peak period. During these times the SFOBB operates at capacity. The SFOBB is also heavily traveled during non-commute hours. Traffic flow on the SFOBB is vulnerable to congestion due to stalled vehicles, accidents and lane closures required for bridge maintenance or construction. There are 274,000 vehicles that use the SFOBB daily. The weekday highest use hour has 10,800 westbound vehicles using the SFOBB.

Retrofit Alternative

The existing bridge is a double deck steel truss resting on shoes at the top of steel and concrete piers. The lower deck roadway is surrounded on the side and above with the steel elements that comprises the truss and upper deck road. A cantilever truss and five overhead trusses, 504 feet in length, enclose the upper deck for about one-mile of the two and one-half mile length of the bridge.

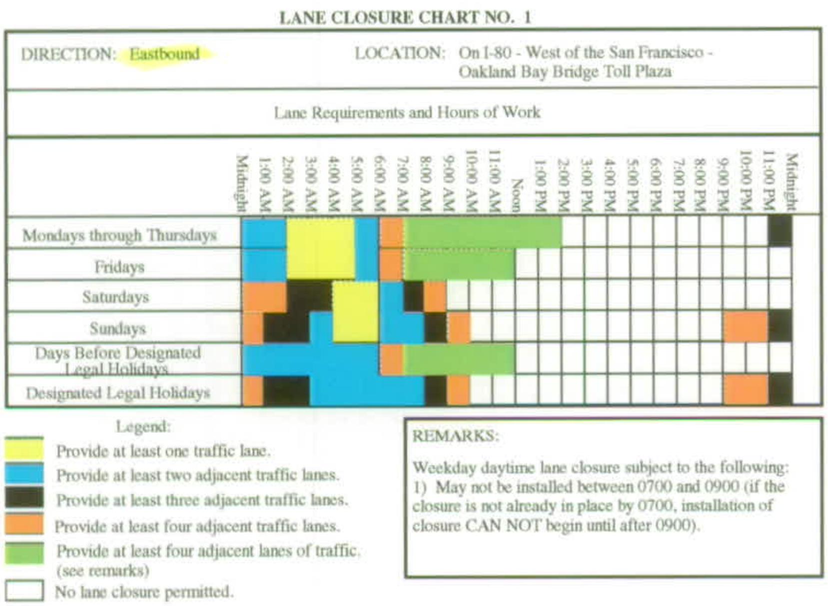
The Retrofit Alternative through the cantilever truss portion would connect the existing truss to a new larger enveloping external steel truss to handle seismic loads. The retrofit of the "504" trusses would require major replacement and strengthening of truss elements, jacking up the truss, installing isolator bearings, and installing transverse expansion joints. With live traffic on the bridge, the trusses would be jacked up and temporarily supported while the new isolator bearings are installed.

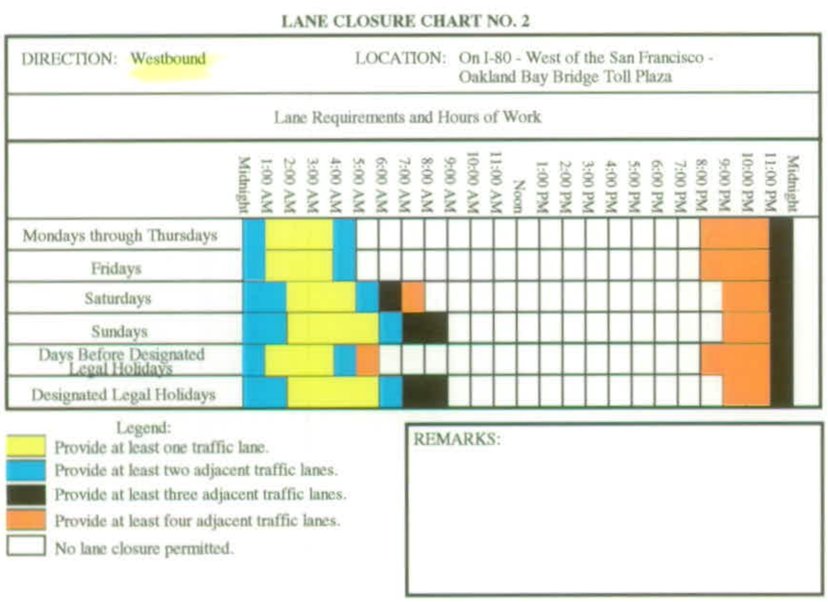
The retrofit of the nineteen trusses which are 288 feet in length would be similar to the 504s: major replacement and strengthening of truss elements above live traffic, jacking up and temporarily supporting the truss, installing isolator bearings, and installing transverse expansion joints. The upper deck of the 288s is not enclosed in a truss. As with the 504s, the trusses would be jacked up and temporarily supported while the new isolator bearings are installed – while the public is still driving on the bridge.

Construction equipment and workers would have to maneuver within feet of traffic while work occurs adjacent to and above traffic.

Construction adjacent to traffic

Avoiding adverse impacts to traffic will be a constant challenge with 274,000 vehicles passing through the construction site every day. Construction would occur on the bridge decks during periods of the day with lower traffic volumes. This reduces the potential for traffic delays and exposure to the construction work zone. A lane closure chart would identify the allowable lane closure times for both directions of traffic.





Lane closure charts for the SFOBB

Traffic patterns would be changed daily as the lane closures are implemented and then removed. All lanes would be available during weekday commute hours.

Construction on the superstructure would be halted during holiday weekends to provide for anticipated high traffic usage. While retrofitting the superstructure is taking place, construction would be scheduled to avoid affecting traffic during commute periods. This condition would persist for much of the nearly 6 year duration estimated to construct the Retrofit Alternative. Where public convenience is given priority over construction activities, the time to complete the construction is lengthened.

Many construction activities would occur adjacent to traffic during the periods of the day with lower traffic volumes. Some of these construction activities include:

- Paint removal
- Rivet removal and replacement
- Bridge painting
- Lifting and attaching steel plates

<u>Replacement Alternative</u>
Traffic will use the existing bridge while the skyway and mainspan portion of the Replacement Alternative is constructed.

After 42 months, westbound traffic will be routed to the new westbound structure while eastbound traffic will continue to use the lower deck of the existing bridge. This is to allow construction of the transition structure on YBI while accommodating traffic. These detours are depicted to the right and on the following pages. The upper photo shows the detours at the Oakland Touchdown while the lower photo shows the YBI detours for the same stage of construction.

As depicted in the series of photo-simulations, the traffic handling during construction is accomplished in five stages:

- Stage 1 – Construct detour structures
- Stage 2 – Route traffic onto detours
- Stage 3 – Remove portion of the existing bridge on YBI
- Stage 4 – Construct the transition structure on YBI and shift traffic to the new transition structure
- Stage 5 – Dismantle existing bridge

On YBI, the detour structures will route traffic{xe "traffic"} around the construction area while portions of the existing east span are demolished and a new transition structure is completed where the existing bridge now stands. The detour structures will allow the replacement structures to be connected to the retrofitted YBI east viaduct while avoiding impacts{xe "impacts"} to traffic. The detour structures will be in place for approximately 32 months.

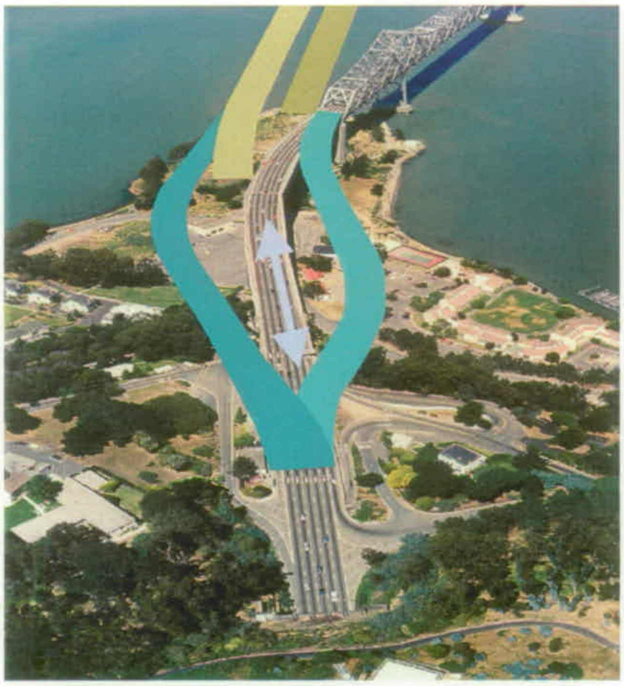
6.1.3 Work Above and Adjacent to Traffic

Safety is improved when traffic and construction activities are separated. In this respect the retrofit and replacement alternatives are fundamentally different.

STAGE 1

- Construct new Bridge
- Construct eastbound (EB) and westbound (WB) detours

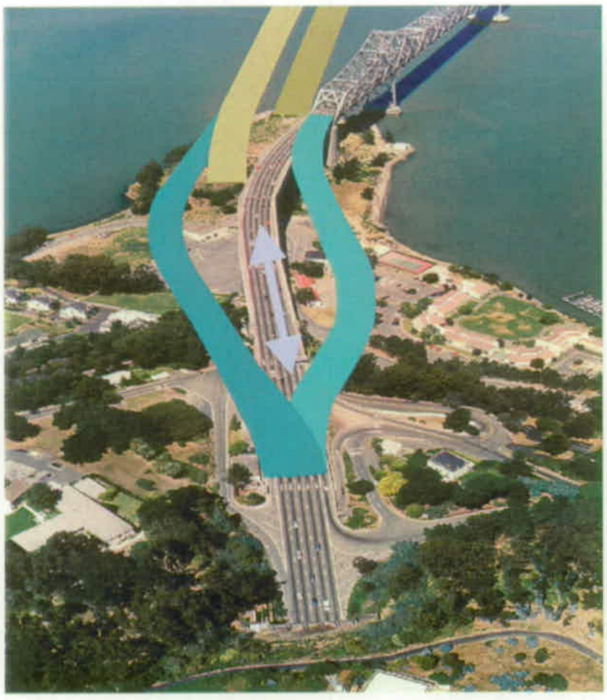
STAGE 1



STAGE 2

- Shift traffic on to detours at Oakland TD
- Construct new WB approach at Oakland TD
- Complete construction of detours at YBI

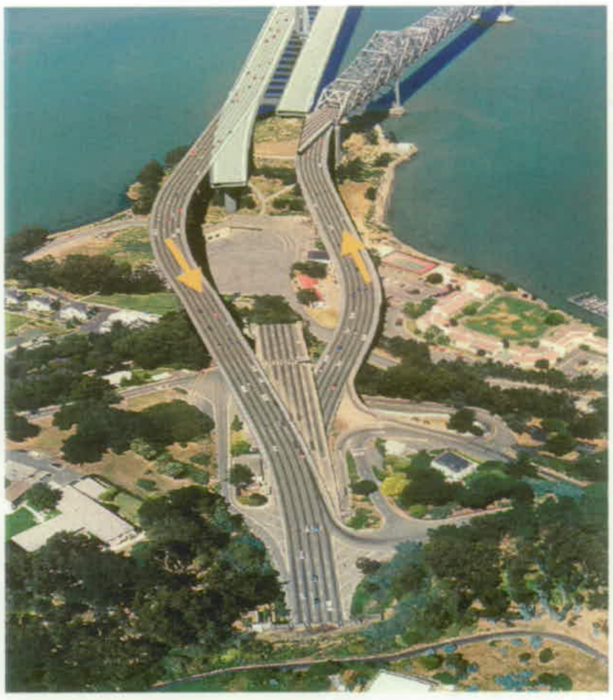
STAGE 2



STAGE 3

- Shift traffic to new WB bridge and detours at YBI
- Construct EB landing at Oakland TD
- Remove existing bridge from Bent 48 to YB1

STAGE 3



STAGE 4

- Construct remaining section of the new bridge at YBI
- Shift all traffic to new bridge

STAGE 4

STAGE 5

- Dismantle existing bridge

Toll Plaza improvements and a Gateway Park shown here are being planned for the Oakland Touchdown area.

STAGE 5

Retrofit Alternative
Traffic would continue to drive on existing bridge decks with construction occurring adjacent to and above traffic lanes. This condition would exist along the entire 4-kilometer (2 ½ mile) length of the bridge.

Replacement Alternative
The new bridge will be constructed while traffic uses the existing bridge. Safety is improved when the traffic and construction activities are separated. In this respect the two alternatives are different. The new bridge will utilize detours as previously described to facilitate construction at the two ends of the bridge.

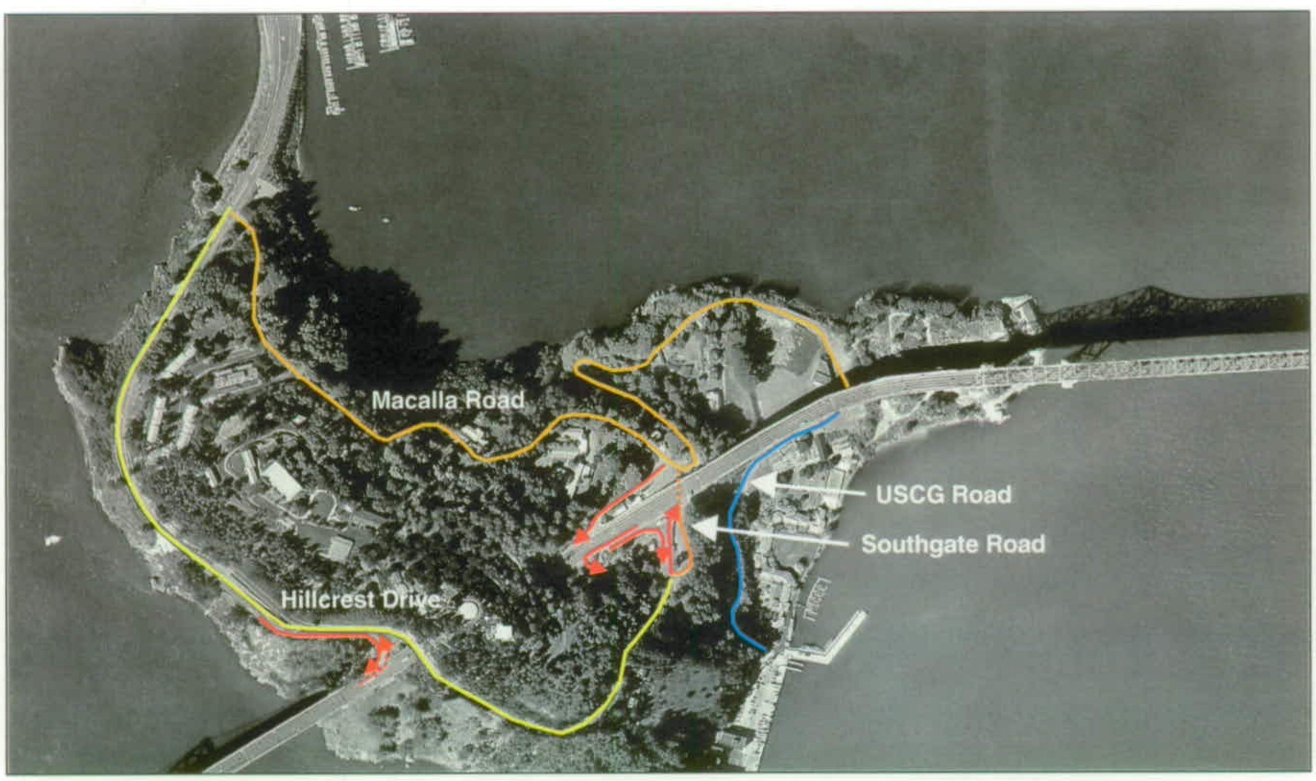
6.1.4 Traffic Access and Circulation on Yerba Buena Island

Regardless of alternative, access to and from YBI and TI is maintained during all phases of construction. However, some ramps will be temporarily closed for the Replacement Alternative.

Currently, access to YBI is provided by ramps on both sides of the YBI tunnel. On the San Francisco side of the tunnel, there is a westbound on-ramp from YBI/Treasure Island (TI) and an eastbound off-ramp to YBI/TI. On the Oakland side of the tunnel, there is a westbound off-ramp to YBI/TI, a westbound on-ramp to San Francisco, an eastbound off-ramp to YBI/TI and an eastbound on-ramp to Oakland.

Local circulation on YBI is currently accommodated by a series of roadways including:

- Hillcrest Drive – Main roadway located on the south slope of YBI connecting the eastside and westside of YBI leading to Treasure Island.
- Macalla Road – Main roadway located north slope of YBI connecting the eastside and westside of YBI. Macalla Road also leads down to the Historic



Circulation roadways on YBI – Ramps (red), USCG Road (blue), YBI Roads (yellow / orange)

District and the USCG facilities.

- Southgate Road – Connection between Macalla and Hillcrest, located east of the tunnel beneath the bridge.

Retrofit Alternative
The Retrofit Alternative does not contemplate any long-term closure of ramps.

The Retrofit Alternative would involve limited traffic restrictions on the portion of Macalla Road leading down to the east end of YBI to move construction equipment.

Replacement Alternative
Access to and from YBI and TI is maintained during all phases of construction. Some ramps will be temporarily closed for the Replacement Alternative. During construction, the westbound on-ramp and the eastbound off-ramp on the eastside of the island will be closed for approximately 32 and 22 months, respectively. Traffic will be able to get on and off the bridge at YBI via the ramps at Hillcrest Road on the westside of YBI. Access to and from Treasure Island will be provided at all times.

Local circulation on YBI will be affected with a replacement alternative.

- Hillcrest Drive will be open at all times.
- Macalla Road will require one-way traffic control through the hairpin turn to facilitate reconstruction of the road. There will be additional traffic restrictions on the portion of Macalla Road leading down to the east end of YBI to move construction equipment.
- Southgate Road will be closed during removal of the existing bridge on YBI and construction of the transition structure, a period of approximately 20 months. As a result, direct access from one side of the bridge to the other will be detoured. Some residents on the south side of YBI will have a more circuitous route to access the westbound on-ramp to San Francisco and to the Historic District/USCG facilities.

6.1.5 Dismantling Structures

Retrofit Alternative
There is no dismantling in the retrofit alternative.

Replacement Alternative
The existing bridge, access trestles, temporary falsework, and detour structures will be removed under the replacement alternative.

6.2 Similarities Between Construction Of Alternatives

There are a number of construction issues common to both the retrofit and replacement alternatives that are substantially similar in nature. The retrofit and replacement

Construction barges on the Vilano Bridge

Dredging techniques – backhoe, clamshell, hydraulic

alternatives have similar construction issues with respect to:

- Scale of work
- In-water construction
- Laydown area on Yerba Buena Island and Oakland Touchdown

6.2.1 Scale of Work

Construction of the retrofit and replacement alternatives would require use of large-scale construction equipment and labor-intensive construction activities. Noise emitted from the driving of large piles would be similar for the retrofit and replacement alternatives. The construction period for the alternatives is anticipated to be approximately 4 ½ to 6 years, including dismantling the existing bridge for the replacement strategy.

6.2.2 In-water Construction

Barge-Based Work

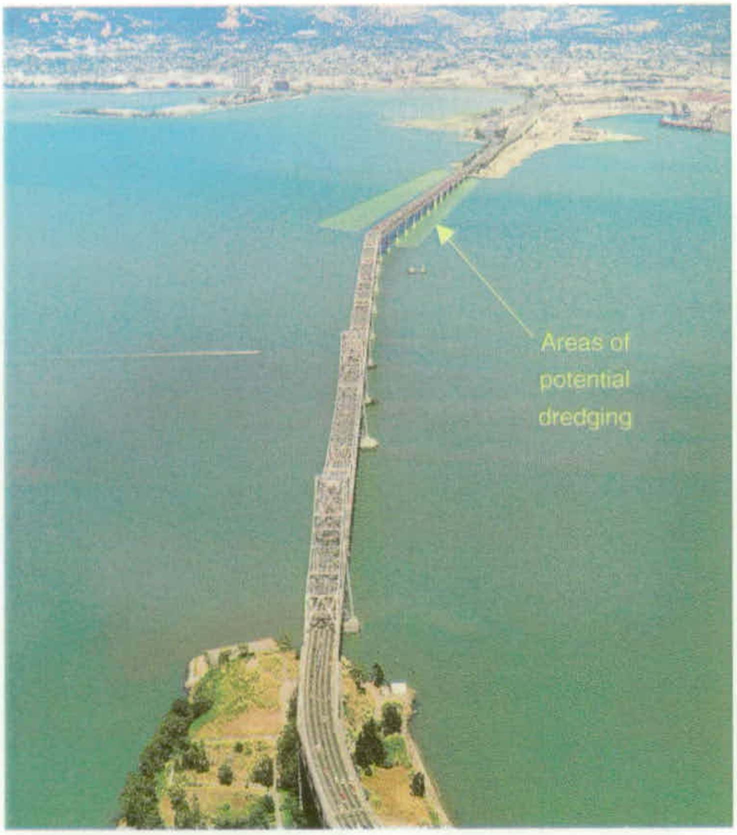
Most in-water construction will take place from barges. Barges will be used for material delivery, dredging, drilling, pile driving, lifting, pile extraction, constructing cofferdams, and demolishing. Special barges and lifting equipment will be used to accommodate heavy equipment needed to support large-scale pile driving. In areas of shallow water, construction will take place from trestles and/or barges.

Marine Access and Navigation

The in-water construction activities required to construct the retrofit and replacement alternatives would have similar effects on the movement of commercial vessels and recreational boats. Marine traffic would be diverted from areas of construction where barge mooring, pile-driving operations, and trestles are in use. The navigation channel near YBI would remain open during construction. The width of the navigation channel will be reduced during construction but not less than the minimum width required by the Coast Guard.

Dredging

Dredging will be required for portions of both the replacement and the retrofit alternatives to excavate cofferdams and to accommodate barge access because in some locations the water depths are shallower than the draft of a necessary barge. The limits of the shallow water that are expected to require dredging for barge access extend a distance of about 1.6 kilometers (1 mile) from the Oakland shore to approximately Pier E-9. The anticipated maximum draft for the barges is 3.6 meters (12 feet). To ensure adequate clearance over potential irregularities in channel depth and to allow for some potential resettlement of materials in the channel after dredging, The channel will be dredged to a depth of -4m (-14 feet).



Areas of potential dredging

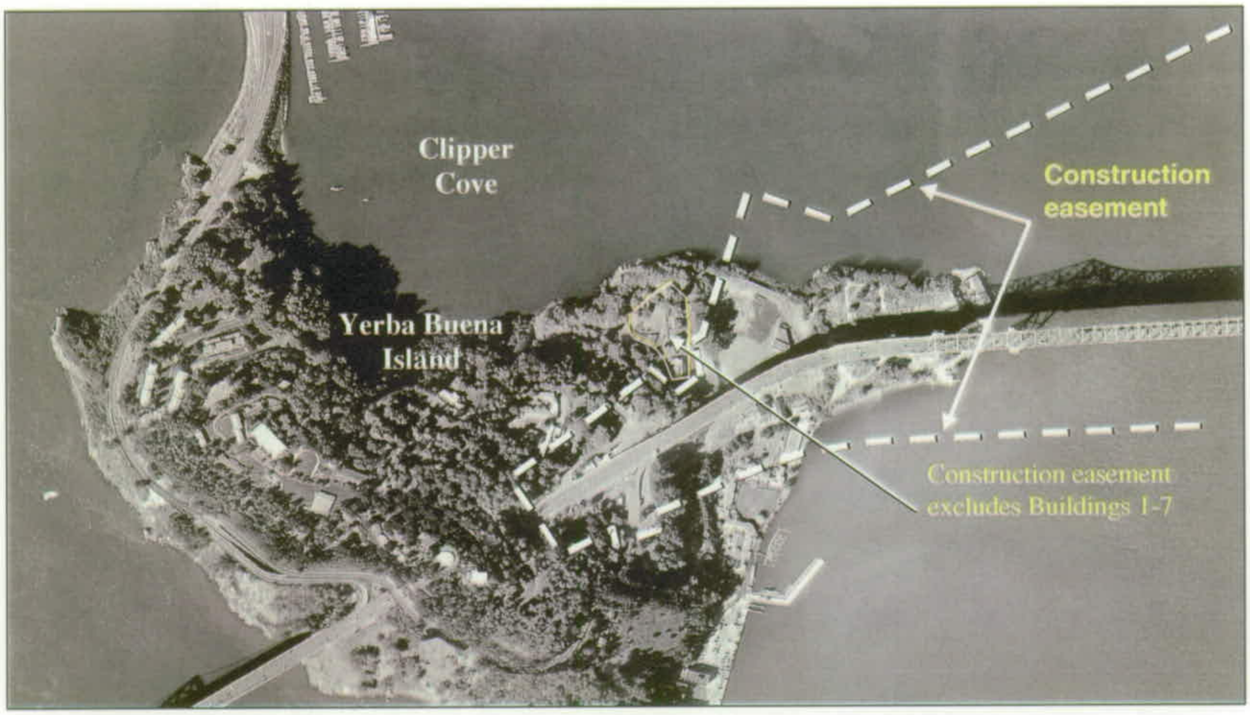
Dredging techniques can generally be categorized as either hydraulic (suction) or mechanical. Hydraulic dredging may involve the use of equipment such as cutterheads, dustpans, hoppers, hydraulic pipelines, plain suction, and sidecasters. The hydraulic method typically minimizes disturbance and re-suspension of sediments, but involves the entrainment of high volumes of water. The water and sediments will have to be discharged at a disposal location. Mechanical techniques involve the removal of material by equipment such as clamshell, dipper, or ladder dredges. Sediments are dislodged and excavated and then raised to the surface and discharged into a barge or scow. It is anticipated that the primary equipment used in the dredging for the East Span Project will be clamshells and cutterheads and that material disposal will take place at designated off-site locations.

Dredging quantities vary from 199,000 cubic meters (260,000 cubic yards) for the Retrofit Alternative to 445,000 cubic meters (583,000 cubic yards) for the Replacement Alternative. The difference in dredge quantities will have cost implications but not result in a change in construction methodology.

Substructure Construction

Construction on the substructure (below the tops of the piers) will consist of piers, cofferdams, foundations, caissons, piles, pile caps, anchoring systems, fenders, and navigation electrical systems. Substructure construction will consist primarily of installation of piers and pile caps. It is expected that cofferdams will be constructed in shallow water and cast-in-steel shell piles will be driven as methods to construct piers. Construction of piers will require large-scale construction equipment to drive large-diameter piles. Pile drivers will be mounted on deep-draft barges.


Pile installation at San Mateo-Hayward Bridge



Proposed construction easement area on YBI for Retrofit and Replacement Alternatives

6.2.3 Construction Staging Area Yerba Buena Island and Oakland Touchdown

For either the retrofit or replacement alternatives, contractors will require construction laydown and access areas on Yerba Buena Island (YBI) and at the Oakland Touchdown for construction storage and staging for the project. The entire eastern end of YBI, including the parade grounds is required. A pier and vessel mooring facility will be constructed near the parade grounds or offshore from the eastern tip of the island to facilitate the loading and offloading of material from barges.

Additionally, the land at the Oakland Touchdown adjacent to the Caltrans right-of-way on the south side of the existing roadway will be required for temporary construction easements. At the Oakland Touchdown, access to the construction area will most likely be from surface streets that align south of I-80, such as Burma Road. The East Bay Municipal Utility District sewer outfall is located in the work area and has shallow ground cover. Protective measures will be taken during construction to preventive damage to the outfall.

7.0 SCHEDULE

The comparison of schedules between the replacement and retrofit alternatives can only be reviewed within the context of the current status of the project. This will determine which approach has the least impact on the current project schedule.

For purposes of this evaluation, the schedules are compared in terms of the time when traffic would be using a seismically upgraded structure to the applicable performance standard. General activities that drive the schedule include:

- Analysis and Design
- Public Contract Bidding Process
- Construction

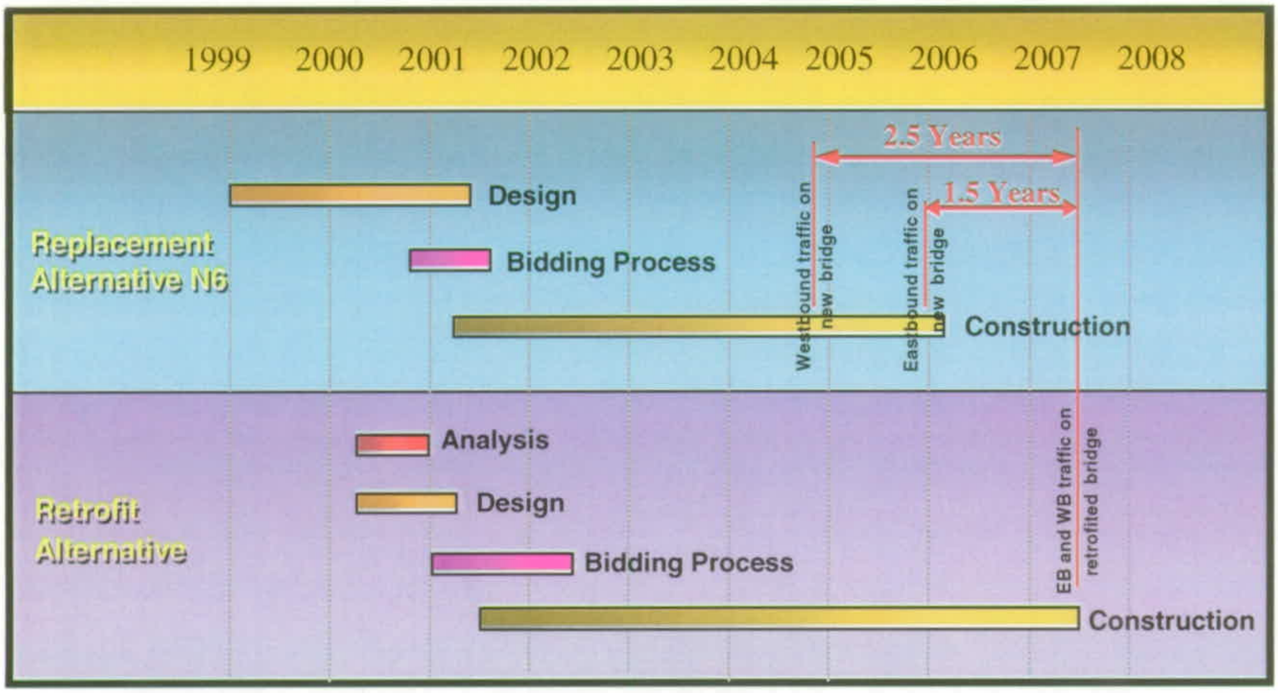
7.1 Replacement Alternative

There are three construction packages being prepared for the Replacement Alternative: Yerba Buena Island/Mainspan, Skyway, and Oakland Touchdown. The analysis for the design is completed. The construction plans for the three construction packages are approximately 65% complete (Skyway Structure plans are 85% complete). The first construction contract is scheduled to be advertised in late 2000 and is the first step in the public contract bidding process. Construction is scheduled to start in early 2001.

Although the construction of a replacement bridge and dismantling the existing bridge is expected to take about 5 ½ years, traffic will be using the new bridge well before construction is completed. As seen in photo-simulations in *Section 6.0, Construction Issues*, the westbound traffic will be shifted to the new westbound structure in Stage 3 of the construction staging plans as shown on page 6-6. This occurs about 3 ½ years after the start of construction. It will take approximately one year to complete Stage 4 construction after which the eastbound traffic will be routed to the new structure.

7.2 Retrofit Alternative

Retrofit plans were approximately 65% complete for the East Span Project before the decision was made to consider



replacement of the east span of the San Francisco-Oakland Bay Bridge as an alternative.

In order to complete plans for the Retrofit Alternative, additional analysis would be needed to finalize the retrofit approach for the cantilever section. However, construction drawings to retrofit other sections of the bridge could be made ready in a few months.

The Retrofit Alternative project would be subdivided into a series of ten smaller construction packages. Each of the contracts would be advertised when ready and in coordination of a total construction effort. Some packages which still require analysis and design effort would be advertised several months after the first contract is released.

The duration of retrofit construction is a function of the traffic control requirements. With a more complex set of construction activities that are constrained by the traffic operational requirements, the duration for construction of the Retrofit Alternative is anticipated to take six years. The construction of the new bridge will be completed away from the existing bridge and the schedule for the Replacement Alternative is not affected by daily traffic control requirements.

7.3 Conclusion

Implementing the Retrofit Alternative at this time would delay seismic safety for eastbound users of the east span of the San Francisco-Oakland Bay Bridge by 1 ½ years and westbound users by 2 ½ years. The figure on the previous page provides a comparison of the retrofit and replacement alternative project schedules.

8.0 ECONOMIC ANALYSIS

Two separate analyses were prepared by Caltrans investigating the cost-effectiveness of the retrofit versus replacement decision.

- *Retrofit vs. New Bridge – An Economic Analysis for the East Span of the San Francisco-Oakland Bay Bridge*, April 1997
- *Replacement Study for the East Spans of the San Francisco-Oakland Bay Bridge Seismic Safety Project*, December 1996

It is important to note that all analyses regarding cost-effectiveness presumed a "base case" replacement structure that would consist of a skyway structure or a skyway/cable-stay structure.

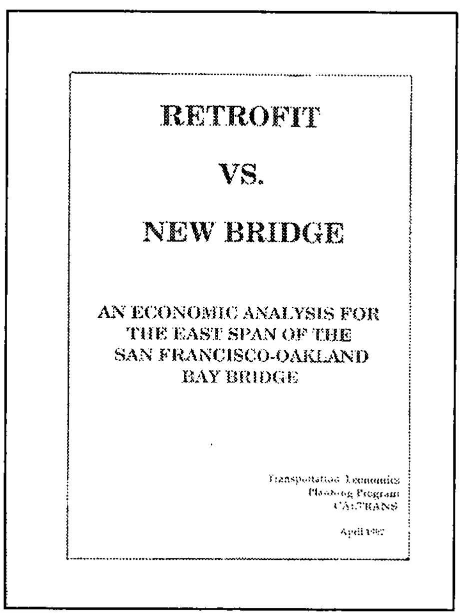
After a decision was made to consider replacement of the bridge, legislation was adopted (Senate Bill 60 of 1997) to provide funding for the project. This legislation provided the Bay Area with the decision making authority to include additional costly amenities in the bridge project (bicycle / pedestrian path, signature span, Transbay Terminal improvements). The Bay Area has included such amenities in the replacement bridge currently under design. The decision to add amenities is independent of the decision to replace or retrofit. Cost-effectiveness, therefore, remains a function of the base case replacement structure.

8.1 Retrofit vs. New Bridge – An Economic Analysis for the East Span of the SFOBB

This analysis investigated the cost issues for the retrofit and replacement alternatives. Issues considered included facility costs and user benefits and costs. Facility costs included construction, rehabilitation, maintenance and operations, probable earthquake damage repair, and salvage and residual values. User benefits and costs considered traffic accidents, traffic delay, and potential loss of life due to an earthquake.

The following is the executive summary from the referenced study:

> *"Two alternative projects have been proposed to improve the safety of the motoring public on the east span of the San Francisco-Oakland Bay Bridge. They are retrofitting the existing bridge or building a new bridge parallel to it. To compare these two options from an economic and investment analysis point of view, a life-cycle/benefit-cost study was conducted to assess all benefits and costs of both options over the entire economic life of the bridge. Even though the west span will also be retrofitted, as reflected in this analysis, the main purpose of this analysis is to assist with investment decision making on the east bridge.*



RETROFIT

VS.

NEW BRIDGE

AN ECONOMIC ANALYSIS FOR THE EAST SPAN OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE

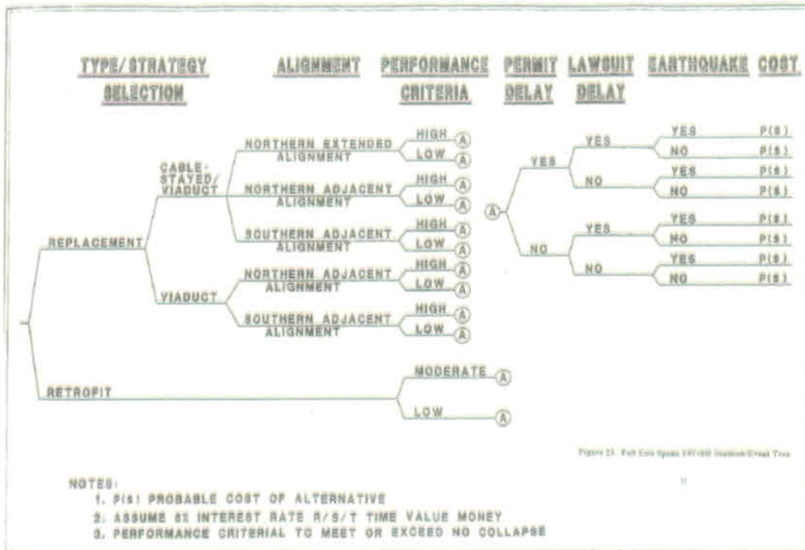
Transportation Economics
Planning Program
CALTRANS

April 1997

> *The agency cost categories considered in the analysis include all administrative support and engineering costs, the bid price, potential costs of an earthquake damage, and a 10 to 20 percent contingency for possible cost overruns. On the user side, all traffic delay and accident costs have been quantified and included. Based on the life-cycle costs and benefits considered in this study, and based on both*

*agency and user costs, the new bridge (skyway option) would cost about **$625** million (**in discounted dollars**) <u>less</u> than the retrofit option. The summary table in the appendix compares the detailed cost of all alternatives.*

*Two additional "cable stay" options – a single tower and a double tower – were also analyzed. It was found that while both of these options would have a higher initial cost than the skyway option, they would have, respectively, a life-cycle cost of **$546** million and **$437** million <u>less</u> than the retrofit alternative."*



Decision Tree from the Economic Analysis

8.2 Replacement Study for the East Spans of the San Francisco-Oakland Bay Bridge Seismic Safety Project

A cost analysis was prepared to assist in the decision making process of retrofit versus replacement. The findings of the analysis are documented in a report prepared by Dr. Brian Maroney titled *Replacement Study for the East Spans of the San Francisco-Oakland Bay Bridge Seismic Safety Project* dated December 17, 1996.


REPLACEMENT STUDY FOR THE EAST SPANS OF THE SAN FRANCISCO - OAKLAND BAY BRIDGE SEISMIC SAFETY PROJECT

Submitted to Elden Davisson
Chief of the Office Of Structure Design
Engineering Service Center

Prepared by Brian Maroney

December 17th, 1996

The alternatives were evaluated in terms of probable outcome and cost. To facilitate comparison of alternatives, probable dollars were used as a measure of effectiveness. This essentially establishes an economic analysis of the decision comparing retrofit and replacement of the east span.

It is recognized that dollar value does not always allow for complete evaluation in what is fundamentally a safety upgrade project. Some outcomes are unacceptable regardless of economy. Therefore, an allowance is given to evaluate outcome as well as cost.

The following items were considered in developing the economic analysis:

- Loss of life
- Earthquake event before and after upgrade
- Structure collapse
- Probability and magnitude of earthquakes
- Structure condition
- Traffic volumes
- Maintenance costs

8.2.1 Capital Costs

Capital costs are based on construction costs for the retrofit and replacement alternatives.

Construction costs developed for the replacement structure is for a concrete viaduct option and did not include bridge amenities subsequently identified by the Metropolitan Transportation Commission (MTC). The bridge amenities, a cable-supported mainspan and a pedestrian/bicycle path, are paid by a separate toll surcharge authorized by MTC.

8.2.2 Life Cycle Costs

With the Retrofit Alternative, the SFOBB is expected to have a remaining service live of 50 years. A replacement structure is expected to have a service life of 150 years.

To assess life cycle costs, a base of 50 years was assumed. Life cycle costs include maintenance costs for painting, other maintenance requirements, and deck rehabilitation. A salvage value was calculated for the remaining 100 years of service life for replacement alternatives.

8.2.3 Earthquake Scenarios

A key challenge is to address the cost of potential earthquake impacts in the economic analysis. The approach includes review with respect to a variety of earthquake events and retrofit strategies. The earthquake events analyzed includes events less than a magnitude 6, magnitude ~6.5, and magnitude 7 or greater.

The economic analysis included repair costs for damage caused by probable earthquakes, both before and after completion of construction of a retrofit or replacement alternative.

8.2.4 Economic Analysis

The following table summarizes the findings of the economic analysis.

	Retrofit	Replacement
Construction Costs	915	1,167
Salvage Value	0	(53)
Paint Costs	8.5	0
Maintenance Costs	8.5	0
Deck Rehab (short term)	12	0
Deck Rehab (long term)	15	0
Safety	3	0
SUBTOTAL	**991**	**1,114**
M6-7 EQ Before const compl	662	293
M 7.0+ EQ Before const compl	220	254
M6-7 EQ Post construction	219	9
M 7.0+ EQ Post construction	212	5
TOTAL	**2,304**	**1,675**

Note: Costs are in millions of 1996 dollars

8.2.5 Conclusions from the Replacement Study (December 1996)

The analysis included the risk cost for an earthquake event and supports a decision to replace the east span of the San Francisco-Oakland Bay Bridge with a new structure.

A replacement alternative is also supported by the high cost of construction for the Retrofit Alternative. This is consistent with State policy. In a June 12, 1996 letter, the State of California, Department of General Services established a policy, based in part on Proposition 152, that dictates consideration of replacement as an alternative when the retrofit costs exceed 75 percent of replacement costs. At the time of Dr. Maroney's report, the capital costs for retrofit was $915 million compared to a cost for replacement of $1,167 (viaduct structure) million. Construction costs for the Retrofit Alternative represented 78% of replacement costs. When considering lifecycle costs on a 50-year basis, the percentage of costs for retrofit compared to replacement increases to 89%.

9.0 CONCLUSIONS

All studies favor the construction of a replacement bridge over retrofit for the east span of the San Francisco-Oakland Bay Bridge. The evidence is consistent not only with respect to the crucial question of seismic safety but also with respect to the key values of public and worker safety, public convenience, and cost-effectiveness.

9.1 Public Safety

With respect to seismic safety, the Retrofit Alternative is inherently less reliable than a replacement alternative, and reliability is a measure of safety. A new bridge will have a high degree of reliability as it will have fewer and newer elements than a retrofitted structure. A replacement bridge will meet the lifeline performance criteria. Constrained by a 1930s level of material and construction technology, it is impossible to retrofit the existing east span to lifeline standards with any reasonable degree of confidence.

Failure at Pier E-9

Seismic safety will also be achieved sooner with the Replacement Alternative. Seismic safety for westbound and eastbound traffic will be achieved 2 ½ years and 1 ½ years sooner, respectively, than for the Retrofit Alternative.

The Retrofit Alternative is less safe for the traveling public and for Caltrans maintenance staff who will maintain the bridge during and after construction. The existing east span structure, which carries 274,000 vehicles per day, is 4 kilometers (2 ½ miles) of highly constrained environment, as high as 61 meters (200 feet) above San Francisco Bay, with five lanes of traffic in each direction and no shoulders for emergency parking. Construction for the Retrofit Alternative on the existing bridge would expose public and workers to potential hazards such as:

- Exposure of public and construction workers to installing and removing lane closures
- Construction adjacent to and above traffic lanes
- Construction equipment, maintenance equipment and traffic immediately adjacent to each other

For a replacement alternative, the vast majority of the construction will be away from the existing east span. This separation eliminates conflicts between the construction crews, maintenance crews, and the traveling public.

Traffic adjacent to construction

9.2 Traffic and Public Convenience

The Retrofit Alternative has a vastly greater adverse impact on public convenience than a replacement alternative both during and after construction. Construction on the steel truss elements above and adjacent to traffic has the greatest impact on the traveling public and is expected to last for the duration of the retrofit construction schedule, approximately six years. Increased traffic control measures, daily closures of multiple lanes, construction equipment and materials in the adjacent traffic lane would all have an impact on the users of the bridge. With most of the construction away from the existing bridge, a replacement alternative will directly affect the traveling public only during the transition of traffic from the existing bridge to the new bridge.

After construction of the Replacement Alternative, two new shoulders in each direction will provide refuge areas accommodating disabled vehicles and routine bridge maintenance activities. The Retrofit Alternative cannot provide roadway shoulder areas.

9.3 Cost-Effectiveness

Based on a life-cycle analysis, the Retrofit Alternative is less cost-effective than a replacement structure. Two economic analyses evaluating the costs indicate that, in a life-cycle analysis and including repair after a large earthquake, the replacement alternative (skyway) costs less than a retrofit alternative.

It is important to note that all analyses regarding cost-effectiveness presumed a "base case" replacement structure that would consist of a skyway structure or a skyway/cable-stay structure.

After a decision was made to consider replacement of the bridge, legislation was adopted (Senate Bill 60 of 1997) to provide funding for the project. This legislation provided the Bay Area with the decision making authority to include additional costly amenities in the bridge project (bicycle/pedestrian path, signature span, Transbay Terminal improvements). The Bay Area has included such amenities in the replacement bridge currently under design. The decision to add amenities is independent of the decision to replace or retrofit. Cost-effectiveness, therefore, remains a function of the base case replacement structure.

9.4 Regional Preference

Through MTC, the region has identified a locally preferred alternative for a replacement bridge. This alternative is a single tower self-anchored suspension mainspan / skyway viaduct on a northern alignment. The selection of the bridge type, location, and the decision to replace rather than retrofit has been endorsed by an overwhelming majority of technical experts from academia, the professional engineering community, and public agencies.

Photo-simulation of Retrofit Alternative

Photo-simulation of Replacement Alternative

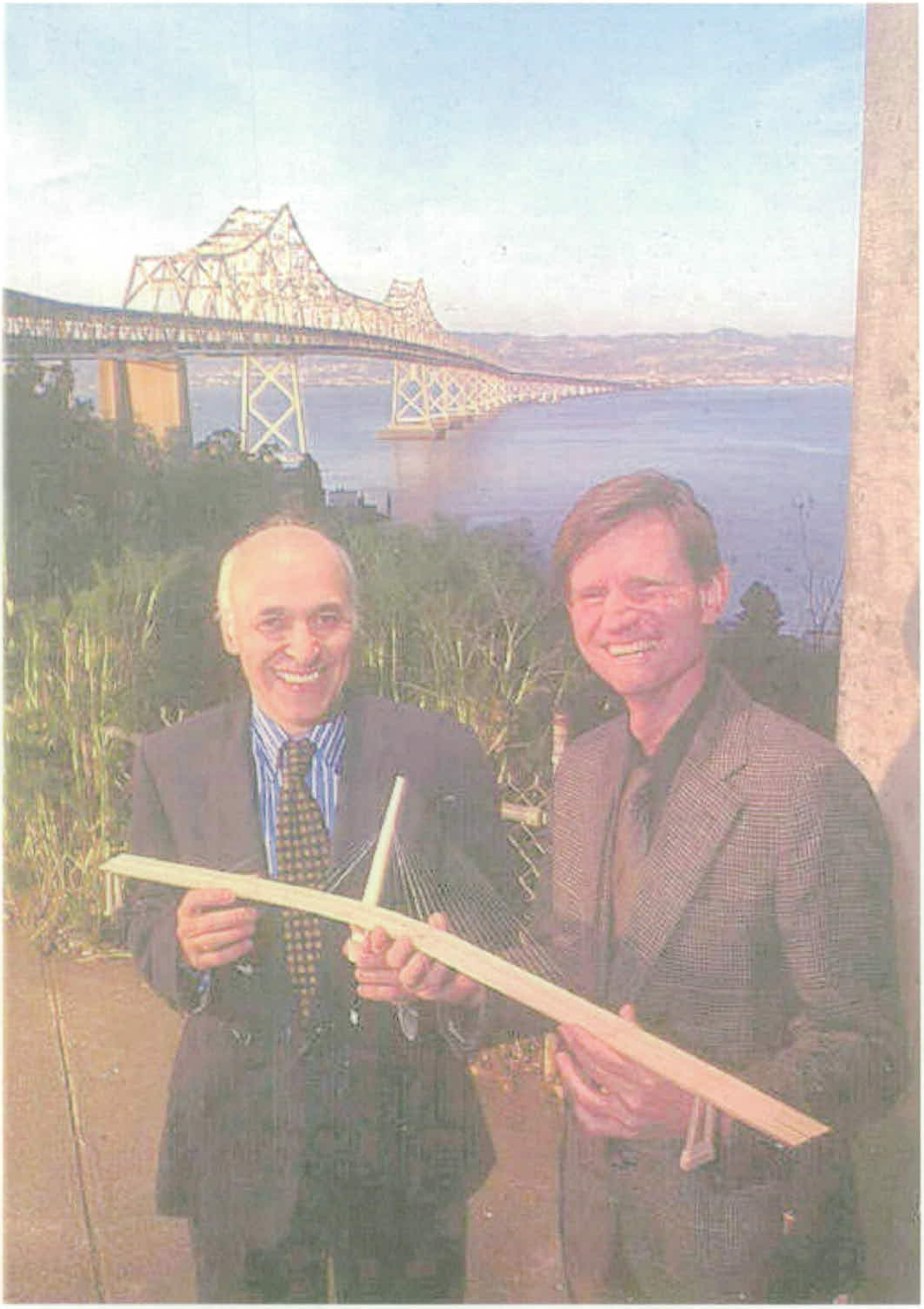
APPENDIX A

**Correspondence to and from
the City and County of San Francisco**

APPENDIX B

Correspondence to and from
Professor Abolhassan Astaneh-Asl

UCB Article about Professor Astaneh



APPENDIX C

Correspondence from
the Caltrans Seismic Advisory Board
and
the SFOBB Seismic Safety Peer Review Panel

APPENDIX D

Correspondence from
Governor Gray Davis

APPENDIX E

Index of Reports and Technical Studies Regarding Retrofit Alternatives

APPENDIX F

Governor's Press Release
Regarding Decision to Replace the East Span of the San Francisco-Oakland Bay Bridge

APPENDIX G

Members of the
Metropolitan Transportation Commission
Bay Bridge Design Task Force

APPENDIX H

Members of the
Metropolitan Transportation Commission
Engineering and Design Advisory Panel

APPENDIX I

Excerpt from "Cable Supported Bridges"
by Professor Niels J. Gimsing

APPENDIX J

Selected Newspaper Articles

APPENDIX K

Bay Bridge Design Task Force / Engineering and Design Advisory Panel Meeting Schedule

APPENDIX L

References

REFERENCES

1. Seismic Retrofit Concepts for the Bay Bridge, Professor Abolhassan Astaneh-Asl, August 24, 1992

2. Competing Against Time, Governor's Board of Inquiry, May 31, 1990

3. The Continuing Challenge, The Northridge Earthquake of January 17, 1994, George W. Housner, January 17, 1994

4. Cost Estimate Investigation for a Replacement Structure for the East Span of the San Francisco-Oakland Bay Bridge, Caltrans, September 1996

5. San Francisco-Oakland Bay Bridge East Bay Crossing Replacement, Value Analysis Findings, Ventry Engineering, December 1996

6. Replacement Study for the East Spans of the San Francisco-Oakland Bay Bridge Seismic Safety Project, Caltrans, Dr. Brian Maroney, December 17, 1996

7. Retrofit vs. Replacement, An Economic Analysis for the East Span of the San Francisco-Oakland Bay Bridge, Caltrans, April 1997

8. Senate Bill 60, August 1997

9. Assembly Bill 699, September 1997

10. Assessment of the San Francisco-Oakland Bay Bridge Seismic Replacement Project's Impact on the EBMUD Sewer Outfall, U. S. Army Corps of Engineers, January 6, 2000

11. Cable Supported Bridges, Professor Niels J. Gimsing, June 1997

Chronology of Correspondence and News Articles Involving Abolhassan Astaneh-Asl

June 12, 1998	An article in The Express quotes Astaneh criticizing MTC's decision on the design of the new East Spans of the Bay Bridge: "They certainly didn't go out and look for the best design." The article describes Astaneh's own design which was rejected.
June 20, 1998	A. Astaneh letter to Mary King, Bay Bridge Design Task Force, Chairperson (expressed concerns about the seismic safety of the proposed new East Spans of the Bay Bridge based on review of the 30% Design Report).
June 23, 1998	Oakland Tribune article, "Bay Bridge plan heads for final OK," quotes Astaneh's letter, 6/20/98, stating that a quake on the Hayward Fault "can severely damage this bridge and possibly cause partial or catastrophic failure of the main span."
June 23, 1998	San Mateo County Times article, "Bridge design decision crosses political chasms," mentions that new questions of the proposed bridge's seismic safety were raised by Astaneh.
June 23, 1998	San Francisco Examiner article, "Bridge dispute erupts," quotes Astaneh's letter, 6/20/98, stating that "There is no rationale in spending $1.5 billion to build a bridge of this importance using a highly questionable system that will very likely be unstable during a major seismic event."
June 23, 1998	James E. Roberts, Director, Engineering Service Center, Caltrans letter to MTC (addressed concerns stated in A. Astaneh's letter 6/20/98).
July 8, 1998	Brian Maroney, Caltrans letter to A. Astaneh (response to A. Astaneh's letter 6/20/98; invited Astaneh to present findings/concerns to the project seismic safety Peer Review Panel).
July 24, 1998	A. Astaneh letter to J. Roberts, Caltrans (declined invitation to speak to Peer Review Panel).
November 1998	Metropolis magazine article, "On shaky ground", mentions that Astaneh and UC Berkeley architecture professor Gary Black submitted a design for the new East Spans of the Bay Bridge.
February 24, 1999	A. Astaneh letter to M. King and Members of the Bay Bridge Design Task Force (subject: "Grave Concerns on Seismic Safety of the New East Bay Bridge Design").

March 25, 1999	B. Maroney letter to A. Astaneh (reiterated invitation to present findings/concerns to the Peer Review Panel).
April 20, 1999	A. Astaneh letter to Jose Medina, Director, Caltrans (outlined concerns about the seismic safety of the proposed new East Spans of the Bay Bridge).
May 20, 1999	Harry Y. Yahata, District Director, Caltrans letter to Professor Astaneh-Asl (detailed response to Astaneh's letter 4/20/99)

BAY BRIDGE DESIGN TASK FORCE
LIST OF MEETINGS[1]

Bay Bridge Design Task Force
Wednesday, October 13, 1999

Bay Bridge Design Task Force
Wednesday, September 8, 1999
1 p.m.

Bay Bridge Design Task Force
Wednesday, July 14, 1999
1 p.m.

Bay Bridge Design Task Force
Engineering and Design Advisory Panel
Tuesday, July 6, 1999
1 p.m.

Bay Bridge Design Task Force
Wednesday, April 14, 1999

Bay Bridge Design Task Force/
Engineering and Design Advisory Panel
Special Joint Informational Briefing
Wednesday, February 24, 1999
1 p.m.

Bay Bridge Design Task Force
Engineering and Design Advisory Panel
Wednesday, January 13, 1999

Bay Bridge Design Task Force
Wednesday, October 14, 1998
1 p.m.

Bay Bridge Design Task Force
Engineering and Design Advisory Panel
Monday, May 18, 1998
9 a.m. – 3 p.m.

Bay Bridge Design Task Force
Monday, June 22, 1998
1 p.m.

Bay Bridge Design Task Force
Wednesday, June 10 1998

Bay Bridge Design Task Force
Wednesday, April 8, 1998
1 p.m.

Bay Bridge Design Task Force
Engineering and Design Advisory Panel
Monday, March 2, 1998
9 a.m.

Bay Bridge Design Task Force
Wednesday, February 11, 1998
1 p.m.

Bay Bridge Design Task Force
Wednesday, January 13, 1998
1 p.m.

[1] All meetings held at:
Joseph P. Bort MetroCenter Auditorium
101 Eighth Street
Oakland, California 94607

ROSTER
Metropolitan Transportation Commission
Bay Bridge Design Task Force

James P. Spering, Chair
Solano County and Cities

James T. Beall Jr., Vice Chair
Santa Clara County

Keith Axtell
U.S. Department of Housing
and Urban Development

Jane Baker
Cities of San Mateo County

Sharon J. Brown
Cities of Contra Costa County

Mark DeSaulnier
Contra Costa County

Dorene M. Giacopini
U.S. Department of Transportation

Mary Griffin
San Mateo County

Elihu Harris
Cities of Alameda County

Tom Hsieh
City and County of San Francisco

Mary V. King
Alameda County

Jean McCown
Cities of Santa Clara County

Charlotte B. Powers
Association of Bay Area Governments

Jon Rubin
San Francisco Mayor's Appointee

Angelo J. Siracusa
San Francisco Bay Conservation
and Development Commission

Doug Wilson
Marin County and Cities

Kathryn Winter
Napa County and Cities

Sharon Wright
Sonoma County and Cities

Harry Yahata
State Business, Transportation and
Housing Agency

Lawrence D. Dahms
Executive Director

William F. Hein
Deputy Executive Director

Box 2, Folder 10

Item 1

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