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**US Army Corps
of Engineers®**

INTERIM FINAL REPORT

U.S. ARMY CORPS OF ENGINEERS

**EVALUATION & ASSESSMENT
OF PROPOSED ALTERNATIVES TO
RETROFIT/REPLACE THE EAST SPAN OF THE
SAN FRANCISCO-OAKLAND BAY BRIDGE**

September 22, 2000

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PROJECT OVERVIEW

Background

In response to the 1989 Loma Prieta earthquake, the State of California Department of Transportation (Caltrans) began a program to seismically retrofit all bridges in the state, including the damaged East Span of the San Francisco-Oakland Bay Bridge (SFOBB). As the plan to retrofit the East Span progressed, it became apparent to Caltrans that it would be more cost effective to replace the structure rather than to retrofit it. Caltrans considered several designs for a replacement span and in 1997 selected a "skyway" design as the best alternative. Based on the costs associated with the skyway design, Caltrans formally decided to replace rather than retrofit the east span. Subsequently, the Metropolitan Transportation Commission (MTC), representing nine Bay Area counties and acting under authority granted by the California legislature, decided to pay the cost of adding "amenities" to the replacement span. These amenities included a self-anchored suspension bridge design, which the MTC decided was more distinctive than the skyway design, and a bicycle/pedestrian path.

The City and County of San Francisco (the City) and Caltrans have asked the U.S. Army Corps of Engineers (COE), as a body of independent experts, to evaluate key technical decisions made by Caltrans. Specifically, the purpose of the COE's assessment is to examine two broad areas of concern as raised by the City and its outside consultants. First, the City believes that, from the standpoint of cost and public safety, it is preferable to retrofit the East Span than to replace it with the currently proposed design. Second, the City believes that the self-anchored suspension design that Caltrans is currently proposing for the replacement span is not seismically safe. To expedite the COE's study of these two concerns, the Federal Highway Administration (FHWA), in cooperation with the U.S. Navy, facilitated the COE's communication with appropriate Federal, State, local agencies and their consultants. The U.S. Coast Guard participated as well.

Time Line

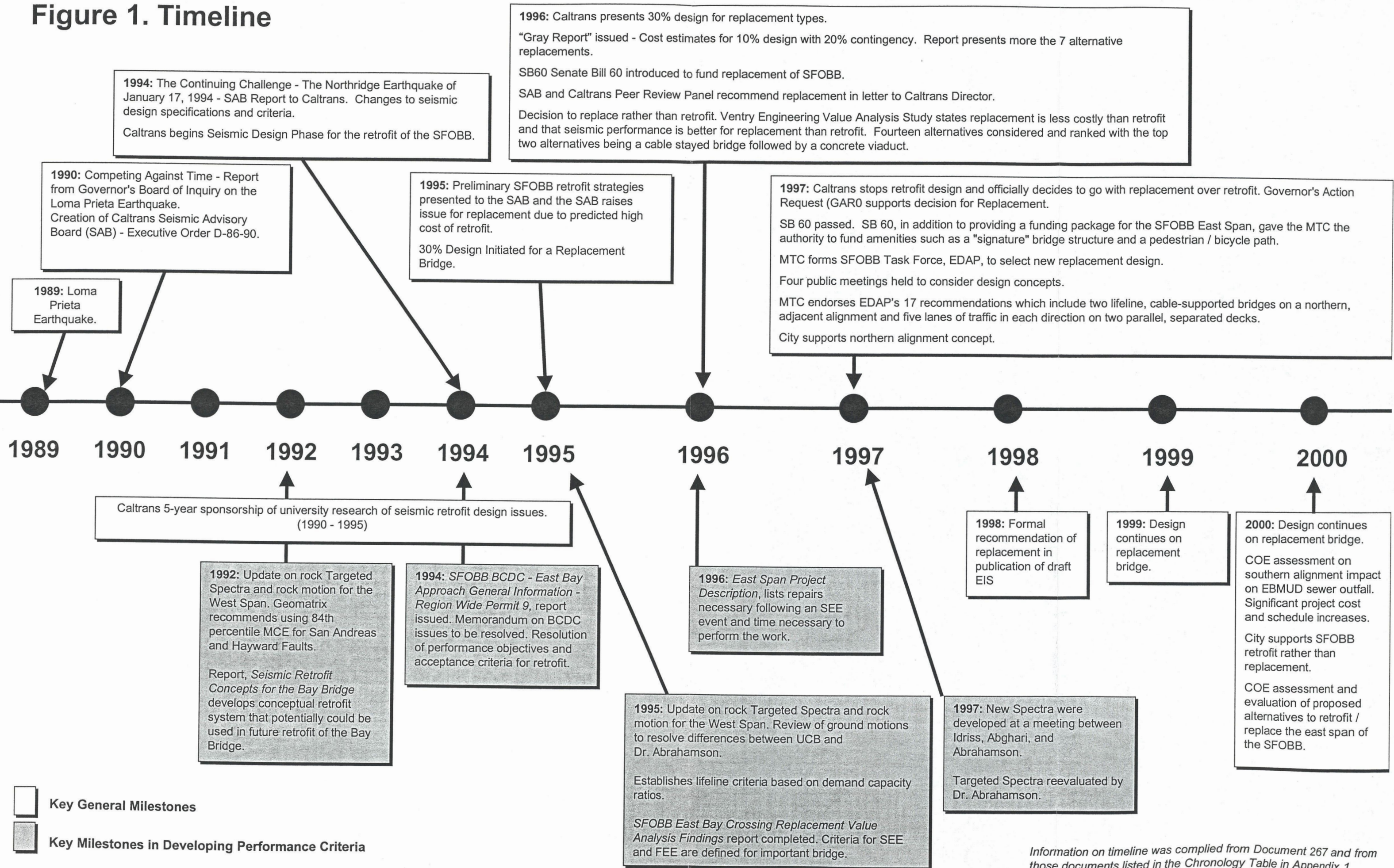
As background information and to facilitate an understanding of the decisions made, a summary time line is presented in Figure 1 on the following page. These events are further described in the Chronological Table provided in Appendix 1.

The City and County of San Francisco and Caltrans have asked the U.S. Army Corps of Engineers, as a body of independent experts, to evaluate key technical decisions made by Caltrans regarding the San Francisco-Oakland Bay Bridge.

The City believes that, from the standpoint of cost and public safety, it is preferable to retrofit the East Span than to replace it with the currently proposed design.

The City believes that the self-anchored suspension design that Caltrans is currently proposing for the replacement span is not seismically safe.

Figure 1. Timeline



Key General Milestones
 Key Milestones in Developing Performance Criteria

Information on timeline was compiled from Document 267 and from those documents listed in the Chronology Table in Appendix 1.

SCOPE OF WORK

Per the scope of work (Appendix 2), the COE Team conducted its evaluation during the two-phase study.

Phase 1, completed on July 25, 2000, included acquiring and cataloging (see Appendix 3 for the updated and current Data Catalog) all reports, data and analyses provided to the COE Team that address the City's two broad areas of concern. The COE team assessed the completeness and quality of that information and whether sufficient data was available to answer the four major questions in the scope of work. Also as part of the data assessment in Phase 1, the COE Team visited the East Span of the San Francisco-Oakland Bay Bridge. The visit included the Oakland Mole, Yerba Buena Island, the cantilever section, the failure span at E9, and the pile cap at E3. In addition, the COE Team viewed the bridge by boat and reviewed half scale test specimens for lattice members from a completed test for the Golden Gate Bridge.

The results of Phase 1 are contained in the U.S. Army Corps of Engineers Interim Letter Report, Evaluation & Assessment of Proposed Alternatives to Retrofit/Replace the East Span of the San Francisco-Oakland Bay Bridge, dated July 25, 2000.

Phase 2 answers the four major questions contained in the scope of work and presents the COE Team's findings in two letter reports: 1) *Interim Final Report USACE Evaluation & Assessment of Proposed Alternatives to Retrofit/Replace the East Span of the San Francisco-Oakland Bay Bridge* and 2) *Final Report USACE Evaluation & Assessment of Proposed Alternatives to Retrofit/Replace the East Span of the San Francisco-Oakland Bay Bridge*.

This report is the Interim Final Letter Report and it addresses Questions 1 and 2 of the scope of work.

Phase Deliverables

Phase 1
*Interim Letter Report –
Data Gap Analysis
(July 25, 2000)*

Phase 2
Interim Final Report
(September 22, 2000)*

*Final Report
(October 20, 2000)*

**This document is the first of two deliverables under Phase 2. It addresses Questions 1 and 2 of the scope of work.*

DATA ASSESSMENT

The Data Catalog provided in Appendix 3 is current with over 387 documents, some of which contain multiple volumes, and represent over 75,000 pages of material. Most of the documents are loose-leaf three ring binders and cover such areas as:

- Historical documents of the as-built structure including plans, news articles, and design and construction articles by the designers.
- Test reports covering the performance of steel elements of the existing bridge towers and superstructure.
- As-built analysis and retrofit design calculations.
- Cost estimates for the retrofit contracts.
- Value engineering studies.
- Comparisons of the retrofit alternative to the replacement alternative ranging from Caltrans internal memos to the Governors Action Request (GAR) report.
- Plans and specifications covering the design of the new replacement alternative.
- Project Engineer / Designer notes.
- Seismic Safety Peer Review Panel (SSPRP) meeting minutes.
- University Research.

The data provided by Caltrans is voluminous. To locate information and clarify document content, several meetings have been held with Caltrans. These meetings have aided the team's effort at locating and understanding the data and the data gaps. The data provided by the City consists mainly of letters and reports authored by Professor Astaneh. The City has submitted neither design nor cost information. Follow up meetings have also been held with Professor Astaneh, who represents the City, to allow further clarification of the City's concerns. The COE Team has spent over 600 man-hours in these meetings with Caltrans and City representatives.

The information in the Data Catalog includes all reports, data, and analyses that have been provided by the City and Caltrans over the course of this study. This information represents the basis for the answers given by the COE Team in response to the questions in the scope of work.

Data gaps were initially identified in the report titled *Phase 1 Interim Letter Report, Evaluation & Assessment of Proposed Alternatives to Retrofit/Replace the East Span of the San Francisco-Oakland Bay Bridge*, dated July 25, 2000. These Data Gaps have been modified and/or lined out to account for additional data and information that has been submitted since the completion of Phase 1. The revised Data Gap listing is as follows:

Phase 1 of the project consists of a Data Gap Assessment. Phase 2 consists of answering the questions provided in the scope of work. Through the course of this project, USACE team members have organized, reviewed, and cataloged over 300 documents.

Significant Data Gaps

1. Design criteria summary for the proposed retrofit alternative. Quantify these criteria in terms of allowable stress and strain levels, displacement limits, and other pertinent parameters. Significant to Questions 1, 2, and 3.

Concise definition of the acceptable level of structural response quantities should be known for seismic performance evaluation of the as-built and retrofitted bridge. Design criteria summary that outlines the pertinent parameters including acceptable stress and strain levels, displacement limits, and other factors that are essential for assessment of the bridge's seismic performance, was not provided in a single document.

- ~~2. Documents outlining the decision process for data supporting costs in the Governor's Action Request (GAR). Significant to Questions 1 and 2.~~

~~Caltrans' recommendation for bridge replacement is summarized in the GAR. The GAR provides cost figures from various sources (i.e., Value Analysis Study, Replacement Study For The East Span of SFOBB Seismic Safety Project, and Retrofit vs. New Bridge Economic Analysis study). There is no outline of the criteria used by Caltrans to support their selection of costs that were used in the GAR.~~

~~This information is needed to substantiate Caltrans' cost effectiveness position that a replacement bridge is more cost effective than retrofitting the existing bridge.~~

3. Basic Geotechnical and Geology Data. Significant to Questions 1, 2, and 3.

The information provided for the Oakland Mole contained in Document 319, and in the other documents referred to in Document 319 is comprehensive and appears to be sufficiently complete. However, a similarly comprehensive presentation of geotechnical and geology data for the rest of the bridge alignment is important for foundation analysis of both the retrofit and the new bridge alternatives.

Several key geotechnical design issues have been identified in the various documents. The information received to date does not include a comprehensive presentation of the resolution to the following issues:

Soil/pile interaction loads, particularly for battered piles.

Data gaps initially identified in the *Phase 1 Interim Letter Report*, dated July 25, 2000, that have since been filled due to the receipt of additional information are identified in this section using text ~~strikethrough~~ (example: ~~strikethrough~~).

Soil structure interaction model incorporated into the global model of the various sections of the bridge.

Geotechnical information (boring logs, CPT, field tests, laboratory tests, etc.).

- ~~4. Seismology and Selection of Ground Motions. Significant to Questions 1, 2, and 3.~~

~~For the retrofit alternative, a comprehensive report on seismology and ground motions has not been made available to us. Only limited ground motion information in various design reports has been provided. However, this information does not provide an overall view of the methodology used to develop multi-support ground motions for the soil structure interaction and the structural analysis of the bridge.~~

5. Analysis and design calculation documents for portions of the bridge associated with Contracts 4 and 5 (Foundations E6 – E16) on proposed retrofit. Significant to Questions 1, 2, and 3.

Without this information it may not be possible to determine if sound analysis and appropriate criteria were used for the subject portions of the bridge.

- ~~6. Work in progress / most current cost data on currently proposed replacement 65 percent design review. Significant to Question 3.~~

~~Currently Caltrans has submitted for review a 65 percent design along with a 35 percent cost estimate. To ensure accurate, realistic, and complete cost evaluation a 65 percent cost estimate is required. Significant to Question 3.~~

Moderate Data Gaps

7. Stage of design to which work each contract had progressed when the decision was made to go to replacement. Significant to Question 1.

With many documents at various stages of design it is difficult to identify which documents are pertinent to the most current design. Without identifying the chronology of events, the decision making process is not clear. The level of design stage of each contract (i.e., conceptual, preliminary, final designs) should be known to accurately evaluate the retrofit alternative. This information is only provided by Caltrans for contract 8, in Document 326.

8. Meeting minutes, notes and/or letters of meetings for the following groups:

Portions of Data Gap 7 were closed with additional information provided. However there was insufficient detail to close the gap entirely.

~~Caltrans Seismic Advisory Board (SAB) from 1990 to present.~~
Caltrans Seismic Safety Peer Review Panel (SSPRP) from 1997 to 1998
and March 2000 to present.

Caltrans retrofit strategy meetings from 1990 to present, including design
engineer's preparation for the meetings.
Significant to Questions 1, 2, 3, and 4.

This information is necessary in providing an outline of the review
process and identifying changes in project direction recommended by
these advisory groups. Significant to Questions 1, 2, 3, and 4.

9. Analysis strategy using various computer models, including the
relationship between the various global and local models for the retrofit
alternative. Significant to Question 1.

This information is necessary to show the relationship of local and global
models. Although specific sections of the bridge can be analyzed
separately, ultimately the bridge must function as a whole. With the
information provided it is difficult to determine whether or not the results
of the local and global models are compatible. In addition, the
information does not show consistency between bridge components.

Minor Data Gaps

10. Material test reports and/or summaries for the condition of the existing
foundations, including concrete, steel, and timber. Significant to
Questions 1, 2, and 3.

Lack of this information limits the ability to assess studies of existing
foundation information and proposed retrofit designs. Evaluation of soil
structure interaction depends on an understanding of existing material
properties.

Portions of Data
Gap 8 were closed
with additional
information
provided. However
there was
insufficient detail
to close the gap
entirely.

DEFINITIONS

Proposed Retrofit Alternative: The “proposed retrofit alternative” refers to the retrofit strategy in the “San Francisco-Oakland Bay Bridge East Span Seismic Safety Project Draft Environmental Impact Statement,” September 24, 1998. This alternative was to be designed to withstand a maximum credible earthquake (MCE) on the San Andreas or Hayward faults, but would not provide a lifeline connection. The retrofit strategy is to strengthen the foundations (piles and pile cap connections), stiffen the towers, and isolate and strengthen the superstructure [Document 276]. This strategy was modified for the cantilever spans.

Original Replacement Alternative / Skyway: The “originally proposed replacement alternative” refers to the skyway design that was initially proposed by Caltrans and does not include the amenities of a self-anchored suspension structure and the bicycle/pedestrian path that were added by the Metropolitan Transportation Commission. The skyway design is a variable depth, haunched, concrete superstructure with spans between single column piers, and includes two parallel structures with each having five traffic lanes and inside and outside shoulders. Design is to be to lifeline conditions [Document 276].

Proposed Replacement Alternative / Signature Span: The “currently proposed replacement alternative” refers to a single-tower, self-anchored-suspension, asymmetric, main span at the shipping channel near Yerba Buena Island with a skyway connecting to the Oakland shore. The bridge is to be on the N-6 alignment in the *San Francisco-Oakland Bay Bridge East Span Seismic Safety Project Draft Environmental Impact Statement*, September 24, 1998. The design includes two side-by-side roadway decks, each with five traffic lanes plus 3-meter shoulders on both sides and a 4.7-meter wide bicycle/pedestrian path on the south side of the eastbound deck, raised 1 foot above the roadway. Design is to be to lifeline conditions [Document 276].

Lifeline Condition: As stated in the project’s scope of work, Appendix 2, “lifeline criteria” are above-average standards for bridge (or other infrastructure) construction. A bridge constructed to meet lifeline criteria could accommodate emergency response vehicles and heavy equipment immediately following a maximum credible earthquake. By contrast, most bridges are constructed to meet a “no-collapse” criteria; these are lower standards that ensure against catastrophic failure or loss of life. The “lifeline condition” of a bridge is a measure of the degree to which the structure meets lifeline criteria.”

Lifeline Performance Criteria: Lifeline performance criteria describe the desired function of a structure after an earthquake. For the SFOBB, lifeline performance criteria provides for post-earthquake emergency relief access linking major population centers, emergency relief routes emergency supply and staging areas, and intermodal links to major distribution centers. This criterion provides full serviceability immediately after the maximum earthquake for which the structure is designed. It assumes emergency vehicles can pass over the bridge after only minor repair and within hours of the event and that limited public passage would be available within days [Document 267].

Lifeline Design Criteria: Lifeline design criteria are the specific engineering standards that must be met and designed into the structure to meet lifeline performance criteria. A review of Caltrans work shows that Caltrans hoped to achieve lifeline condition by limiting stresses to or below the elastic limit and demand-capacity ratios to unity.

KEY QUESTIONS

In preparing a response to the scope of work's key questions, the COE Team's approach is to state the question and present a summary conclusion. Detailed analysis for each question are referenced and contained in the appendixes.

In responding to the key questions, the COE Team has based its conclusions on the data submitted and documented in the Data Catalog. During the course of the study, discussions were held with Caltrans and City representatives to help the team gain a better understanding of the project and to assist in locating relevant information within the documents provided. Only written, verified documents have been used in development of the conclusions. The COE Team performed no new analyses. Where data can be corroborated and supported by a document in the Data Catalog the document's number is referenced in brackets.

This study combines a short time schedule with the daunting task of reviewing a massive amount of documentation on both the retrofit and replacement projects (studies, university research, plans, specifications, etc.). The documents span nearly a decade since the Loma Prieta earthquake. It has been a challenge for the COE Team to separate and review all the pertinent project data. The goal has been to piece together the relevant data needed to give unqualified answers to the key questions. Both Caltrans and the City have gone to great lengths to provide the needed data to the COE Team. However, for the data provided, the level of completeness is only sufficient for the COE Team to give qualified answers.

The questions are in and of themselves complex and difficult to answer in a straightforward manner. The COE Team provided the most complete answer possible, using the information provided. The answers are based on a holistic (global) perspective, encompassing the total length of the bridge.

The following section makes reference to stages of project planning and design using acronyms; the following provides a key to these design stages as defined by Caltrans:

| | |
|--|--------------------------|
| Advanced Planning (AP) | 0 – 35% Complete |
| General Plans (GP) | 35 – 75% Complete |
| Plans, Specifications, & Estimates (PS&E) | 75 – 95% Complete |

It should be noted:

Comments contained herein only reflect consideration of technical issues.

Responses are based solely on information made available to the COE Team, absent of independent analyses.

Answers to Questions

Question 1: Was Caltrans' selection of the proposed retrofit alternative reasonable -- i.e., was it based on appropriate criteria and sound analysis, including consideration of realistic, accurate and complete cost figures?

Conclusion: Caltrans had separated the retrofit design into eleven design projects. These designs were in various stages of completion from AP to PS&E. It is the COE Team's conclusion that Caltrans initially used a structured approach to evaluate alternate retrofit strategies, but as explained below, the selected retrofit strategy does not appear to be reasonable due to concerns regarding the isolation strategy, incompleteness of design, and definition of performance criteria.

Isolation Strategy

Caltrans' proposed retrofit alternative is seismic isolation of truss systems with the exception of the cantilever section. The suspended portion of the cantilever section is cut off and isolated using two new pier supports, while the rest of the cantilever section remains fixed to its piers but is strengthened by edge trusses. Ordinarily, an isolation system is considered for relatively rigid structures to elongate their period of vibration in order to reduce seismic force demands and to provide additional damping through friction or other means. Most spans of SFOBB are long-period structures with fundamental periods of vibration in the range of several seconds.

The seismic force demands for such long-period spans in their existing conditions are approximately at the same level of the proposed isolated spans. On this basis, the use of an isolation system appears unreasonable. Documents submitted for review do not demonstrate why a flexible structure with low seismic force demands should be stiffened by concrete encasement and then softened back to its original condition using isolation bearings. Computer analyses of the isolated bridge are based on unrealistic modeling and input assumptions and they provide limited results. The validity and effectiveness of the isolation retrofit strategy has not been demonstrated.

The following statement, from the Seismic Advisory Board's meeting minutes (January 3 and 4, 1991), supports the concerns stated above: "Because of the sensitivity of base-isolated structures to the longer periods of free-field ground motion, base isolation should be avoided at very soft sites such as those on San Francisco Bay fill" [Document 372]. Two letters to Director James van Loben Sels (December 4 and 5, 1995) also document the concern regarding unprecedented use of an isolation system.

It is the COE Team's conclusion that Caltrans initially used a structured approach to evaluate alternate retrofit strategies, but as explained, the selected retrofit strategy does not appear to be reasonable due to concerns regarding the isolation strategy, completeness of design, and definition of performance criteria.

The seismic force demands for such long-period spans in their existing conditions are approximately at the same level of the proposed isolated spans. On this basis, the use of an isolation system appears unreasonable.

Incomplete Design

The proposed retrofit strategy design of the entire bridge is incomplete. None of the 11 design projects that comprise the retrofit have a finalized, verified retrofit solution, particularly the cantilever truss spans and their foundations. Retrofit designs for the cantilever portion of the bridge including the superstructure and foundations, have not been completed and only preliminary concepts have been derived. No analyses have been provided to demonstrate that they are reasonable and workable.

Criteria

A general statement for seismic design criteria has not been defined. Criteria is inconsistently applied and continually modified. Criteria appear to change as the efforts on the cantilever portion of the bridge progressed.

As can be expected for a bridge of this complexity, Caltrans appeared to struggle with design and cost issues to meet lifeline criteria. Further, they did not have any reasonable degree of confidence that a retrofit alternative could be designed to meet lifeline performance criteria. At the time that the decision was made to proceed with the replacement alternative, Caltrans' documents indicate that the retrofit design did not meet lifeline criteria and was being designed to meet the lesser criterion of no-collapse.

COE Team's detailed review of the data supporting this question can be found in Appendix 4, Retrofit Support Documents.

Question 1a: Did Caltrans adequately consider/evaluate other retrofit alternatives, including a West Span-type retrofit and other steel retrofits, and did this evaluation include consideration of realistic, accurate and complete cost figures?

For informational Purposes: The West Span retrofit scheme is to directly strengthen the steel tower members with additional steel components (as verbally provided by FHWA). The West Span refers to the suspension bridge west of Yerba Buena Island.

Conclusion: The COE Team has found that Caltrans considered numerous other retrofit alternatives as reflected in Table 1. The alternatives considered apply to all aspects of the retrofit including foundations, towers and superstructure. The alternatives were not usually evaluated to a level of being able to produce realistic, accurate and complete cost figures. However, to make prudent decisions for retrofit, this is not always necessary. Even though the COE Team questions the reasonableness of Caltrans' selected

The proposed retrofit strategy design of the entire bridge is incomplete. No analyses have been provided to demonstrate that they are reasonable and workable.

At the time that the decision was made to proceed with the replacement alternative, Caltrans' documents indicate that the retrofit design did not meet lifeline criteria and was being designed to meet the lesser criterion of no-collapse.

Even though the COE Team questions the reasonableness of Caltrans selected retrofit alternative, it does not disagree with the decision process that led to that selection.

retrofit alternative, it does not disagree with the decision process that led to that selection.

The pursuit of a valid retrofit scheme should not be compared to the preliminary design stages of a new bridge structure as this question suggests. Choosing several global schemes for the retrofit and taking them to a 30% design level in order to find the “best” solution is not the normal process for retrofit. This is more practical for a new structure because the type is not restricted by existing conditions. Retrofit alternatives, however, are limited by the existing bridge.

An accepted process in developing a valid retrofit scheme is to consider (brainstorm) possible options and, based on discussions of technical feasibility, aesthetics, and preliminary costs, bring forward the most promising overall scheme or strategy. Caltrans conducted an initial analysis to identify the seismically vulnerable items for the existing “as-built” bridge. Given these items, various retrofit schemes for all the components of the bridge were brainstormed and discussed. Schemes considered are shown in Table 1.

Two general retrofit strategies typically evaluated are: 1) to strengthen elements; or 2) to divert (reduce) forces away from elements that lack capacity for the design load. Forces can be diverted by adding members or by using seismic isolation. These two retrofit strategies are generally considered on two levels: 1) global (entire bridge, or at least by superstructure, frame-by-frame, type), or 2) local (individual components or elements). The selected retrofit includes both of these strategies.

On the local element-by-element level, valid “alternatives” should have been thoroughly evaluated. The COE review team could not verify in the documents provided that an adequate evaluation took place at this level to support several key decisions regarding the strategy path taken. The critical

| Table 1 Retrofits Considered | |
|---|--|
| Towers | <ul style="list-style-type: none"> • Steel Strengthening • Hollow Concrete Encasement • Solid Concrete Encasement • Solid X-Bracing Encasement • Boxed Section Steel Retrofit |
| Superstructure | <p>Cantilever Truss Spans</p> <ul style="list-style-type: none"> • Cable System • Edge Arch System • Superstructure Frame • Substructure Frame • Additional Towers with Supplemental Tube • Additional Towers with Base Isolation and Articulated Superstructure <p>Cantilever and 504’ and 288’ Truss Spans</p> <ul style="list-style-type: none"> • External Edge Truss System • Retrofitted Towers and/or Additional Towers |
| Foundations | <ul style="list-style-type: none"> • Ground Improvement (Grouting) • Small Diameter Piles • Large Diameter Vertical and Battered Steel Piles with New Pile Cap/Load Transfer Structure Above the Water Surface • Post Tension Rock Anchors |

The critical step of abandoning a more typical “strengthening” scheme for the selected scheme using seismic isolation bearings was not adequately documented.

step of abandoning a more typical “strengthening” scheme for the selected retrofit scheme (using seismic isolation bearings) was not adequately documented.

Considering the West Span type retrofit, Caltrans had evaluated this retrofit in a comparison with the selected concrete-encasement type. The evaluation was done by the Contract 2 design team for the towers on Yerba Buena Island. The foundations for these towers are supported by rock. Therefore, the effect of the additional concrete dead load is not as detrimental to the tower foundation as it is on the foundations for the caisson and pile supported piers. This comparison, which led to the conclusion that the concrete encasement was the better solution (steel versus concrete), considered only the cost of the tower retrofit and not the impact to the pile and caisson foundations.

As stated in the conclusion for Question 1, a final valid scheme for the selected retrofit alternative had not been achieved. However, the decision process that Caltrans had followed for this project was adequate. After consideration of various alternatives, what Caltrans considered to be the most promising retrofit scheme, was brought forward into the analysis and design phase. This approach makes use of the vast experience and knowledge available at Caltrans, by quickly considering and eliminating less plausible solutions, and saving the expense of investigating non-viable alternatives.

COE Team’s detailed review of the data supporting this question can be found in Appendix 4, Retrofit Support Documents.

Question 1b: Did Caltrans adequately consider/evaluate the ability of other retrofit alternatives, including a West span-type retrofit and other steel retrofit, to meet lifeline criteria? Which (if any) retrofit alternatives meet lifeline criteria?

Conclusion: The documents provided did not demonstrate that any retrofit alternative met lifeline criteria. Consequently, Caltrans did not evaluate in detail the ability of other retrofit alternatives to meet lifeline criteria.

COE Team’s detailed review of the data supporting this question can be found in Appendix 4, Retrofit Support Documents.

Caltrans did not evaluate in detail the ability of other retrofit alternatives to meet lifeline criteria. The documents provided did not demonstrate that any retrofit alternative met lifeline criteria.

Question 1c: Did Caltrans adequately consider/evaluate the costs of retrofitting the span to meet lifeline criteria?

Conclusion: The data reviewed clearly shows that Caltrans did not have a reliable retrofit solution. Therefore, a retrofit solution that could be classified as meeting lifeline performance criteria did not exist. The cost data reviewed by the COE Team were found to be adequate and supportable to the level of design completed. In this case, that level, as stated by Caltrans, was to no-collapse and not lifeline conditions [Document 267]. Analysis to substantiate either performance level is not evident. The COE Team found that Caltrans used sound judgement and estimating procedures, including the use of appropriate cost items, which were consistent and accurate to the level of design under consideration. A cost was not specifically developed for an alternative that would meet lifeline criteria.

COE Team's detailed review of the data supporting this question can be found in Appendix 4, Retrofit Support Documents.

Question 2: Was Caltrans' cost-benefit analysis comparing the originally proposed replacement alternative vs. the proposed retrofit alternative reasonable -- i.e., was it based on appropriate criteria and sound analysis, including consideration of realistic, accurate and complete cost figures?

Conclusion: The COE Team found that the procedures used by Caltrans to form the cost-benefit analyses were reasonable, and Caltrans used sound judgment and estimating procedures, including the use of appropriate cost items. The items are consistent and accurate for the level of design under consideration.

Caltrans' cost figures for the retrofit strategy include the appropriate elements needed to produce a reasonable budgetary tool commensurate with the level of design. The cost presented represent a broad range of numbers and values that were based on engineering and cost assumptions. The lifecycle costs used in the economic analyses could not be substantiated by the data submitted and reviewed, but did represent a reasonable range of costs for this type of analysis.

Caltrans' cost figures for the originally proposed replacement alternative are based on appropriate criteria and sound analysis. Support documentation is provided in Appendix 5.

Cost items considered in the cost-benefit or lifecycle analysis include traffic delays, hazardous work areas, lane closures, work conducted in traffic, lead base paint abatement, worker and public safety, and maintenance as well as

Data reviewed clearly shows that Caltrans did not have a reliable retrofit solution. Therefore, a retrofit solution that could be classified as meeting lifeline performance criteria did not exist.

The COE Team found that Caltrans cost-benefit analysis procedures were reasonable and used sound judgment and estimating procedures, including the use of appropriate cost items, which were consistent and accurate to the level of design under consideration.

Key documents conclude that the replacement approach is much more desirable from a lifecycle cost standpoint.

The lifecycle costs suggest that the decision to select a replacement alternative may have been made even if the retrofit alternative construction costs were substantially less.

costs associated with working with steel and concrete construction over water.

Document 250 is the primary lifecycle/economic analysis report while Documents 23 and 249 also address the lifecycle costs of the retrofit alternative and the originally proposed replacement alternative. Document 250 is supported by Documents 23 and 249. These documents make the same conclusion, i.e. that the replacement approach is preferable based on lifecycle costs.

Even though backup data is limited, the economic or lifecycle analyses sufficiently addresses the significant issues and costs (limited data includes cost items and probabilistic methods to estimate seismic damage, etc.). The lifecycle analyses are reasonable. The lifecycle costs as presented by Caltrans indicate that the decision to select a replacement alternative would be justified given a retrofit with substantially less construction costs.

Question 3: How does the currently proposed replacement alternative, including as well any work in progress, compare to various retrofit alternatives in terms of a) cost and b) seismic reliability (including ability to meet lifeline criteria)?

Question 3 will be addressed in the Final Letter Report to be dated October 20, 2000.

Question 4: Is the currently proposed replacement alternative seismically safe? How will the currently proposed replacement alternative perform in a maximum credible earthquake? Specifically, does the currently proposed replacement alternative meet lifeline criteria? To what extent and how quickly could it accommodate passenger vehicles?

Question 4 will be addressed in the Final Letter Report to be dated October 20, 2000.

SUPPLEMENTAL QUESTIONS

During the course of this study many questions, some of which were not specifically contained in the agreed to scope of work, were asked of the COE Team. In an effort to help all parties reach agreement and make informed decisions, the COE Team, within the context of its mandated scope of work, is compiling and addressing these questions. The COE Team's response to the questions will be included as an appendix item in the Final Letter Report to be dated October 20, 2000.

Conclusion - Questions 1 and 2

The COE Team can summarize its review of the data concerning Questions 1 and 2 by stating the following:

- Documents provided did not demonstrate that any retrofit alternative met lifeline criteria.
- Caltrans' proposed retrofit strategy is not reasonable due to concerns regarding the isolation strategy, incompleteness of design, and definition of performance criteria.
- Based on safety considerations, it is the COE Team's opinion that, at this point in time, a replacement alternative is preferable to a retrofit alternative. A replacement alternative is the path that most quickly resolves the exposure of the public to the seismic vulnerabilities of the existing structure.

List Acronyms and Abbreviations

| | |
|-----------------|--|
| AASHTO | American Association of State Highway & Traffic Officials |
| AISC | American Institute of Steel Construction |
| AP | Advance Planning |
| ASA | Assistance Secretary of the Army, Civil Works |
| ATC | Applied Technology Council |
| Caltrans | State of California Department of Transportation |
| CISS | Cast-In-Steel-Shell |
| City (the City) | City and County of San Francisco |
| COE | US Army Corps of Engineers |
| CPT | Cone Penetration Test |
| D/C | Demand Capacity Ratio |
| EDAP | MTC Task Force Engineering and Design Advisory Panel – Established early 1997 |
| FEE | Functional Evaluation Earthquake |
| FHWA | Federal Highway Administration |
| GAR | Governor's Action Request |
| GP | General Plans |
| MCE | Maximum Credible Earthquake |
| MTC | Metropolitan Transportation Commission – Regional transportation planning agency for the Bay Area |
| PS&E | Plans, Specifications, and Estimates |
| SAB | Caltrans Seismic Advisory Board – Established Summer 1990 by Governor's Executive Order D-86-90 |
| SEE | Safety Evaluation Earthquake |
| SFOBB | San Francisco Oakland Bay Bridge |
| SSI | Soil-Structure Interaction |
| SSPRP | Seismic Safety Peer Review Panel – Established Spring 1997 |
| Task Force | MTC Bay Bridge Design Task Force – Established early 1997 |
| TBPRP | Caltrans Toll Bridge Peer Review Panel – Established 1994 to review & guide retrofit strategies for State owned toll bridges |
| THA | Time-History Analysis |
| UCB | University of California, Berkeley |

Proprietary Compute Software Referenced

| | | |
|-----------|--------|----------|
| SHAKE | WFRAME | XSECTION |
| GTSTRU DL | ADINA | COM624 |
| GROUP | | |

Appendix 1

Appendix 2

Appendix 3

Appendix 4

SFOBB CHRONOLOGICAL TABLE

Date: 13Sep2000

| DATE | R/S | Doc# | Major Decisions | Cost | Seismic | Geotech | Performance Criteria / Lifeline | Analyses and Design |
|-----------------|-----|-----------|---|------|---|---------|---------------------------------|--|
| 1989 | | | | | | | | |
| 17Oct89 | | 321 | Loma Prieta Earthquake | | | | | |
| 1990 | | | | | | | | |
| 31May90 | | 247 | Competing Against Time report from Governor's Board of Inquiry. | | | | | |
| 02Jun90 | | 248 & 321 | Order to create Caltrans Seismic Advisory Board (SAB) per Governor Deukmejian, by Exec. Order D-86-90. | | | | | |
| 00Sep90 | R | 248 | Caltrans appoints 8 members to SAB to review seismic design, retrofit, and hazard mitigation activities as these relate to policy and technical procedures. | | | | | |
| 1991 | | | | | | | | |
| 01Jan91 | R | 372 | Seismic advisory board says "base isolation should be avoided at very soft sites such as those on the San Francisco Bay fill. | | | | | |
| 1994 | | | | | | | | |
| Fall 94 | R | 263 | | | | | | Retrofit- Seismic Design Phase Begins. |
| 00Oct94 | R | 248 | Seismic Advisory Board report to the Caltrans Director. "The Continuing Challenge". | | Assessment of Bridge Performance during seismic events. | | | Changes to Seismic Design Specs and Criteria. |
| 1995 | | | | | | | | |
| Sum95 | R | 263 | SAB raises issue for replacement due to predicted high cost of retrofit. | | | | | Retrofit - Preliminary strategies presented to SAB |
| Sum95 | S | 263 | | | | | | 30% Design initiated for Replacement. |
| 5Jul to 14Aug95 | R | 84 | | | | | | Caltrans' decision made to isolate superstructure. (Evident by changes to global model analysis. |
| 01Dec95 | R | 372 | Seismic advisory board states its concern "on the use of a seismic isolation system called FPS, of unprecedented size and shape for the east crossing of the SFOBB" ... "Proof testing of this magnitude and force level has never been done before." | | | | | |

SFOBB CHRONOLOGICAL TABLE

Date: 13Sep2000

| DATE | R/S | Doc# | Major Decisions | Cost | Seismic | Geotech | Performance Criteria / Lifeline | Analyses and Design |
|---------|-----|------|--|--|---------|---------|---|--|
| 01Dec95 | R | 372 | Seismic advisory board states "Soil structure interaction (SSI)...is not being applied rigorously in the retrofit analysis of all toll bridges, due to the lack of time. The SAB and PRP are very concerned that SFSI analysis..." | | | | | |
| 1996 | | | | | | | | |
| 02Jan96 | R | R | | | | | | Van De Pol memo "conclusion of prismatic edge truss". |
| 12Jan96 | R | 326 | | | | | Meeting initiates no drop retrofit strategy & stops other strategies for cantilever section. | |
| Mid96 | S | 263 | Eng. & Design Advisory Panel (EDAP) to advise against skyway & a 2nd alternative - a two-piered, cable-stayed bridge. | | | | | Presentation of 30% design for Replacement Types. (per S. Hulsebus, 8/21/2000, this is Gray Report, Doc252.) |
| 01Sep96 | S | 252 | | Gray Report - Cost Estimates for 10% Design w/ 20% Contingency. | | | | Gray Report - Presents more than 7 Alternative Replacements. |
| 28Oct96 | R | 168 | Director Van Loben Sels - memo places top priority on completion of all toll bridge programs. | | | | | |
| 06Nov96 | R | 168 | Structural Design Chief Division - memo places top priority on SFOBB retrofit projects. | | | | | |
| 06Dec96 | S | 254 | SB60 Senate Bill 60 Introduced to fund replacement of SFOBB. Passed 8/11/97. | | | | | |
| 10Dec96 | S | 329 | Caltrans Seismic Advisory Board & Caltrans Peer review Panel recommend replacement. Letter received by Director Van Loben Sels on 12/09/96. | | | | | |
| 16Dec96 | S | 23 | Decision to replace rather than retrofit. Cable stayed is preferred in conjunction with concrete viaduct. | Value Analysis Findings by Ventry Eng. Replacement is less costly than retrofit. | | | Seismic performance is better for replacement than for retrofit (pg1.3). And, performance level is higher for replacement(pg4.3). | Report examines 14 alternatives of which two are rank-ed the highest. Cable stayed bridge is first with concrete viaduct the second. |

SFOBB CHRONOLOGICAL TABLE

Date: 13Sep2000

| DATE | R/S | Doc# | Major Decisions | Cost | Seismic | Geotech | Performance Criteria / Lifeline | Analyses and Design |
|--------------|-----|-----------|--|---|---------|---------|------------------------------------|--|
| 17Dec96 | S | 249 | | Cost Analysis and Decisions to replace instead of retrofit. | | | | |
| 1997 | | | | | | | | |
| 29Jan97 | R | 219 | Caltrans Management decides "to replace... rather than retrofit..." and "...to halt all work on the retrofit..." | | | | | |
| 07Feb97 | S | 329 | "GAR", Governor's Action Request. Decision to Replace instead Retrofit. | | | | | |
| After 2/7/97 | S | 276 | SFOBB Task Force organized by Metropolitan Transportation Commission (MTC). Task Force is to produce a consensus design recommendation. All members are MTC Commissioners. | | | | | |
| After 2/7/97 | S | 276 | Task Force forms an Eng.& Design Advisory Panel (EDAP) to advise Task Force. | | | | | |
| 27Mar97 | S | 276 | 1st of 4 public meetings is held to consider design concepts. | | | | | |
| 01Apr97 | R/S | 250 | | Retrofit vs. New Bridge. Economic Analysis by Caltrans. Life cycle cost. Supports GAR | | | | Various design proposals submitted to MTC. |
| 00May97 | S | 321 & 263 | EDAP presents concept design proposals to MTC Task Force. EDAP advises against continuous skyway bridge and 2 pier, cable stayed bridge. | | | | | |
| 21Jul97 | S | 321, 267 | San Francisco / Mayor Brown "support the northern alignment" which includes a signature bridge cost (replacement). [Doc 267, App. A] | | | | | |
| 30Jul97 | S | 271, 321 | MTC recommends a replacement bridge on a northern, adjacent alignment. | | | | MTC recommends "lifeline" service. | MTC recommends 2-30% design alternatives for cable supported bridge. |
| 11Aug97 | S | 254 | SB60 Senate Bill 60 passes Senate and Assembly. Introduced 12/06/96. | | | | | |

Appendix 5

Appendix 2

Appendix 3

Appendix 4

13 June 2000

**Scope of Work
for Services provided by the U.S. Army Corps of Engineers
to Evaluate and Compare Proposed Alternatives to Retrofit and Replace
the East Span of the San Francisco-Oakland Bay Bridge**

BACKGROUND

In response to the 1989 Loma Prieta earthquake, the State of California Department of Transportation (Caltrans) began a program to seismically retrofit all bridges in the state, including the damaged east span of the San Francisco Oakland Bay Bridge. As its plan to retrofit the east span progressed, Caltrans concluded preliminarily that it would cost little more to replace the structure altogether. Caltrans considered several designs for a replacement span and in 1997 selected a "skyway" design as the best alternative. Based on the cost of that design, Caltrans formally decided to replace rather than retrofit the east span. Subsequently, the Metropolitan Transportation Commission, representing nine Bay Area counties and acting under authority granted it by the California legislature, decided to pay the cost of adding "amenities" to the replacement span. These amenities included a self-anchored suspension bridge design, which the Commission felt was more distinctive than the skyway design, and a bicycle/pedestrian path.

The City and County of San Francisco (the City) and the State of California have asked the U.S. Army Corps of Engineers (COE), as a body of independent experts, to evaluate key technical decisions made by Caltrans. Specifically, the purpose of the COE's assessment is to examine two broad concerns raised by the City, outside experts, including Professor Abolhassan Astanek of the University of California, Berkeley, and others. First, the City believes that, from the standpoint of cost and public safety, it is preferable to retrofit the east span than to replace it with the currently proposed design. Second, the City believes that the self-anchored suspension design that Caltrans is currently proposing for the replacement span is not seismically safe. To expedite the COE's study of these two concerns, the Federal Highway Administration (FHWA), in cooperation with the U.S. Navy, will facilitate the COE's communication with appropriate Federal, State and Local Agencies, consultants to those agencies and other outside experts. The U.S. Coast Guard will participate as well.

SCOPE OF WORK

Approach and Major Questions: The COE will evaluate technical assumptions, engineering analyses and cost estimates as contained in *existing sources of data* -- specifically reports, backup data, and other analyses provided by Caltrans, the City, their consultants, other Federal and State Agencies, and relevant outside experts. (The parties must provide 4 copies of *all* pertinent information--including information that has not yet been made public-- to the COE at least one week prior to "kickoff" meetings, as discussed below.) The aim is to address the two broad concerns identified above: whether retrofit is preferable to the currently proposed replacement alternative; and whether that same replacement alternative is seismically safe. Specifically, the COE will answer the following four major questions, to which the City, the State and key Federal agencies (Federal Highway Administration, Navy, Coast Guard and the National Economic Council) have all agreed:

1. Was Caltrans' selection of the proposed retrofit alternative reasonable -- i.e., was it based on appropriate criteria and sound analysis, including consideration of realistic, accurate and complete cost figures?
 - a. Did Caltrans adequately consider/evaluate other retrofit alternatives, including a West Span-type retrofit and other steel retrofits, and did this evaluation include consideration of realistic, accurate and complete cost figures?
 - b. Did Caltrans adequately consider/evaluate the ability of other retrofit alternatives, including a West Span-type retrofit and other steel retrofits, to meet lifeline criteria? Which (if any) retrofit alternatives meet lifeline criteria?
 - c. Did Caltrans adequately consider/evaluate the costs of retrofitting the span to meet lifeline criteria?
2. Was Caltrans' cost-benefit analysis comparing the originally proposed replacement alternative vs. the proposed retrofit alternative reasonable -- i.e., was it based on appropriate criteria and sound analysis, including consideration of realistic, accurate and complete cost figures?
3. How does the currently proposed replacement alternative, including as well any work in progress, compare to various retrofit alternatives in terms of a) cost and b) seismic reliability (including ability to meet lifeline criteria)?
4. Is the currently proposed replacement alternative seismically safe? How will the currently proposed replacement alternative perform in a maximum credible earthquake? Specifically, does the currently proposed replacement alternative meet lifeline criteria? To what extent and how quickly could it accommodate passenger vehicles?

Assumptions:

- The COE will rely on *existing sources of information*; it will not generate any new data or analyses.
- If the parties to the study do not provide information or data to the COE, the COE will assume that it does not exist.
- The parties providing analyses to the COE will review them for quality and accuracy.
- Caltrans has supporting documentation for its identification of the currently proposed replacement alternative as the preferred alternative. Experts and others who share the City's concerns have supporting documentation for their concerns.
- If any party withholds critical data or documentation, the Federal Government may cease further activity related to this scope of work.

Definitions:

- The “*originally* proposed replacement alternative” refers to the skyway design that Caltrans initially proposed; it does not include the amenities (the self-anchored suspension structure and the bicycle/pedestrian path) that were subsequently added.
- The “*currently* proposed replacement alternative” refers to the N-6 alignment in the "San Francisco-Oakland Bay Bridge East Span Seismic Safety Project Draft Environmental Impact Statement," September 24, 1998. It includes the self-anchored suspension structure and pedestrian/bicycle path.
- The “proposed retrofit alternative” refers to the retrofit approach described in the "San Francisco-Oakland Bay Bridge East Span Seismic Safety Project Draft Environmental Impact Statement," September 24, 1998.
- "Lifeline criteria" are above-average standards for bridge (or other infrastructure) construction. A bridge constructed to meet lifeline criteria could accommodate emergency response vehicles and heavy equipment immediately following a maximum credible earthquake. By contrast, most bridges are constructed to meet “no-collapse” criteria; these are lower standards that ensure against catastrophic failure or loss of life. (For more detail on lifeline criteria, see the “San Francisco-Oakland Bay Bridge East Span Seismic Safety Project Draft Environmental Impact Statement,” September 24, 1998.) The "lifeline condition" of a bridge is a measure of the degree to which the structure meets lifeline criteria.

TASKS AND SCHEDULE: PHASE ONE

The COE will conduct its evaluation in two distinct phases. During Phase One, which is scheduled to take four weeks, the COE will a) receive from the parties all reports, data and analyses that pertain to the four major questions, and b) assess the completeness and quality of that information. At the conclusion of Phase One, the COE will meet with the parties to review this information and identify any significant gaps in the information needed to answer the major questions. If such gaps exist, the Corps may decide not to proceed to Phase Two. If the available information is adequate to answer the major questions, the COE will begin Phase Two.

Task I. Hold Kickoff Meetings (Week 1)

The COE will begin Phase One one week after a Memorandum of Agreement has been signed. It will hold two meetings in the first week to receive briefings from, and ask questions of, the parties. The first meeting will feature the City and its experts. The second meeting will feature the State and its experts. Both meetings will include FHWA, Navy, Coast Guard and other relevant Federal agencies.

In advance of these meetings, the COE will receive specific reports, backup data, and analyses from the parties. Parties must provide at least 4 sets (original and 3 copies) of this and any other material (including pertinent information that has not yet been made public) to the COE at least one week prior to the meeting. Each party also will provide the COE with information on a

primary point of contact and an alternative point of contact, including name, telephone number, mailing address and e-mail address. FHWA, in cooperation with the Navy, will schedule these meetings and in other ways facilitate the study.

Task II. Assess Data (Week 2)

The COE will catalog the reports, data, analyses and design review processes that the parties provide. This data catalog will include the COE's initial assessment of the quality and completeness of the data for answering the major questions. Each member of the COE team will catalog the data within his or her area of technical expertise

Task III. Identify Data Gaps (Week 3)

Using this data catalog, the COE will determine whether or not sufficient data is available to address the major questions. The COE will document any data deficiencies and contact the relevant parties to determine whether additional data is available.

Task IV. Determine Significance of Data Gaps (Week 3)

The COE will assess how significant the remaining data gaps are to its ability to answer the major questions. Each data gap will be rated as having a low, moderate, or high degree of significance.

Task V. Prepare Interim Letter Reports (Week 4)

The COE will prepare an interim letter report summarizing the availability and quality of data for each of the two broad concerns addressed by its evaluation: retrofit vs. the proposed replacement alternatives, and the seismic safety of the currently proposed replacement alternative. In addition, the letter reports will indicate whether sufficient data is available to answer the four major questions and recommend whether to undertake Phase Two. One day in advance of the meeting to conclude Phase One (see Task VI), the COE will provide copies of these interim letter reports to the City, Caltrans and key Federal agencies.

Task VI. Hold Review Meeting to Conclude Phase One (last day of Week 4)

At the end of Phase One, the COE will meet with the City, Caltrans and key Federal agencies to brief them on the status of its work and the significance of any data gaps. If the data gaps are not significant, the parties will adjust and/or finalize the scope of work for Phase Two. If the data gaps are significant, the COE may recommend that it terminate the study.

TASKS AND SCHEDULE: PHASE TWO

During Phase Two, the COE will review the information it has collected so as to answer the four major questions. As part of that process (and to the extent necessary to answer the four major questions), the COE will evaluate key design alternatives -- the originally proposed replacement alternative, the currently proposed replacement, and various retrofit alternatives (including the one proposed by Caltrans and another championed by Professor Astaneh). The criteria for evaluating these alternatives, as reflected in the major questions, include cost-effectiveness, seismic safety, and lifeline condition.

Task VII. Evaluate Alternatives

To determine whether the data/analyses support key conclusions by Caltrans and the City, the COE will look at the relevant alternatives in terms of three major criteria:

Cost-effectiveness reflects life-cycle costs associated with the construction, maintenance, and operation of the relevant alternative. These include initial construction costs, costs to maintain traffic during construction, construction-related accidents, traffic delay, on-going maintenance and operations costs (including inspection, painting, replacement and servicing of structural elements, and resurfacing), and the time value of money.

Seismic safety refers to the performance and reliability of the relevant alternative during mild, moderate and maximum credible earthquakes. This measure takes into account the exposure of bridge users (drivers, passengers, maintenance crews, etc.) to risk, the extent of damage, the costs of having the bridge closed following a seismic event, costs of repair, and loss of life or injury to motorists.

Lifeline condition reflects the degree to which the relevant alternative meets lifeline criteria. This criterion takes into account whether, immediately following a maximum credible earthquake and during the post-earthquake recovery, the structure could accommodate emergency vehicles, heavy equipment, and other vehicles transporting critical supplies.

Task VIII. Answer Four Key Questions

Based on its evaluation of key design alternatives in terms of the major criteria, the COE will answer the four major questions identified on page two.

Task IX. Identify Remaining Concerns

The COE will identify which, if any, of the four major questions cannot be answered because of insufficient information.

Task X. Prepare Final Letter Reports (Week 12)

The COE will prepare two final letter reports: The first, due week 12, will summarize the evidence comparing the retrofit alternative with the originally proposed replacement alternative in terms of cost-effectiveness, seismic safety, and lifeline condition; and with the currently proposed replacement alternative in terms of cost-effectiveness. The second letter report, due week 16, will summarize the evidence on the seismic safety/reliability of the currently proposed replacement alternative. The letter reports will state whether the major questions are adequately answered. If any questions are not answered, the letter reports will explain why and identify what actions are needed to answer the questions. One day prior to the final assessment meeting, the COE will provide copies of its final letter reports to the City, Caltrans and key Federal agencies.

Task XI. Hold Final Assessment Meeting (last day of Weeks 12 and 16)

The COE will meet with the City, Caltrans and key Federal agencies to brief them on the final results of its study, as reflected in the final letter reports. The COE will present the results of its "retrofit study" on the last day of week 12, and the results of the "replacement study" on the last day of week 16. The COE anticipates that this meeting will conclude its involvement in the study.

SFOBB Document Inventory, Table for Data Catalog

| Doc # | Grp | Subject | Provided by | Description | Date | R/S (Retrofit / Signtr) | REMARKS | Rev init | CT Eng name |
|-------|-----|-----------------|-------------|---|---------|----------------------------|---------------------------------------|-------------|----------------|
| | | Univ Research | | | | | | | |
| 1 | S | Testing | CT / UCB | Cyclic Tests of Existing & Retrofitted Sway Frames of SFOBB - Astaneh --(288 Ft Section) | 27May98 | R | | Ma | Akinsanya |
| 2 | S | Testing | CT / UCB | Cyclic Behavior & Seismic Design of Steel H-Piles - Astaneh --(Test results compared w/design) | 20May98 | R | | DG, Ma | Akinsanya |
| 3 | S | Testing | CT / UCB | Final. Proof-Testing of Latticed Members & Their Connections on SFOBB - Astaneh --(Research not completed) | 00Jun98 | R | | Ma | Akinsanya |
| 4 | S | Testing | CT / UCB | Cyclic Tests of Rivets for SFOBB Sway Frame Specimens - Astaneh --(288ft section) | 00May96 | R | | Ma | Akinsanya |
| 5 | S | Testing | CT / UCB | Cyclic Tests of Riveted & Bolted Angle Connections of SFOBB - Astaneh --(288ft section) | 00May96 | R | | Ma | Akinsanya |
| 6 | S | Testing | CT / UCB | Cyclic & Monotonic Tests of Truss Verticals of SFOBB - Astaneh --(288ft section) | 00Dec96 | R | | Ma | Akinsanya |
| 7 | S | Testing | CT / UCB | Final. Proof-Testing of Latticed Members & Their Connections on SFOBB - Astaneh --(Work terminated by Caltrans) | 00May98 | R | | Ma | Akinsanya |
| 8 | G | Analysis | CT / UCB | Analysis of Cyclic Behavior of Existing & Retrofitted Sway Frames of SFOBB - Astaneh --(288ft section) | 00Jan97 | R | | Ma | Akinsanya |
| 9 | S | Concepts Report | CT / UCB | Seismic Retrofit Concepts for the Bay Bridge - Astaneh | 24Aug92 | R | Need detailed eval. by CT | RT | Akinsanya |
| 10 | S | Research | CT / UCB | Latticed Research Vol III. Various correspondence and reports on lattice research. 1 & 2 of 2. --(288ft section) | 96-'97 | | | Ma | Akinsanya |
| 11 | S | Research | CT / UCB | Research on Truss Sway Frames. Correspondence between Caltrans/UCB. Report : Analysis of Cyclic Behavior & Retrofitted Sway Frames of SFOBB. Report Number: UCB/CEE-Steel-96/05. Also, invoice info for UCB. | 93-'98 | R | Retrofit stopped before report final. | Ma | Akinsanya |
| 12 | S | Short Course | CT / UCB | Vol 1: Business Correspondence. - Astaneh. 96-99. Vol 2: Seismic Design of Components of the East Bay Crossing --(by Astaneh - Handout for short course to Caltrans engineers by Astaneh. Anal. and testing of lattice members. Discussion for test program and setup.) | 00Apr95 | R | | Ma | Akinsanya |
| 13 | S | Analysis | CT / UCB | Seismic Condition of the East Bay Bridge, Results of the Elastic 3-D Dynamic Analysis of The 288-ft Spans From E11 To E23. - Astaneh -- (SAP 90 anal. output, linear analysis.) | 00Apr95 | R | | YG | Akinsanya |
| 14 | S | Analysis | CT / UCB | Seismic Condition of the East Bay Crossing of the SFOBB. Volume 5: 3-D Modeling & Analysis Using The Facts Program. - Astaneh --(volume 5/12) | 00Dec93 | R | Missing 11 volumes? | Ma, YG | Akinsanya |
| 15 | S | Analysis | CT / UCB | Seismic Condition Assessment of the East Bay Bridge, Results of the Elastic 3-D Dynamic Analysis of The Cantilever Span. - Astaneh -- (SAP 90 anal. output only, linear analysis.) | 09Jun93 | R | | YG | Akinsanya |
| 16 | S | Analysis | CT / UCB | Seismic Condition Assessment of the East Bay Bridge, Results of the Elastic 3-D Dynamic Analysis of The 500-ft Spans from E4 to E11. - Astaneh -- (SAP 90 anal. output only, linear analysis.) | 09Jun93 | R | | YG | Akinsanya |
| 17 | S | Testing | CT / UCSD | Structural Systems Research Project, Cyclic Performance of As-Built Latticed Members for the SFOBB. - Uang / Kleiser --(concentric and eccentric seismic loads, by subcontractor to UCB.) | 00Jun97 | R | | Ma | Akinsanya |
| 18 | S | Testing | CT / UCB | SFOBB Cyclic & Monotonic Tests of Truss Verticals of SFOBB, Report No.: UCB/CEE-Steel-96/04 | 01Dec96 | | ?Missing | | Akinsanya |

SFOBB Document Inventory, Table for Data Catalog

Date: 13Sep00

| Doc # | Subject | | Provided by | Description | Date | R/S (Retrofit / Sigrnt) | REMARKS | Rev init | CT Eng name |
|-------|---------|----------------------|--------------|---|-------------|----------------------------|--|-------------|----------------|
| | Grp | Type | | | | | | | |
| 19 | S | Testing | UCB, others | Proof-Testing of Latticed Members and Their Connections on SFOBB, Final Summary of Report Report Number: UCB/CEE-Steel-98/03 --(contract & admin. correspondence.) | 01Jun98 | R | Compare to Doc 7; Concerns about Isolation Devices. See comments by Ma | Ma | Akinsanya |
| 20 | S | Testing | CT / UCB | Cyclic Tests of Existing and Retrofitted Sway Frames of SFOBB, Report No.: UCB/CEE-Steel-98/02 | 27May98 | | ?Missing | | Akinsanya |
| 21 | S | Testing | CT / UCB | Cyclic Tests of Riveted & Bolted Angle Connections of SFOBB, Report No.: UCB/CEE-Steel- 96/03 | 01May96 | | ?Missing | | Akinsanya |
| 22 | A | Value Analysis | Ventry | Value Analysis Summary of the SFOBB East Bay Spans Foundation, Contract No. 53Y286 --(VE cost proposal) | 16Aug96 | R | See cmnts by | RT, AC, BF | Akinsanya |
| 23 | A | Value Analysis | Ventry | SFOBB East Bay Crossing Replacement Value Analysis Findings --(life cycle cost matrix) | 00Dec96 | S | no detailed cost on retro. See comments by Ma. | RT, Ma | Akinsanya |
| 24 | A | Other | | memos, newspaper articles, magazine articles, invoices, letters --(info for retrofit & original construction) | var | R | Good History | PS | Akinsanya |
| 25 | S | G Seismic Evaluation | &E EngSys In | Seismic Evaluation for SFOBB - deterministic and probabilistic approaches -- (nonlinear stick model of existing bridge w/ seismic input) | 00Dec94 | R | Model recmndn for EQ. See comments by Ma. | RT, Ma | Akinsanya |
| 26 | A | Articles | ENR | Series of articles published in ENR about SFOBB written by Chief Engineer, Bridge Engineer, & Engr of Design for the Bay Bridge --(Descript of original design, constr, & seismology) | 3/34 - 4/37 | | Historical Description, good geotech reference. | PS, MR | Akinsanya |
| 27 | G | Caltrans Plans | Caltrans | East Span of the SFOBB Log of Test Borings (Preliminary Geologic Report to the MTC EDAP. Projects 3, 4, 5 & 6. EQ Retrofit. | 18Apr97 | R | Includes Retrofit Summary Costs, good geotech reference Same as 95. | DG, MR, BF | Akinsanya |
| 28 | S | Plans | Caltrans | Project No. 4 GP and other plan sheets (E6 - E9) EQ Retrofit. | 00Dec96 | R | Foundation retro. | Ma | Akinsanya |
| 29 | S | Plans | Caltrans | Project No. 10. Plan sheets - lower chord retrofit details E9-E23, vertical member retrofit details, various other detail sheets --(compliment to design / analysis & cost) | 05Dec96 | R | not checked or signed | PS | Akinsanya |
| 30 | S | Plans | Caltrans | Project No. 3 GP and other plan sheets (unchecked details) EQ Retrofit. -- (compliment to design / analysis & cost) | 00Jun96 | R | Enlarge caisson | PS | Akinsanya |
| 31 | S | Plans | Caltrans | Project No. 9 GP and other plan sheets (unchecked details) Seismic Retrofit -- (compliment to design / analysis & cost for 500ft section) | 30Jul96 | R | not checked or signed | PS, Ma | Akinsanya |
| 32 | S | G Plans | Caltrans | Project No. 5 GP and other plan sheets. EQ Retrofit. --(compliment to design / analysis & cost; foundation plans) | 31Dec96 | R | not signed | PS, AC | Akinsanya |
| 33 | S | G Plans | Caltrans | Project No. 2 GP and other plan sheets. EQ Retrofit. (34 pages) --(compliment to design / analysis & cost; encase steel tower, add piles; foundation plans- YB) | 26Oct95 | R | not signed | PS, Ma, AC | Akinsanya |
| 34 | S | G Plans | Caltrans | Project No. 2 GP and other plan sheets. EQ Retrofit. (49 pages) --(compliment to design / analysis & cost; foundation plans - YB) | 31Dec96 | R | update Doc 33 | PS, Ma | Akinsanya |
| 35 | S | Plans | Caltrans | 504' truss span sheets. (Interim Seismic Retrofit.) --(compliment to design / analysis & cost, including steel tower retrofit) | 06Jun97 | R | not signed | PS | Akinsanya |
| 36 | S | G Plans | Caltrans | Project No. 6 GP and other plan sheets (P&Q). EQ Retrofit. --(compliment to design / analysis & cost; enlarge footing and add piles.) | 10Mar97 | R | not signed | PS, Ma | Akinsanya |
| 37 | S | G Plans | Caltrans | Cofferdam at Caisson E3 details. Electrical (PS&E) | 30Dec95 | R | | DG | Akinsanya |

SFOBB Document Inventory, Table for Data Catalog

Date: 13Sep00

| Doc # | Subject | | Provided by | Description | Date | R/S (Retrofit / Signtr) | REMARKS | Rev init | CT Eng name |
|-------|---------|-------------------------|---------------|---|-------------|----------------------------|--|------------------|----------------|
| | Grp | Type | | | | | | | |
| 38 | S | C | Caltrans | Project No. 7 Structure PS&E plans. EQ Retrofit. --(compliment to design / analysis & cost backup) | 31Dec96 | R | not signed | PS, MR | Akinsanya |
| 39 | A | C | Caltrans | Cantilever superstructure, retrofit project No. 8, E1, E4 anchorage. Retrofit release analysis, retrofit concept development, quantity & cost summary and detail generation | 22Oct96 | R | not signed | PS, MR, BF | Akinsanya |
| 40 | A | Report | CA DPW | General Safety of the SFOBB From Earthquake Point of View & Geologic and Seismic Conditions Affecting SFOBB | 24May38 | | historical interest, good geotech reference. | GC, MR | Akinsanya |
| 41 | A | Report | Caltrans | SFOBB & Port of Oakland Overcrossing, October 17, 1989 Loma Prieta Earthquake Damage/Repair Report (Robert Bidwell) --(no cost estimate) | 01May90 | | Good Description and geotech reference. M65+M78 | PS, MR | Akinsanya |
| 42 | A | Report | Caltrans | Post Earthquake Report for the SFOBB (Robert Bidwell) | 29Jun92 | R | historical data on Loma P | RT | Akinsanya |
| 43 | S | Permit Application | Caltrans | Draft #1, Permit Application to BCDC for SFOBB Retrofit | 00Jan97 | R | Discussion of rejected alternatives; numerous mini-contracts. Later ver. at #70. | PS, MR | Akinsanya |
| 44 | S | Plans | Caltrans | Connection Team: various plans, meeting notes, memos, details, alt. Concept, retrofit. -- (Details of 'drop span' joint mod. @ added piers & steel Jt design criteria) | | R | Ref. to concrete encasement, but no supporting data. | RF, Ma, BF | Akinsanya |
| 45 | | Contract related | | | | | | | |
| 46 | | Contract | Caltrans, UCB | Various contract monitoring documents by Caltrans for UCB research | 95-98 | | ?missing? | | Akinsanya |
| 47 | | Contract | Caltrans, UCB | Various contracting out documents for UCB research | 95-98 | | ?missing? | | Akinsanya |
| 48 | | Design Related | | | | | | | |
| 48 | S | | Caltrans | 04-00434GI - East Anchor Arm - Checked Details. Retrofit. | 8/96-1/97 | R | | GK | |
| 49 | S | | Caltrans | 04-00434GI - East Cantilever - Checked Details. Retrofit. | 8/96-1/97 | R | | GK | |
| 50 | S | | Caltrans | 04-00434GI - West Anchor Arm - Checked Details. Retrofit. | 8/96-1/97 | R | | GK | |
| 51 | S | | Caltrans | 04-00434GI - West Cantilever - Checked Details. Retrofit. | 8/96-1/97 | R | | GK | |
| 52 | S | | Caltrans | 04-00434GI - Suspended Span - Checked Details. Retrofit. | 12/95-1/97 | R | | GK | |
| 53 | S | | Caltrans | SFOBB East Bay Member Survey - 288' truss YB3 to E1 Volume II, Book 3 of 3; with Section 5 and Section 6 | | R | ?3of3 missing? See 188 & 199 | GK | |
| 54 | S | | Caltrans | SFOBB Hand Calculations - Binder No. 3 - Cantilever Structure - Truss Spans - East Bay Connector, 1, 2, & 3 of 3. | 00Aug93 | R | 4 copies 1of2, 1 cop. 2of2; ? Not all copies present | GK | |
| 55 | S | | Caltrans | SFOBB Hand Calculations - Binder No. 5 - Cantilever Structure, East Bay Connector - Truss Spans -- (hand calcs / section props / DL & LL) | 00May93 | R | | CC, GK | |
| 56 | S | | Caltrans | SFOBB Dead Loads and Section Props - 504' Spans -- (DL / Section props / static anal.) | 92-96 | R | | CC | |
| 57 | S | | Caltrans | SFOBB Demand / Capacity -- (DL and inertia) | 1/95 - 5/96 | R | Need force demand calcs | CC | Avila |
| 58 | S | | Caltrans | SFOBB East Bay - Model Geometry and Loading Cases -- (500' span truss model) | yr1995 | R | limited and incomplete (YG) | CC, YG | |
| 59 | S | | Caltrans | SFOBB Isolation - [504' Truss Frame / Heel Stiffener Install SEQ] (Friction Pendulum Bearing w/ Tension Load Capacity) -- (vendor cost est / Exp. Joints; includes FPS isolation) | 00Jun96 | R | | RF, BF | |
| 60 | S | C | Caltrans | SFOBB 504' Spans Notes + Various (Scheduling, Estimates, Tasks, etc.) | yr1996 | R | Good retrofit cost brkdwn | CC | |
| 61 | S | | Caltrans | SFOBB Peer Review - 504' Truss Spans | 13Dec96 | R | 500' Span retrofit | CC | |
| 62 | S | | Caltrans | SFOBB Jacking Operation and Heel Strengthening (Book 2) | 00Nov96 | R | Old Drawings (1934) | CC | |
| 63 | G | | Caltrans | SFOBB New Alignment - Foundation Design | 00Apr96 | S | | DG | |
| 64 | G | | Caltrans | SFOBB Analysis of Existing Foundations - Book 1, 7/17; Book 3, 8/28/95 | 17Jul95 | R | | MR | |

SFOBB Document Inventory, Table for Data Catalog

| Doc # | Subject | | Provided by | Description | Date | R/S | REMARKS | Rev | CT Eng name |
|-------|---------|------|-------------|--|------------|-----|---|------------|-------------|
| | Grp | Type | | | | | | | |
| 65 | S | | Caltrans | SFOBB Member Typical Sections | 06Jun96 | R | (Retrofit / Signtr) Extension of Doc 55 | init | Siemens |
| 66 | S | | Caltrans | SFOBB UC3 to UC7 Portal Frame Analysis / calculations --(Cantilever) | 00Jul96 | R | | CC | |
| 67 | S | | Caltrans | Cantilever Truss - Final -- (Strudl, ADINA runs for existing only??) | 00Jul95 | R | FE model input / plots | CC | |
| 68 | S | | Caltrans | YB Spans - Final | 00Jun95 | R | FE model input / plots | CC | |
| 69 | A | | Caltrans | SFOBB Survey Control - Dist 04 R/W Engineering | 00Jun96 | R | Surveying - not needed | CC | |
| 70 | A | | Caltrans | Draft #1 - SF Bay Conservation and Development Commission for SFOBB -- (Permit Appl., Retrofit description) | 00Jan97 | R | Good geotech reference. See 43 for earlier version.M51 | CC, MR | |
| 71 | G | | Caltrans | SFOBB Retrofit Strategy for the Foundations of Piers E-17 to E-22 | | R | Good calcs on Foundation | BF | |
| 72 | S | G | Caltrans | SFOBB Modeling Guidelines, Assumption - Notes and Meeting Summaries -- (ADINA design of retro approach) | 5/95-2/97 | R | Focus on pier rehab | CC, MR | |
| 73 | S | G | Caltrans | SFOBB Hand Calculations E-17, E-22, E-23, Segment E-17 to E-23 --(Retrofit calcs, including Finite Element) | 3/94-3/95 | R | | CC, MR | |
| 74 | S | G | Caltrans | SFOBB Correspondence --(Geotech Info) | 95 - 96 | R | Various Retro Schemes | CC, MR | |
| 75 | S | | Caltrans | SFOBB East Crossing 288' Double Deck Truss - Spans E9 - E22 - Misc Calcs | yr1993 | R | | CC | |
| 76 | S | | Caltrans | GT STRUDL INPUT 288's and Cantilever - Section Properties and Beta Angles | 00Jun95 | R | | | |
| 77 | S | | Caltrans | GT STRUDL INPUT 504's | | R | | | |
| 78 | S | | Caltrans | SFOBB East Crossing 504' Through Truss - Spans E4 - E8 - Misc Calcs | 93-95 | R | Useless Info | CC | |
| 79 | A | | Caltrans | SFOBB Miscellaneous Notes and Calculations -- (Seismic, cost est, 504' span - for Retro) | 00Jun93 | R | Historical Criteria | BT | |
| 80 | S | C | Caltrans | SFOBB East Crossing Double Deck - Cantilever Truss - Spans E1 - E3 - Misc. Calcs | yr1993 | R | F.E. input, not much use | CC | |
| 81 | A | | Caltrans | SFOBB BCDC - East Bay Approach - General Information - Region Wide Permit | 9/93-11/94 | R | Some criteria discussion | PS | |
| 82 | A | | Caltrans | SFOBB Project Planning Descriptions | 13Apr95 | R | W & E Info & alternative designs | BF, PS | |
| 83 | S | | Caltrans | Capacities | 2/93-3/96 | R | Hand calcs, not much use | CC | |
| 84 | S | | Caltrans | Special Analysis Loads and Miscellaneous --(modeling E6 to E23, memos, DL cant. Deflection) | 00Dec94 | R | | MR, RT | |
| 85 | S | G | Caltrans | Predicted Large Earthquake Response Scenario for the East Spans of the SFOBB in its Current (12-1996) State and Condition Seismic Life Safety Evaluation | 06Jan96 | R | by Maroney to Davison. Good reference. | RT, CC, BF | |
| 86 | S | G | Caltrans | Seismic Evaluation SFOBB Progress Meeting Presented to Caltrans of Structures on Contract No. 59U064 | 21Mar94 | R | Results show need for retrofit | CC, MR | |
| 87 | S | | Caltrans | Miscellaneous Retrofit Binder | 95-96 | R | Good Info, disorganized | CC | |
| 88 | S | | Caltrans | SFOBB Substructure Misc. Binder | 00Nov94 | R | Not very useful | CC | |
| 89 | G | | Caltrans | SFOBB Geotechnical Misc. Binder | 00Aug94 | R | Seismic Geot, pile survivability. Good geotech reference. | BT | |
| 90 | S | | Caltrans | SFOBB Member Typical Sections F, K, N, Q, R, S, X, AB, A, B, W, E, P, T, C, O, I, D, H, Y, L, V, Z, J, M | 00Dec96 | R | Backup data, no use. | CC | |
| 91 | S | | Caltrans | Member Capacity Hand Calculations --(Cantilever span, backup data) | 00Jun96 | R | no use. | CC | |
| 92 | S | | Caltrans | SFOBB Cantilever Structure East Bay (Binder 2) includes Section Properties, Truss | 00Aug93 | R | See Docs 54 & 55 | | |

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Date: 13Sep00

| Doc # | Subject | | Provided by | Description | Date | R/S (Retrofit / Signitr) | REMARKS | Rev init | CT Eng name |
|-------|---------|------|-------------|--|-------------|-----------------------------|---|-------------|----------------|
| | Grp | Type | | | | | | | |
| 93 | S | | Caltrans | Misc.-Gales/Suspended Span; Lower Chords & Bottom Lateral; North & South Truss; Portal Frames, etc.) --(I.D. members in model, no calcs) | 1995 | R | | CC | |
| 94 | S | | Caltrans | Program CAPP Binder; Member Database (runs with "CAPP") | 18Apr97 | R | No use. | CC | |
| 95 | G | | | East Span of SFOBB Log-of-Test-Borings Apr. 18, 1997 | | R | Good geotech reference. Same as 27. | MR | |
| 96 | S | | Caltrans | Stick Model (E1-E5) | 00Jun96 | R | Backup data. | CC | |
| 97 | S | | Caltrans | SFOBB - E2 (Retrofit analysis for E2) | 00Mar96 | R | Good document | CC | |
| 98 | S | | Caltrans | SFOBB/Jacking Operation & Heel Strengthening Book 1 | 00Nov96 | R | See Docs 62 | MR | |
| 99 | G | | Caltrans | SFOBB Analysis of Existing Foundations | 00Nov99 | R | See Doc 64. Good geotech ref. | MR | |
| 100 | G | | Caltrans | SFOBB Analysis of Existing Foundations Book 1 | 17Jul95 | R | Missing Original. Good geotech reference. | MR, AC, DG | |
| 101 | G | | Caltrans | SFOBB Analysis of Existing Foundations Book 2 | 00Sep95 | R | Ref #64 for book 3. Good geotech reference. | MR, DG | |
| 102 | G | | Caltrans | SFOBB Analysis of Existing Foundations Book 4 | 17Jul95 | R | Good geotech reference. | MR | |
| 103 | G | | Caltrans | SFOBB Analysis of Existing Foundations Book 5 | 18Nov95 | R | Good geotech reference. | MR | |
| 104 | S | | Caltrans | SFOBB Analysis of Existing Tower Shoes Book 1 | 17Jul95 | R | not much use | CC | |
| 105 | S | | Caltrans | Analysis & Design Concrete Encased Steel Towers -- (details & x-section runs for pushover) | 28Aug95 | R | No summary (CC) | RF, BF | |
| 106 | S | | Caltrans | Towers E13, E14, E15 m/s/ Steel Calculations Binder #1 --(demand capacity calcs) | 2/95 - 3/95 | R | | PS | |
| 107 | S | | Caltrans | 1st Binder for Towers E13 to E16 Models & Section Properties --(computer analysis) | 00Feb95 | R | | PS | |
| 108 | S | | Caltrans | SFOBB E13-E16 Tower Binders --(computer analysis) | 00Dec94 | R | | PS | |
| 109 | S | | Caltrans | SFOBB Towers E13 - E15: Binder #1; Binder #2 "as-built" Capacities & Joint Capacities --(analysis of existing towers) | 00Mar95 | R | | PS | |
| 110 | S | | Caltrans | SFOBB E13 & E14 Binder #3 Steel Capacities --(analysis of existing towers) | 00Jul95 | R | | PS | |
| 111 | S | | Caltrans | SFOBB Binder #4, E15 & E16 Steel Capacities --(calcs & analysis backup info) | 00Jul95 | R | | PS | |
| 112 | G | | Caltrans | Pier E23 -- (Time histories, spring supports, ductility & strength) | 00Apr96 | R | | AC | |
| 113 | S | G | Caltrans | Pier E17 to 22 -- (Modeling analysis & design assumptions, etc.) | 00May95 | R | | AC | |
| 114 | S | G | Caltrans | Pier E17 to 22 -- (value analysis & recommendation. ADINA model assumptions, analysis, calcs, discussions) | 00Aug96 | R | | RT | |
| 115 | S | | Caltrans | Pier E7 -- (Drawings & calcs, computer input+F169+F193+F169) | 00Apr95 | R | | PS | |
| 116 | S | | Caltrans | Rocking Analysis E2 --(ADINA model I/O - no roadmap or conclusion) | 00Jun96 | R | | RT | |
| 117 | G | S | Caltrans | SFOBB - Cantilever Project Engineer Binder 04-0434GI | 00Jan97 | R | Steel alternative strategy | BF | |
| 118 | S | | Caltrans | SFOBB - East Bay Member Survey, Volume II, Book 2 of 3, 288' Truss, YB3 to E1, Anchor Arm, Cantilever Arm, Suspended Span --(detailed list of Cant. truss members) | 00Dec94 | R | See Doc 53 | PS | |
| 119 | S | | Caltrans | SFOBB - East Bay Member Survey, Vol. II, Book 3 of 3, 288' Truss, YB3 to E1, Anchor Arm, Cantilever Arm, Suspended Span --(detailed list of Susp. Truss members) | 00Dec94 | R | See Doc 53 | PS | |
| 120 | S | | Caltrans | SFOBB Concrete Retrofit Binder #1 --(Tower E13, development of computer model) | 00Sep95 | R | | PS | Soon |

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Date: 13Sep00

| Doc # | Subject | | Provided by | Description | Date | R/S (Retrofit / Signtr) | REMARKS | Rev init | CT Eng name |
|-------|---------|-------|-------------|---|-----------|----------------------------|---|-------------|----------------|
| | Grp | Type | | | | | | | |
| 121 | S | | Caltrans | SFOBB Concrete Retrofit Binder #2 --(Towers E10, E12 to E16, design of Conc. Encasement alternative.) | 00Oct95 | R | | PS | Soon |
| 122 | S | | Caltrans | SFOBB Concrete Retrofit Binder #3 --(Towers E13 to E16, design of Conc. Encasement alternative.) | 00Nov95 | R | | PS | Soon |
| 123 | C | | Caltrans | SFOBB Towers E13-16 Quantities --(Steel retrofit alternative; Quantity backup w/ no cost data.) | 00Dec95 | R | | BF, PS | Soon |
| 124 | S | | Caltrans | Cantilever -- (Struct Calcs) | 00Feb96 | R | | PS | Soon |
| 125 | S | | Caltrans | SFOBB Towers E10-12 -- (struct calcs, as built) | 94-95 | R | | PS | Soon |
| 126 | S | | Caltrans | Supplemental Revised Sheets: 288 Spans - East Bay Member Survey --(as built section properties) | 00Nov92 | R | See doc 53 | RF | |
| 127 | S | | Caltrans | Capacity Binder: Types I, J, L, K, M, N, O, Q, R, S, V -- (Cantilever section properties & member capacities - as built) | 00Jul96 | R | | RF | |
| 128 | S | | Caltrans | Misc.: Adina Results; YB3 to E10 Demands to Capacities; E4 Moment Frame; Various Pier Calcs. Superseded. Parts 1 & 2 of 2 | 95-97 | R | | RF | |
| 129 | A | Plans | Caltrans | Structure Plans 1933 | 1933 | R | copies missing | RF | Slocum |
| 130 | A | Plans | Caltrans | Retrofit Plans 1960 (portion of) | 1960 | R | all missing | RF | Slocum |
| 131 | A | Plans | Caltrans | Contract 04-043434 Plans for Retrofit (Sheets 38 to 157) (As-built 1999 East Approach) | 1995 | R | 1 orig + 5 copies | RF | Slocum |
| 132 | A | C | Caltrans | Quantity Estimates --(East approach beyond pier 23; Quantity / Cost summary) | 1994 | R | | BF, RF | Slocum |
| 133 | | | Caltrans | Contract 04-043434 Special Provisions --(East Approach beyond pier 23) | 1995 | R | | RF | Slocum |
| 134 | A | | Caltrans | Engineering Criteria Review Board - Retrofit Presentation to BCDC | 27Jul94 | R | Summary w/o Recommnd. | BT | Slocum |
| 135 | S | | Caltrans | SFOBB East Approach - Design Notes (3 binders) (East Approach beyond pier 23; encompasses Bents 22-39) | 93-94 | R | Retrofit Strategy | RF, MR | Slocum/Lian |
| 136 | C | | Caltrans | Estimating File (3 folders) --(East Approach beyond pier 23; EQ retrofit; Bid cost seismic retrofit;) | 94-95 | R | | BF, RF | Slocum |
| 137 | G | | Caltrans | Indicator Pile Test Program - Contract 04-043494 - Final Report --(East Approach beyond pier 23) | 30May95 | R | | RF, MR | Slocum |
| 138 | S | | Caltrans | Super Structure Strengthening Design Notes (& calcs for West Bay) | 00Sep96 | R | YBI | BT | Slocum |
| 139 | S | | Caltrans | Yerba Buena Island (YBI) Existing Column Capacities, Designs & Calcs. --(for West Bay) | 00Mar95 | R | | RF | Masoor |
| 140 | S | | Caltrans | Retrofit Design Bent 39-52 -- (Loads & calcs, for West Bay) | 00Apr95 | R | | RF | Masoor |
| 141 | S | | Caltrans | Check Super-Structure Capacities Base Isolation Alternative --(for West Bay) | 00Feb97 | R | | RF | Masoor |
| 142 | | Plans | Caltrans | Contract 04-043001 Interim Retrofit - East Bay Yerba Buena Island Viaduct --(for West Bay) | 1997 | R | | RF, BF | Masoor |
| 143 | S | | Caltrans | Retrofit Options (various) --(struct analysis for West Bay, detail calcs for YBI approach, retrofit) | 00Jun96 | R | | BF, RT | Masoor |
| 144 | C | S | Caltrans | Bay Bridge E23 SFOBB --(Details & Quantities only, also for E23 & trestle data) | 00Feb95 | R | | RF, BF | Hight/Adams |
| 145 | S | | UC-SD | Cyclic Testing of Latticed Member UCSD-1 for SFOBB, Progress Report, & Misc. Items | 00Nov96 | R | w/ envrnmntl assmnt. See Doc #3 for Final Report. | RF | Hight/Adams |
| 146 | S | | Caltrans | Isolation Bearing Data File | 1995 | R | Same as Doc #6 | RF | Hight/Adams |
| 147 | A | | Caltrans | Original SFOBB Reports & Post Earthquake Reports (various) | 1934-1990 | | | AC | Hight/Adams |
| 148 | S | | Caltrans | Cyclic & Monotonic Tests of Truss Verticals of SFOBB - Astaneh | 00Dec96 | R | | RF | Hight/Adams |

SFOBB Document Inventory, Table for Data Catalog

| Doc # | Subject | | Provided by | Description | Date | R/S (Retrofit / Signtr) | REMARKS | Rev init | CT Eng name |
|-------|---------|------|-------------|--|-------------|----------------------------|--|-------------|----------------|
| | Grp | Type | | | | | | | |
| 149 | G | | Caltrans | Designer's File E17-E22 Contract 6 - Bay Bridge Foundations | 00Apr96 | R | | RF | Hight/Adams |
| 150 | A | | Caltrans | Designing & Building SFOBB (13 Articles appearing in Engineering News & Record 1934-1937) | 1934-1937 | | See Doc 26 | RF | Hight/Adams |
| 151 | C | G | Caltrans | Bay Bridge PE File SFOBB Seismic Retrofit Cost Estimate (Piers E17 - E 22, mtg mins, environmental, etc.) | 00Nov96 | R | Mostly memos for foundations. Little cost estimate #s. | RF, MR | Hight/Adams |
| 152 | G | | Caltrans | SFOBB Retrofit Strategy for Foundations of Piers E17-E22 | 00Feb97 | R | Good geotech ref. | RF | Hight/Adams |
| 153 | A | C | Caltrans | SFOBB East Bay Spans Summary of Meetings Memos, Piers E9-E23, 288 ft. Trusses | 00Feb96 | R | Note: Attachement 'F' | RF | Hight/Adams |
| 154 | S | C | Caltrans | SFOBB Research & Testing Data File -- (Lattice testing - Astaneh | 2/95-7/96 | R | See Doc #3 | RF | Hight/Adams |
| 155 | S | | Caltrans | SFOBB Design & Calculations, Design Section 4 -- (EQ Retrofit, 208' Truss spans E9 to E23, calcs w/no map) | 00Feb97 | R | | RF, AC | Hight/Adams |
| 156 | S | | Caltrans | Design Notes for Steel Members (SFOBB) Notebook #1 --(copies of tech. Papers) | 00Oct95 | R | Mtg w/ Astaneh. Retrofit 5/94 | RF | Hight/Adams |
| 157 | A | | Caltrans | Project Eng. Binder SFOBB -- (Laced Mbr. - Astaneh, work schedule data) | 00Oct94 | R | | RF | Hight/Adams |
| 158 | S | | Caltrans | SFOBB Retrofit Project 10 Spans E9-E23 --(retrofit plans) | 00Jul96 | R | | RF | Hight/Adams |
| 159 | S | | Caltrans | SFOBB (Gen. Plan) Deck Joints - Seismic Revisions E17-E23 --(&89' post EQ retrofit plans) | 00Jun93 | R | | RF | Hight/Adams |
| 160 | S | | Caltrans | Analysis of Cyclic Behavior of Existing & Retrofitted Sway Frames of SFOBB -- (by Astaneh; ABACUS modeling & results discussion) | 00Jan97 | R | Same as Doc #8 | RF | Hight/Adams |
| 161 | S | | Caltrans | Towers E5 - E16 Retrofit Summary of Results -- (Sect prop. of existing & axial cap calcs. AND alternative for all piers shown) | 11/95-1/97 | R | inclds summary of work | RT, RF | Sadek |
| 162 | S | C | Caltrans | SFOBB E5 - E16 Memos & Estimates -- (Includes - Interim Retrofit Strategy; encasement vs. steel, FPS bearings, etc.; Cost summary) | 00Mar00 | R | Good Insight to Retrofit progrsn | RF, RT | Sadek |
| 163 | S | | Caltrans | E11 - E17 Existing Tower Analysis -- (all Calcs) | 1/94-12/95 | R | | RT | Sadek |
| 164 | S | | Caltrans | Towers E5 - E8 Retrofit Analysis | 10/95-1/97 | R | Need verif. of encsmnt strlty. | RT | Sadek |
| 165 | S | C | Caltrans | Piers E5 - E8 Quantities --(quantity takeoff) | 00Dec95 | R | | WH | Sadek |
| 166 | S | | Caltrans | SFOBB Project File Vol. 1 - memo's, minutes, reports, isolators, seismic loads | 1995 | R | | WH, RF | Asnaashaari |
| 167 | S | | Caltrans | SFOBB Project File Vol. 2 - towers YB-1, YB-2, & YB-4 retrofit | 8/95-10/95 | R | | RF | Asnaashaari |
| 168 | S | | Caltrans | Various folder: memos, final 288' Truss Strudl, isolation model, specifications, E1 & E4 anchorage, --(Full model w/ retrofit changes) | 9/95-1/97 | R | | RF | Asnaashaari |
| 169 | A | C | Ventry | Value Analysis Summary of SFOBB East Bay Replacement Contract No. 53Y 286, Oakland, CA | 7/8-8/23/96 | S | Compares retrofit to replcmnt. Very Important. | BF, MR | Maroney |
| 170 | A | | Ventry | Value Analysis Summary of SFOBB East Bay Replacement Bridge Retrofit Project "Structural Report" | 00Sep96 | S | Compares retrofit to replcmnt. Very Important. | RT, MR | Maroney |
| 171 | A | | Caltrans | Peir Construction Data As Built | 28Jul37 | | Historical | MR | Moran |
| 172 | S | | Caltrans | Modeling of E2-E5, 3-D Stick, 1-D, Check Calculations -- (prelim analysis) | 00Apr95 | R | | PS | Moran |
| 173 | A | | Caltrans | Papers and Reports by Others for information only | 00Mar97 | | | MR | Moran |
| 174 | A | | Caltrans | SFOBB- Final Report Drawings | | | Historical | MR | Moran |
| 175 | G | | Caltrans | Steel Sheet Piling -- (Catalog) | | | | DG | Moran |
| 176 | G | | Caltrans | Report on Cofferdams and Caissons -- (by Ben Gerwick) -- (copy of text chapter) | | | | MR | Moran |
| 177 | S | G | Caltrans | SFOBB- Seismic Analysis of existing West Bay Span | 00Nov94 | | | MR | Moran |

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| Doc # | Subject | | Provided by | Description | Date | REMARKS | Rev | CT Eng |
|-------|---------|---------|-------------|--|-----------|---------------------------------|--------|-----------|
| | Grp | Type | | | | | | |
| 178 | S | | Caltrans | Design Criteria- Section 5 Concrete Structures (Specifications) | | (Retrofit / Signitr) | init | |
| 179 | G | | Caltrans | Design Criteria- Section 10 Foundations (Specifications, standard design manual) | | R /S (replacement) | PS | Moran |
| 180 | | | Caltrans | ADINA- Software Information | 94-95 | | PS | Moran |
| 181 | A | | Caltrans | SFOBB- Annual Progress Report 1 and 2 | 7/34-7/35 | | PS | Moran |
| 182 | A | | Caltrans | SFOBB- Annual Progress Report 3 and 4 | 7/36-7/37 | | PS | Moran |
| 183 | A | | Caltrans | SFOBB- Annual Progress Report 5 and 6 | 7/38-7/39 | | PS | Moran |
| 184 | S | | Caltrans | Structural Steel Information -- (Various Sources) | 23Sep93 | | PS | Moran |
| 185 | S | G Plans | Caltrans | SFOBB Drawing- Substructure East Crossing | 00Jul33 | R Original Foundation Plans | PS | Moran |
| 186 | G | S Plans | Caltrans | SFOBB Drawing- Misc. -- (EQ Retrofit, plans, specs & estimates; west span costs) | 00Oct95 | R | PS | Moran |
| 187 | S | | Caltrans | SFOBB Seismic Retrofit Pier E-2 Modeling 2-D --(prelim analysis) | 24Mar95 | R | PS | Moran |
| 188 | G | S | Caltrans | SFOBB- Foundation Analysis and Design for New Piers of the East Span | 00Feb97 | R Good geotech ref. | MR | Moran |
| 189 | G | | Caltrans | SFOBB- Soil Columns and Foundation Stiffness | 00Jul95 | R Good geotech ref. | MR | Moran |
| 190 | A | C | Caltrans | SFOBB- East Span Caisson Information: Vol I -- (Quantities & costs) | 00May96 | R | MR | Moran |
| 191 | A | C | Caltrans | SFOBB- East Span Caisson Information: Vol II -- (Quantities & Cost) | 00May96 | R | MR | Moran |
| 192 | G | S | Caltrans | SFOBB- West Span Misc Files by EM | 00Jul95 | R | DG | Moran |
| 193 | G | C | Caltrans | SFOBB- Cofferdam Contract files by EM --(Quantity takeoff, no cost data) | 94-96 | R | DG | Moran |
| 194 | G | S | Caltrans | SFOBB- Caisson Engineering Analysis and Design | 94-96 | R | MR | Moran |
| 195 | A | | Caltrans | SFOBB- Peer Review file by EM -- (Presentation slides) | 95-96 | R Good summary | MR | Moran |
| 196 | A | | Caltrans | SFOBB Misc. files by EM --(foundation and soil struct interaction info) | 94-97 | R | PS | Moran |
| 197 | A | Info | Caltrans | Computer Software Information -- (Adina, Microstation; soil spring info) | 4/95-7/95 | Reference only | PS | Moran |
| 198 | S | Plans | Caltrans | Various as-built packages for all aspects of the cantilever -- (Drawings from 1930's) | | Historical | PS | VanDe Pol |
| 199 | S | | Caltrans | Design Guidelines binder --(mostly Dead Load calcs and detailed backup) | yr1993 | R | PS | VanDe Pol |
| 200 | S | | Caltrans | Replacement Alternative No. 1 binder -- (FEA of original Alternative) | | S FEA of original Retro | AC | VanDe Pol |
| 201 | S | | Caltrans | Replacement Alternative No. 2 binder -- (FEA of original Alternative) | 00Aug96 | S FEA of original Retro | AC | VanDe Pol |
| 202 | A | C | Caltrans | Replacement Alternative No. 2 cost estimate --(Quantity takeoff & cost summary) | 00Mar96 | S Also Retrofit? | BF | VanDe Pol |
| 203 | S | C | Caltrans | Replacement Alternative Presentation Binder --(cable stayed alternative, double deck steel; Quantity takeoff & cost summary) | | S | BF, MR | VanDe Pol |
| 204 | A | C | Caltrans | Replacement Alternative Planning Estimate Binder --(cable stayed alternative) | 26Aug96 | S Alternate #2 w/ Quantities | BF | VanDe Pol |
| 205 | A | | Caltrans | No-Drop E2 and E3 Anchorage Top Analysis Binder --(other retrofit investigation) | 06Feb96 | R Fixing E2 & E3 | AC | VanDe Pol |
| 206 | S | | Caltrans | No-Drop E4 Tower/Caisson Interface Analysis Binder | 00Feb96 | R Fixing E4, Lead Paint | AC | VanDe Pol |
| 207 | S | | Caltrans | No-Drop E2 and E3 Tower/Caisson Interface Analysis Binder | 00Feb96 | R GTSrudl Run | AC | VanDe Pol |
| 208 | C | | Caltrans | E1 Anchorage Retrofit Estimating Binder -- (Stringer Seats) -- (other retrofit) | 00Nov96 | R Quant. Take-off and estimate | BF | VanDe Pol |
| 209 | S | | Caltrans | No-Drop Strategy No. 1 Binder -- (Cantilever Spans) -- (2 new piers) | 00Sep96 | R Piers to support Cant span. | YG | VanDe Pol |
| 210 | S | | Caltrans | Longitudinal SuperStructure Push No. 1 Binder -- (Modeling Data) | 00Jun96 | R Outline of anal. Valuable Eng | YG | VanDe Pol |
| 211 | S | | Caltrans | Bay Bridge Notes Binder | 00Aug95 | R Modeling outline | AC | VanDe Pol |
| 212 | S | | Caltrans | Cantilever Structure Member Properties Binder --(handwritten) | 00Aug93 | R non-linear analysis | AC | VanDe Pol |
| 213 | S | | Caltrans | No-Drop E4 Anchorage Top Analysis Binder | 00Jan96 | R Refer to 199. Hard to read. | AC | VanDe Pol |

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| Doc ## | Grp | Grp | Subject | | Provided by | Description | Date | R/S (Retrofit / Signtr) | REMARKS | Rev init | CT Eng name |
|-----------|-----|-----|-------------|---|-------------|-------------|------------|----------------------------|-------------------------------------|-------------|----------------|
| | | | Type | | | | | | | | |
| 214 | S | | Caltrans | E1 Shoe Analysis Binder | Caltrans | | 00Feb96 | R | | AC | VanDe Pol |
| 215 | S | | Caltrans | Revised Edge Truss Analysis Binder | Caltrans | | 00May96 | R | | AC | VanDe Pol |
| 216 | S | G | Caltrans | Replace Alt. 2 Presentation -- (Items for Cost Savings) --(cable stayed alternative) | Caltrans | | 00Aug96 | | Estimate | BF | VanDe Pol |
| 217 | S | | Caltrans | East Bay -- West Anchor Arm Properties | Caltrans | | 00Aug96 | R | | AC | VanDe Pol |
| 218 | S | | Caltrans | East Bay -- West Cantilever Arm Properties | Caltrans | | 00Sep96 | R | | AC | VanDe Pol |
| 219 | S | | Caltrans | Retrofit Project No. 8 Wrap-up Binder | Caltrans | | 00Feb97 | R | Decision to Replace | BF | VanDe Pol |
| 220 | S | | Caltrans | E1 and E4 Articulated Barrier Binder | Caltrans | | 00Feb97 | R | | AC | VanDe Pol |
| 221 | S | | Caltrans | Total Cantilever Structure GTS Model Binder | Caltrans | | | R | | AC | VanDe Pol |
| 222 | S | | Caltrans | E1 and E4 Anchor Replacement Model Binder -- (Retro Concepts) | Caltrans | | 00Oct96 | R | | AC | VanDe Pol |
| 223 | S | | Caltrans | Articulated Barrier Analysis Binder -- (Barrier Rail Comparisons) | Caltrans | | 00Jan97 | R | Concept Comparisons | AC | VanDe Pol |
| 224 | S | | Caltrans | E1 Anchorage Presentation Binder (3 binders) | Caltrans | | 10/95-4/97 | R | | AC | VanDe Pol |
| 225 | S | | Caltrans | Edge Beam 8 and 9 and Combined Binder -- (Calcs and Data) | Caltrans | | 00Jan96 | R | | AC | VanDe Pol |
| 226 | S | | Caltrans | Edge Beam 1 to 7, BR1 and BR2 GTS Model Binder -- (Calcs, analysis and data) | Caltrans | | 00Nov95 | R | | PS | VanDe Pol |
| 227 | S | C | Caltrans | Edge Truss Notes and Discussion Binder -- (Quantity takeoff & no cost data; Lead Paint; computer analysis and discussion) | Caltrans | | 00Jan96 | R | | PS | VanDe Pol |
| 228 | S | | Caltrans | Top Existing + Edge Truss Push Models Binder -- (Calcs, analysis, data and discussions) | Caltrans | | 00Jan96 | R | | PS | VanDe Pol |
| 229 | S | | Caltrans | Replacement Option Cap X-Section Binder --(computer analysis) | Caltrans | | 00Apr96 | R | | PS | VanDe Pol |
| 230 | S | | Caltrans | E1 Anchorage Retrofit Conclusions Binder -- (Peer Review; Cant. Truss Alt Development) | Caltrans | | 00Oct95 | R | Retro - Pros and Cons; good summary | BF, RT | VanDe Pol |
| 231 | S | | Caltrans | Revised Longitudinal Structure Push Binder --(Computer Models, summary of analysis) | Caltrans | | 00Jun96 | R | | PS | VanDe Pol |
| 232 | S | | Caltrans | E1 Anchorage Analysis Binder No. 4 | Caltrans | | 00Jun97 | R | Retro Conclusion | PS | VanDe Pol |
| 233 | S | | Caltrans | E1 Anchorage Analysis Binder No. 1 & No. 2 --(analysis discussion) | Caltrans | | 00Mar97 | R | | PS | VanDe Pol |
| 234 | S | | Caltrans | E1 Anchorage Analysis No. 3 Binder | Caltrans | | 00May97 | R | details included | PS | VanDe Pol |
| 235 | S | | Caltrans | E1 Anchorage Retrofit Structure Plans --(detailed plans) | Caltrans | | | R | This portion was deleted firm | PS | VanDe Pol |
| 236 | S | | Caltrans | Articulated Barrier Preliminary Details | Caltrans | | | | Includes 237. Need backup. | PS | VanDe Pol |
| 237 | S | | Caltrans | E1 and E4 Anchorage Hold-down Preliminary Details --(Information) | Caltrans | | | | Includes 236 | PS | VanDe Pol |
| 238 | S | | Caltrans | Binder of GTS Models -- 1, 2, & 3 of 3 --(detailed computer input) | Caltrans | | 00Nov95 | R | | PS | VanDe Pol |
| 239 | A | | Caltrans | Tower Retrofit Details -- (Doc 239 to 241) | Caltrans | | 95-97 | R | Includes Replacement | PS | VanDe Pol |
| 240 | A | | Caltrans | Various Preliminary No-Drop Retrofit Details -- (Doc 239 to 241) | Caltrans | | | R | Includes Replacement | PS | VanDe Pol |
| 241 | A | | Caltrans | Miscellaneous Details -- (Doc 239 to 241) -- (Doc 239 to 241) | Caltrans | | | R | Includes Replacement | PS | VanDe Pol |
| 242 | S | | Caltrans | East Anchor Cantilever Arm Properties --(Detailed calcs for section properties) | Caltrans | | 00Aug96 | R | Used for computer input | PS | VanDe Pol |
| 243 | S | | Caltrans | Suspended Span Properties --(Detailed calcs for section properties) | Caltrans | | 00Aug96 | R | Used for computer input | PS | VanDe Pol |
| 244 | S | | Caltrans | East Cantilever Arm Properties | Caltrans | | 00Sep96 | R | | PS | VanDe Pol |
| 245 | A | | Caltrans | Retrofit construction schedule | Caltrans | | 05May00 | | | BF | Toan |
| 246 | A | | Caltrans | Replacement construction schedule -- Governor's Schedule | Caltrans | | Yr2000 | | | BF | Toan |
| 247 | A | | Govnr's Bnd | Competing Against Time | Govnr's Bnd | | 31May90 | | General References | RT | Toan |
| 248 | A | | SAB | The Continuing Challenge, The Northridge Earthquake of 1/17/94 (prepared by the Seismic Advisory Board) | SAB | | 00Oct94 | | | MR | Toan |

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|------------------------------|-----|-------------------|-------------|---|---------|--------------------------------|--------|----------|
| ## | Grp | Type | | | | R/S (Retrofit / Signtr) | init | name |
| 249 | A | Report | Caltrans | "The Yellow Report" Replacement Study for the East Spans of the Bay Bridge Seismic Safety Project | 00Dec96 | S Maroney to Davison | RT, MR | Toan |
| 250 | A | C Report | Caltrans | Retrofit vs. New Bridge, An Economic Analysis for the East Span of the Bay Bridge | 00Apr97 | R Investment Analysis | RT, AC | Toan |
| 251 | A | Strip map | Caltrans | Strip map showing the location of individual retrofit contracts along the Bay Bridge | | Ref. Only | RT | Toan |
| 252 | C | Plans | Caltrans | "The Gray Report" Cost Estimate Investigation for the East Spans Replacement | 00Sep96 | S Summary Replcmnt Options | RT | Toan |
| 253 | C | Estimate | Caltrans | Seismic Retrofit Cost Summaries | 30Dec96 | Abridged replaced w/ | BF | Traina |
| 254 | A | Legislation | Caltrans | Senate Bill 60 (SB 60) Transportation Funding for Toll Bridges | 06Dec96 | Ref. Only | BF | Toan |
| REPLACEMENT DOCUMENTS | | | | | | | | |
| New East Span | | | | | | | | |
| 255 | A | Plans | Caltrans | 65% YBI structure plans -- Transition E. Bound on Ramp | 15Sep99 | S no calcs | RT | Hulsebus |
| 256 | A | Plans | Caltrans | 65% Main Span structure plans -- (Suspension) | 15May99 | S See 277 for later revision | | Hulsebus |
| 257 | A | Plans | Caltrans | 85% Skyway structure plans -- (super and sub - structures) | 15Feb00 | S no calcs | RT | Hulsebus |
| 258 | A | Plans | Caltrans | 65% In-Progress YBI structure/Oakland Approach structure plans | 01Sep99 | S | | Hulsebus |
| 259 | A | Plans | Caltrans | 65% Skyway structure plans | 01Apr00 | S Supersceded by 255 - 258 | RT | Hulsebus |
| 260 | | Plans | Caltrans | 45% Main Span structure plans | 15Jan99 | S Supersceded by 255 - 258 | RT | Hulsebus |
| 261 | | Plans | Caltrans | 45% Skyway structure plans | 15Jan99 | S Supersceded by 255 - 258 | RT | Hulsebus |
| 262 | | Plans | Caltrans | 45% YBI/Oakland Approach structure plans | 15Jan99 | S Supersceded by 255 - 258 | RT | Hulsebus |
| 263 | A | Report | Caltrans | 30% Type Selection Report -- (Summary for replcmnt, w/ costs) | 01May98 | S inice Doc. - no calcs | RT | Hulsebus |
| 264 | C | Report | Caltrans | Supplement to 30% Design Report -- (Cost summary, EDAP directives) | 22Jun98 | S | RT | Hulsebus |
| 265 | A | C Report | Caltrans | Contractors Information Session -- (East bay; Estimates, Geology, Environmental, Description, Demolition) | 23Jun98 | S Overview, Ref 263. Good ref. | RT, MR | Hulsebus |
| 266 | A | C Report | Caltrans | Contractors Outreach Information -- (East bay; Estimates, Geology, Geotech, Substr info.....) | 01Mar99 | S Ref 263. Good Ref. | RT, MR | Hulsebus |
| 267 | A | Report | Caltrans | Replacement vs. Retrofit for East Span -- (Summary of history) | 01Apr00 | S Also Retrofit. No backup | RT | Hulsebus |
| 268 | A | Minutes | Caltrans | Seismic Safety Peer F261Review meetings Nov 98 to Feb 00; Add 18May00 Min-utes. X-Ref Doc 303. F308-- (includes mtg minutes & handouts for design) | Var | S Need calcs | YG | Hulsebus |
| 269 | | Plans | Caltrans | 95% roadway/electrical plans for Skyway | 01Jun00 | S | RT | |
| 270 | A | Quantities | Caltrans | Preliminary contract quantities. Structure: SAS Oakland Approach (CIP), YBI Transition, YBI Temporary Detours, Skyway (segmental box girder). Roadway: Skyway, YBI/SAS. | Var | | RT, BF | |
| 271 | A | Letter | Caltrans | MTC Planning & Design recommendations for replacement bridge | 01Jul97 | MTC position paper | RT | |
| 272 | A | Letter | Caltrans | Additional replacement recommendations from EDAP for Single Tower Design | 04Jun98 | MTC decision paper | RT, BF | |
| 273 | G | Geotechnical repo | Caltrans | Geotechnical related material for replacement (transferred from COE SF District) - 21 documents | var | See Doc for references | MM | |
| 274 | S | G Plans | Caltrans | Pile Installation Demonstration Project plans -- (Boring data) | 01Aug99 | S | RT | |
| 275 | A | Plans | Caltrans | West Span contracts 15, 16, and 18 | 33-99 | | | |
| 276 | A | Document | Caltrans | Draft Environmental Impact Statement/Statutory Exemption (DEIS) | 24Sep98 | | RT | |
| 277 | | Plans | Caltrans | 65% Main Span Suspension Bridge -- (Revised to Mar 2000) | 02Aug99 | S Latest 65% after Doc 256. No | RT | |
| 278 | | Plans | Caltrans | SFOBB East Viaduct, Seismic Retrofit, Description & Summary | 18Jul00 | S | | Masroor |
| 279 | | Specs | TY Lin | 85% Specs, Skyway Structures, East span w/ Transmittal Letter | 15Feb00 | S | RT | |

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|-------|-----|---------------|--------------|---|---------|----------------------------|---|-------------|-----------------------|
| 280 | | Chart | CT | SFOBB Staff Chart by Span & Project for Retrofit | 19Jul00 | | | | |
| 281 | | Plans | Caltrans | SFOBB GP/ Planning study - Alternative #1 Viaduct - Seismic analysis by Mario Velado, lead design engineer (see gray report Doc 252) (Vols. A - C) | 01Oct96 | R | | | Mac Leay Akinsanya |
| 282 | | Plans | Caltrans | SFOBB East Span, Log of Test Borings, Projects #3 - #6. Seismic Retrofit. | 00Jul97 | R | | | Akinsanya |
| 283 | | Plans | Caltrans | SFOBB Skyway Structures, 100% in Progress (01) Plans. | 02Aug00 | | | | Akinsanya |
| 284 | | Plans | Reserved | Reserved | | | | | |
| 285 | | Plans | Reserved | Reserved | | | | | |
| 286 | | Document | TY Lin | Design Criteria, East Span. -- (ref to AASHTO and Caltrans design guides) | 30Jun00 | S | Incomplete | RT | |
| 287 | G | Document | Earth Mchncs | Time Histories for Conc. Piles (by Earth Mechanics) | 22Feb99 | S | | RT | |
| 288 | G | Document | Fugro | Preliminary Pile Drivability Evaluation, East Span. | 13May98 | S | /retrofit | RT | |
| 289 | G | Document | Fugro | Pile Installation Demonstration Project. East Span. --(soil condition summary) | 25Jun99 | S | /retrofit | RT | |
| 290 | G | Document | Fugro | Executive summary - Seismic Hazard Ground Motion Criteria | 15Jun99 | S | | RT | |
| 291 | G | Document | Earth Mchncs | Design ARS Spectra, Lateral Pile Cap & Drivability @ Oakland Mole Approach | 01Jun99 | S | | RT | |
| 292 | G | Document | Fugro | Factual Soils Data, Borings 98-49 & 98-82 | 12Jun99 | S | | RT | |
| 293 | G | Document | Fugro | Large Offshore Hammer Inventory and Manufacturers | 00Jun99 | S | | RT | |
| 294 | | Document | Fugro | Dynmaic t-z & p-y Method for Bay Bridge SSI Model for 2.5m Diameter Piles | 09Mar99 | S | Additional work for refined input & motion? | RT | |
| 295 | | Letter | Astaneh | Transmittal Letter w/ copies of slides, articles, and references to information. | 03Jul00 | R | | RT | |
| 296 | | Proposal | Mayor - SF | Proposed Scope of Work w/ 17 Questions | 27Jun00 | | Presented at 6/27 Mtg. | MR | |
| 297 | | Information | Astaneh | Information to Facilitate Document Review | 27Jun00 | | | | |
| 298 | | Report | Astaneh | Seismic Design, Evaluation and Retrofit of Steel Bridges. Report # UCB/CEE-STEEL-96-09 ; Printed November 1996 | 05Jul00 | | | | |
| 299 | G | S Information | Quest | 2 Papers: 1st - 3-D Structural Influences ... 1989 Loma Prieta ... 2nd - Calcs of Broad Band Time Histories of Ground Motion: Comparison of ... 1994 Northridge | 06Jul00 | | Ref Only | | |
| 300 | A | Information | Caltrans | Caltrans Deputy Directive to Minimize Motorist Delay | 15Jun00 | | | | |
| 301 | A | Information | Caltrans | Power Point Slides for Presentation, 6/28 by Steve Hulsebus & Maroney | 28Jun00 | | | BF | |
| 302 | A | Information | Caltrans | CD-ROM for Power Point Slides, Presentation, 6/28 by Hulsebus & Maroney | 28Jun00 | | | | |
| 303 | A | S Document | Caltrans | Peer Review Minutes, E. Span Retrofit, 12/3/93 to 12/13/99; X-Ref Doc 268. | 03Jul00 | R | Minutes reference other docs | YG | |
| 304 | | Video Tape | Corps | SFOBB / Corps Kickoff meeting, 6/27 & 28/00 | 28Jun00 | | | | |
| 305 | A | C Document | Caltrans | 30% Design Definition for Type Selection of the Bay Bridge East spans Replacement Project | 14Aug97 | S | Used for Quantity Estimates | BF | |
| 306 | S | Specs | Caltrans | Structural Specifications for 65% Main Span | 25Aug99 | S | | | Hulsebus |
| 307 | S | Specs | Caltrans | Structural Specifications for 85% Sky Way | 15Feb00 | S | | | Hulsebus |
| 308 | S | Design | Caltrans | INDEX of Main Span (Suspension) Design Calcs | 11Aug99 | S | | | Hulsebus |
| 309 | S | Design | Caltrans | SFOBB East Spans Retrofit-504' Truss Seismic Retrofit-Design Loading and Truss Analysis w/details (w/disks) | 00Jan96 | R | Strategy Notes | PS | |

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|-------|-----|----------------|-------------|---|---------|-------------------------|--|----------|-------------|
| 310 | S | Design | Caltrans | SFOBB East Spans Retrofit-YBI Tower and Foundation Retrofit Seismic Model and Strategy Notes (w/disks & strategy report) --(Summary of Steel vs Conc) | | R | | PS, AC | Asnaashari |
| 311 | S | Design | Caltrans | SFOBB East Spans Retrofit-Steel Tower E5-E-8, E10-E16 Encasement in the Bay | 00Oct95 | R | Composite Discussion | PS | Sadek |
| 312 | A | Value Analysis | CT/TVI | San Francisco-Oakland East Bay Bridge Replacement EA04-10200K, Contract 53A0005 | 00Jun98 | S | | BF | Falsetti |
| 313 | | Report | TYL/DOKKEN | SFOBB East Span Seismic Safety Project-Demolition Technical Memorandum-Bridge Removal | 24Apr98 | S | | BF | Falsetti |
| 314 | | Report | TYL/DOKKEN | SFOBB East Span Seismic Safety Project-Demolition Technical Memorandum-Bridge Removal-Supplement to Section 5, 290' Span Steel Truss | 24Jun98 | S | | BF | Falsetti |
| 315 | | Report | TYL/DOKKEN | SFOBB East Span Seismic Safety Project-Cost Report-Bridge Removal | 11May98 | S | | BF | Falsetti |
| 316 | A | Display | Caltrans | SFOBB Plan and Elevation for East Bay Spans, Display | | R | | | Maroney |
| 317 | A | Display | Caltrans | SFOBB East Bay, Cantilever Retrofit, Seismic Deflected Shape by Adina Modeling | | R | | | Maroney |
| 318 | A | Display | Caltrans | SFOBB East Bay Spans, Retrofit-Elevation & Global Dynamic Seismic Model | | R | | | Maroney |
| 319 | | Report | CT | Geotech Design Report, Oakland Mole Touchdown, Seismic Safety Report | 00Dec99 | | | | Hulsebus |
| 320 | | Minutes | CT | EDAP Meeting Minutes from 4/9/97 to 9/24/99 | 17Jul99 | | | | Hulsebus |
| 321 | | Report | CT | Caltrans Presentations to COE on 06/28/00, 2 Vols., A & B (submitted previously on CD-ROM, Doc 302) | 17Jul99 | | | | Hulsebus |
| 322 | C | Design | CT/Traina | Bid Analysis and Summaries on various contracts from 03/20/97 to 09/08/99, Add 8/08/00 | 11Aug00 | | | BF, WH | Traina |
| 323 | G | Design | CT/Adams | Retrofit Strategy for the SFOBB Foundations E17 - E23 - summary --(strategy discussion and brief analysis summary) | 18Jul00 | R | good discussion | PS, DG | Adams |
| 324 | G | Design | CT/Maroney | Executive summary - Seismic Hazard Ground Motion Criteria | 01Jul99 | R | S Design Criteria | RT | Maroney |
| 325 | S | Design | CT/Maroney | Adina - Global Baseline Model --(Brief summary of model. See Doc 318, Display) | | R | need more detail, good starting point. | PS, AC | Maroney |
| 326 | S | Design | Caltrans | SFOBB East Bay Cantilever Retrofit, EQ Retrofit Strategy Summary Report -- (detailed summary of cantilever.) | 11Jul00 | R | good summary | PS, BF | Van de Pol |
| 327 | | Design | Caltrans | SFOBB East Bay Spans, Retrofit-Elevation & Global Dynamic Seismic Model - Diskettes(4 copies of same) | 13Jul00 | R | | | Mitchell |
| 328 | S | Design | CT | SFOBB East Bay Cantilever Retrofit, Seismic Summary Report at Cease Work | 22Nov96 | | | PS, BF | Lynch |
| 329 | A | Document | Governor | Governor's Action Request (GAR) Decision to Replace Existing with New | 07Feb97 | | | MR | Hulsebus |
| 330 | | Report | CT | Study - Rock Slope Stability @ YBI Piers E1 & E2 Retrofit | 16Jun97 | R | | MR | Beck |
| 331 | | Report | Earth Mech | Executive summary - Seismic Hazard Ground Motion Criteria | 15Jun99 | S | | | Lam |
| 332 | | Report | Earth Mech | Revised Draft, Main Span & Skyway, Axial Pile Design & Drivability, Seismic Safety Project | 01Aug99 | S | | DG | McNeilan |
| 333 | | Memo | Earth Mech | Effects of Lateral Spreading on Pile @ Oakland Mole, Response to Comments For SFOBB East Span Seismic Safety Project | 20May99 | S | | | Law |
| 334 | | Seminar | UCB | UCB Engineering Seminar - Computational Simulation of the Transient Response of Long Span Bridges, McCallen, Larsen, Astaneh. | 23Nov98 | | | | |
| 335 | | Report | Earth Mech | Seismic Ground Motion for SFOBB East Span Seismic Safety | 24Dec98 | | | | Law |

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|-------|---------------|------------|-------------|---|---------|----------------------------|---------|-------------|----------------|
| 336 | Report | Earth Mech | Earth Mech | Final Marine Geotech Site Characterization, SFOBB East Span Seismic Safety Project, Vol. 1A- Main Test & Vol. 1B-Plates | 00Feb99 | S | | DG | McNeilan |
| 337 | Report | Earth Mech | Earth Mech | Final 2-D Marine Geophysical Survey Report, SFOBB East Span Seismic Safety Report | 00Jun98 | S | | | McNeilan |
| 338 | Report | Earth Mech | Earth Mech | Draft-Final 3-D Marine Geophysical Survey Report, SFOBB East Span Seismic Safety | 00Aug99 | S | | | McNeilan |
| 339 | Report | Earth Mech | Earth Mech | Final-Oakland Shore Approach, Geotech Site Characterization Report, SFOBB East Span Seismic Safety: Vol. 1-Main Text; Vol.2A-Appendices Land Borings 98 - 51 to 60; Vol. 2B-Appendices Marine Borings 98 - 39 to 44; Vol. 3- Appendices CPT Soundings; Vol. 4-Additional Reports, Memos & Testing | 00Aug99 | S | | | McNeilan |
| 340 | Memo | Earth Mech | Earth Mech | Summary of Studies For Lateral Spreading of Fills at Oakland Mole, SFOBB East Span Replacement | 25Aug99 | S | | | Law |
| 341 | Vacated | | Vacated | Duplicated at 294 | 25Jul00 | | | | |
| 342 | Report | Earth Mech | Earth Mech | Rock Slope Stability Report For West Pier & Main Pylon, SFOBB East Span Seismic Safety | 00Oct99 | S | | | Law |
| 343 | Directive | Caltrans | Caltrans | Deputy Directive - Transportation Management Plans - Traffic Delays & contingencies. | 15Jun00 | | | BF | |
| 344 | Document | Caltrans | Caltrans | SFOBB East Spans Seismic Safety Project, Seismic Design Criteria, Replacement, ver12. | 27Jun00 | S | | AC, RT | Maroney |
| 345 | Index | TYL | TYL | SFOBB East Bay - YBI Transition - Index for 65% Structural Design Calcs, 4 Vols. & Appdx. | ?? | | | | |
| 346 | Index | TYL | TYL | SFOBB East Bay - Skyway - Index for 65% Design Calcs & Analysis | ?? | S | | BF | Abbas |
| 347 | Diary | TYL | TYL | SFOBB East Bay - Seismic Safety Project - Weekly Diaries 3/97 to 6/97 | 19Jul00 | | | | |
| 348 | Index | Caltrans | Caltrans | SFOBB East Bay Spans - Testing Programs - 8 count list | 19Jul00 | | | | |
| 349 | Document | Caltrans | Caltrans | SFOBB East Bay Spans - Testing Program - Scope of work. | 08Apr00 | | | | |
| 350 | Document | TYL | TYL | SFOBB - Quality Assurance /Quality Control Plan - Update | 17May99 | | | | |
| 351 | Document | Caltrans | Caltrans | SFOBB East Bay Summary of Cost Estimates, Comparison of Retrofit to 30% Replacement | 20Jul00 | | | BF | |
| 352 | Letter | CT | CT | Bolt/Fish Response To COE - Concerning 10" Displacement - SFOBB East Spans Seismic | 11Jul00 | | | | Fish/Bolt |
| 353 | Specs | Caltrans | Caltrans | SFOBB Skyway Structures, 100% in Progress (01) Specs | 02Aug00 | S | | | Akinsanya |
| 354 | Report | CT | CT | SFOBB East Spans Retrofit - Project Description 7/96 & Performance Criteria Statement 1/97 - by Zelinski | 21Jan97 | R | | BF, MR | Zelinski |
| 355 | Vacated | | Vacated | Vacated to Doc 25 due to duplication | 25Jul00 | R | | | |
| 356 | Search | Maroney/CT | Maroney/CT | Work Product by Maroney - for Astaneh Document 1992 | 19Jul00 | R | | BF | Maroney |
| 357 | Document | Caltrans | Caltrans | SFOBB East Spans YB1-E23, Analysis procedure from linear to non-linear | 30Jun94 | R | | MR | Maroney |
| 358 | Document | Caltrans | Caltrans | SFOBB Cantilever Segment -Seismic retrofit, strategy selection. | yr96 | R | | MR | |
| 359 | Photos | Caltrans | Caltrans | SFOBB Photos w/Captions showing Interim Retrofit examples of difficulties, issues, dangers, environmental problems, and others. | 31Jul00 | R | | | Hulsebus |
| 360 | Document | Caltrans | Caltrans | SFOBB Retrofit Strategy 288' Trusses, E9-E23, Exit Report for Peer Review | 30Oct95 | R | | BF | Hight |
| 361 | Document | Caltrans | Caltrans | SFOBB Cable Stay, Alternatives #1-#3, Cost Backup for "GAR" Alternatives, Structure cost only. | 00Aug96 | S | | BF | Traina |

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|-------|-----|--------------|-------------|--|---------|-------------------------|--------------------------------------|------------|-------------|
| 362 | | Document | Caltrans | SFOBB Viaducts, Alternatives #1-#3, Cost Backup for "GAR" Alternatives, Structure cost only. | 00Aug96 | S | | BF | Traina |
| 363 | G | Report | Caltrans | SFOBB East Span Seismic Retrofit Geotechnical Reports, 14 Items per Memo, 8/03/00. - Add to - Rock Motions for San Andreas Event by Norm Abrahamson, 1994 | 03Aug00 | R | Best geotechnical reference document | MR, AC, GC | Abghari |
| 364 | S | Report | Caltrans | SFOBB Cantilever Truss Retrofit, Project #8, Edge Truss Investigation Report -- Modeling | 18Jan96 | R | | RT | Van De Pol |
| 365 | C | Report | Caltrans | SFOBB Cantilever Truss Retrofit, Project #8, Edge Truss GP Estimate Elements (for Existing Structure Strengthen) Contract Costs and Discussion | 30Jan96 | R | | RT | Van De Pol |
| 366 | C | Report | Caltrans | SFOBB Cantilever Truss Retrofit, Project #8, Edge Truss GP Estimate Elements (for Existing Structure Strengthen) Individual Responsibilities | 16Jan96 | | | | Van De Pol |
| 367 | S | Calcs | CT/TYL | SFOBB East Bay, Suspension Span Design Calculations 65% Submittal - 41 Volumes. Vol. 1 w/ Design Criteria 4/9/99, Rev. 6. | 09Apr99 | S | | CW, RT | |
| 368 | S | Des Code | AASHTO | Proposed LRFD Guide Specifications for Design of Segmental Concrete Bridges, January 1997 | 00Jan97 | S | | | Akinsanya |
| 369 | S | Des Code | AASHTO | Guide Specifications for Design and Construction of Segmental Concrete Bridges, Proposed 2nd Edition, January 1998 | 00Jan98 | S | | | Akinsanya |
| 370 | C | Document | Caltrans | SFOBB Cost-Estimate Comparison. Compares between Retrofit, 30% Replacement, and 65% Replacement. | 11Aug00 | R/S | | BF, WH | Traina |
| 371 | G S | | Caltrans | SFOBB GP/ Planning study - Alternative #1 Viaduct - Seismic analysis by Mario Velado, lead design engineer (see gray report Doc 252) (Vols. A - C) | 12Mar96 | S | | BF, RP | Velado |
| 372 | A | Minutes | Caltrans | CALTRANS Seismic Advisory Board Meeting Minutes, 1/03/93 thru 10/10/95 and 12/05/95 thru 5/30/00. | 17Aug00 | | | BF | Gates |
| 373 | S | Manual | Caltrans | SFOBB Seismic Retrofit Evaluation & Design Manual for Latticed Members & Connections. Final Draft by Latticed Members Task Group. | 00Apr95 | R | | | Sadek |
| 374 | S | Calcs | Caltrans | SFOBB Retrofit for Cantilever & Towers E3, E2 - Design Calcs & Exit Notes | 28Jan97 | R | | BF | Soon |
| 375 | | Document | Boyle/CT | Exit Report for Contract 3 of SFOBB East Span, Retrofitting Cassions w/email from Moran --(Also refer to Docs 172, 180, 189, 194, 195) | 22Aug00 | R | | | Moran |
| 376 | G | Documents | Caltrans | Geotech and Foundation Reports for Proposed New East Span of SFOBB. List shows item #4 with twenty one bullets. | 96 & 97 | R | | DG | Akinsanya |
| 377 | A | Letter | Astaneh | Astaneh Letters, to MTC 6/24/98 - Seismic Safety of Replacement: to MTC Task Force 6/20/98 - Seismic Safety w/ Attachments | 24Aug00 | S | | | Astaneh |
| 378 | S | Calcs | CT/TYL | SFOBB East Bay, Skyway Superstructure Design Calculations 65% Submittal - 17 Volumes. Vol. 1 w/ Design Criteria 7/16/99, Rev. 7. | 15Jul99 | S | | | Akinsanya |
| 379 | A | Document | Caltrans | SFOBB Retrofit, Cantilever Strategy meeting minutes from 4/95 to 11/96 | 24Aug00 | R | | | Zelinski |
| 380 | A | Document | Caltrans | SFOBB Retrofit, General Team Strategy meeting minutes w/ Design Engineers from 7/94, 8/95, 1/96 | 24Aug00 | R | | PS | Zelinski |
| 381 | S | CD | Caltrans | SFOBB Suspension Span, East Pier Analysis. 2-dimensional site response, input, output, and time history info using QUADA. 4 CD copies w/ Transmittal Letter. | 06Sep00 | S | | CW | Hulsebus |
| 382 | C | Letter | Caltrans | SFOBB East Bay Retrofit Estimate, Explanation for Cost Calcs, "Division by 2" As shown in Doc 249. | 28Aug00 | S | | WH | Maroney |

SFOBB Document Inventory, Table for Data Catalog

| Doc # | Subject | Provided by | Description | Date | REMARKS | Rev | CT Eng |
|-----------------------------|----------------|-------------|---|-------------|-----------------------------------|------|--------|
| ## | Grp:Grp: Type | | | | R/S (Retrofit / Signitr) | init | name |
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| HISTORICAL DOCUMENTS | | | | | | | |
| 1 | Historical | | First to Sixth Annual Progress Report SFOBB | 7/34 - 7/36 | ?Check Doc #'s and revise | | |
| 2 | Plans | Caltrans | Final Report drawings for SFOBB | 1930's | Docs 181 to 182 Find & Clarify | | |
| 3 | Specifications | Caltrans | SFOBB Specifications Contract No. 3 - San Francisco Anchorage | yr1933 | Find & Clarify | | |
| 4 | Specifications | Caltrans | SFOBB Specifications Contract No. 4 and 4a - Substructure East Bay Crossing | yr1933 | Find & Clarify | | |
| 5 | Specifications | Caltrans | SFOBB Specifications Contract No. 5 - Yerba Buena Crossing | yr1933 | Find & Clarify | | |
| 6 | Construction | Caltrans | SFOBB Construction Report Contract No. 2 - West Bay Crossing | yr1933 | Find & Clarify | | |
| 7 | Specifications | Caltrans | SFOBB Specifications Contract No. 7 - Substructure East Bay Crossing | yr1933 | Find & Clarify | | |

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Appendix 4. Retrofit Support Documents

Executive Summary for the Proposed Retrofit Alternative

This appendix discusses the proposed retrofit for the East Span of the SFOBB. The retrofit was divided into 11 separate contracts that included various portions of the proposed retrofit. Seismic and geotechnical considerations as they pertain to all contracts are discussed, followed by independent evaluation of each contract. For each contract, geotechnical and seismic issues and analysis and criteria are described and evaluated. Conclusions drawn for individual contracts do not necessarily reflect conclusions for the entire retrofit. Comments in this summary are based on evaluation of the entire retrofit proposed.

Although various alternatives had been considered, only a conceptual design had been completed for the cantilever portion. With exception of the cantilever portion of the bridge, the proposed retrofit alternative was based on an isolation strategy. Foundations and towers were to be strengthened and stiffened, isolation bearings were to replace existing bearings and the superstructure was to be strengthened at various locations. The cantilever portion of the bridge was to be modified by reinforcing the pier foundations, modifying the towers, adding two new towers, and separating the trusses into three spans.

A consistent and formal definition of performance and design criteria that pertains to the bridge as a whole has not been identified. It appears that the initial goal was to provide lifeline conditions, and ensure elastic behavior; however, this criterion was not clearly defined for all portions of the structure, and criterion is not consistent for all portions of the structure. The design criteria for the cantilever portion of the bridge were apparently relaxed and a no-collapse or no-drop criteria was considered. Analysis to substantiate the performance level was not complete.

Adequate and appropriate subsurface and physical property investigations were carried out to determine the soil properties. Appropriate procedures were employed to develop five ground motions for the site, and the maximum earthquake magnitudes and rock ground motions are appropriate. However, kinematic interaction of the foundations and soil for retrofitted foundations was not considered, and the effects of possible differential permanent displacements that could occur between the adjacent piers for a situation where one support is founded on rock (Pier E1) and another on soil (Pier E2) were not considered.

Analysis and design calculations are included in various documents, most of which are incomplete and unorganized, with few narratives, plots, figures, or tables describing the actual procedures or results. The documentation does not provide a clear statement on specific requirements regarding the type and sequence of analysis, or how the various analyses are inter-related. Several types of models of varying complexity were generated, but it is not explained how results of these various analyses were coordinated in determining retrofit strategies (Data Gap 9). For certain contracts (Contracts 4 and 5 and

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9), there is very little evidence of time history analyses, and summaries of the meaning of results are not available. Verification of various models was not fully determined (Data Gap 5).

It is evident that a considerable effort was given to development and utilization of a global model of the full structure employing ADINA. There is, however, no detailed description of the model or discussion of results. Furthermore, there are questions regarding validity of the analyses that were carried out. In various analyses, it was reported that the structure damping was increased from 5% damping to 10% damping, apparently to reduce the isolator displacement demand. The level of damping used in the analysis was never justified and is inappropriate for a nonlinear dynamic analysis. In analyses that include isolation bearings (i.e. retrofitted structure) it is apparent that the properties of the retrofitted cantilever structure were not included.

Various other retrofit alternatives were considered on a local basis for given contracts. There were no other global retrofit alternatives that were considered with any level of detail.

Conclusion Statement

- The validity of a base isolation strategy has not been demonstrated and is questionable.
- The basis for a demand capacity ratio (D/C) limit of one to satisfy lifeline performance criteria has not been demonstrated and is questionable.
- Analyses were not adjusted to reflect the proposed retrofit concepts for final design efforts.
- The retrofit design was not developed to a level that substantiates the validity of the retrofit strategy.

Given the items noted above, the seismic reliability and reasonableness of the retrofit cannot be assumed. This conclusion does not imply recommendation of either retrofit or replacement. Rather, it is not clear that the decision to replace was based on a substantially completed engineering effort.

1. Introduction

This appendix describes the proposed retrofit alternative. It is organized first to cover those factors relating to the East Span retrofit as a whole, followed by a summary of the retrofit contracts and evaluation of each contract.

Considering the East Span as a whole, the current retrofit strategy considered relies heavily on one item – isolation of the superstructure. This concept resulted in modification of a long period structure that resulted in a structure with similar period. The concept, therefore, does not appear to improve the overall performance, and analyses were not conducted to substantiate the viability of this chosen retrofit alternative.

Criteria

The SFOBB has been designated as a lifeline route on the State Highway System. As such, it has been deemed critical that the bridge remain open immediately following a major earthquake for emergency response/life saving activity use. This project has been subject to a two-part performance criteria as described in the following paragraphs.

A formal definition of lifeline and associated performance and design criteria that pertains to the bridge as a whole has not been identified. It is evident, however, that various qualitative and quantitative criteria were established. In a letter from James Gates, Chief, Office of Earthquake Engineering (1993), requirements for a functional evaluation earthquake (FEE) and a safety evaluation earthquake (SEE) are specified (a similar, somewhat refined version, is provided in the 1997 GAR, [Document 329]). For important bridges including the SFOBB, immediate service level with minimal damage following the FEE event is required. Terminology such as "minimal damage" is ambiguous and requires further definition to define design requirements. In a performance criteria statement from January 21, 1997, the following is stated [Document 354]:

- The original performance goal was to provide full serviceability immediately following the SEE, (the maximum earthquake that the retrofit bridge is designed for). This goal was in accordance with the recommendation from the Governor's Inquiry Board following the 1989 Loma Prieta Earthquake.
- However, a series of analyses for varying strategies (apparently related to the cantilever span) and cost-benefit studies caused Caltrans management to retreat from this idealistic goal.
- The current goals will allow access to emergency vehicles within hours of the event; limited public access within one month; 3 lanes of public traffic each direction after 6 months; and full traffic after one year. (This criteria is not substantiated by quantifiable criteria.)
- The goal is designed to be consistent with expected damage on both sides of the bay in a SEE event, and the limited need for public traffic to cross the bridge under those circumstances.

On this basis, Caltrans' engineers developed the following qualitative criteria:

- deck system and supports must remain elastic
- damage of service load carrying members limited to minor yielding
- minor buckling of service load carrying members allowed if capacity not reduced
- local buckling of wind bracing allowed
- permanent deflections must be less than a few inches
- expansion joints and seats will be designed for 1.25 times the maximum calculated displacement

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- damage to foundations, piles, and all portions of structure below water is not allowed.

These criteria are somewhat vague, and a summary of how these criteria were met with the given retrofit is not provided in any of the documents. This statement did provide a direction during the early parts of the studies (mid-year 1995).

Criteria regarding structure response to the ground motion were not clearly defined for all portions of the structure, and consistent criteria were not utilized for all portions of the structure. A 1994 (Caltrans) letter provided preliminary guidelines on determining capacity of various steel and concrete members and specified a limiting D/C of 1.2. These criteria were provided as a guide to develop a preliminary cost estimate. Later documents pertaining to superstructure and tower retrofit show that this limit was taken as 1.0. This was consistent with the original lifeline performance goal and was followed for most of the bridge excluding the cantilever portion. The relaxation of the criteria from the lifeline criteria is apparently a result of the studies for the cantilever section. Similar specific performance criteria were never developed for foundations.

It is evident that the goal of retrofit was to provide a structure that would remain elastic under the SEE. The criteria, however, is not consistent, may be over-conservative, and were not fully developed for foundations. Elastic D/C was used for the 288' and 504' spans and these elastic criteria were apparently abandoned for the cantilever portion of the bridge. A no-drop strategy was specified and specification criteria were not developed. It appears that Caltrans relaxed the elastic requirement to a realistic goal for the cantilever spans as alternatives were identified and analyzed. Regarding the requirements to remain elastic, it is arguable as to whether such conservative limitations ($D/C < 1.0$) are necessary to satisfy the lifeline or service level requirements. Studies to pursue structural behavior with allowance of D/C greater than 1.0 were not conducted. For foundations, specific performance criteria in terms of acceptable D/C ratios were not developed. Designers were given the latitude to develop retrofit strategies that would accomplish the overall lifeline performance objective.

2. Seismic Evaluation

2.A. Description

The SEE ground motions for the existing and retrofitted East Span were developed deterministically for two maximum credible earthquake events on the Hayward and San Andreas faults. The maximum magnitudes for these events were based on a Geomatrix Consultants study of seismic hazard for the Northern California bridges and the 1992 study by Bolt and Gregor for the East Span. The 84th percentile ground motions were developed for each event. According to the Geomatrix probabilistic hazard assessment of ground motions for the Northern California bridges, the 84th percentile level of ground motion is between 1000- and 2000-year return period equal hazard spectra. The estimated peak bedrock ground accelerations for these events ranged from 0.55 g to 0.65 g [Documents 72, 96, 189, 325, 363, 375].

2.B. Earthquake Ground Motion Criteria

The safety evaluation earthquakes adopted for the East Span of Bay Bridge were two maximum credible earthquake events on the Hayward and San Andreas faults. A moment magnitude of $M_w = 7.3$ was assigned to the Hayward fault located 8 km from Pier E23 and a $M_w = 8$ to the San Andreas Fault located 19 km from Pier YB1. The ground motions were characterized in terms of two response spectra at Pier E23 for the Hayward event and at Pier YB3 for the San Andreas event. These response spectra were developed for the 84th percentile level of ground motions using a composite of the most recent attenuation relationships. The average horizontal response-spectra obtained in this manner were adjusted to obtain fault-normal and fault parallel components. The rock motion acceleration time histories for each event were developed to match the respective response spectra and then were computed at each pier location by applying the spatial variation effects.

2.C. Rock Motions

Rock motion target response spectra were developed at Pier E23 for the Hayward event and at Pier YB1 for the San Andreas event using a composite attenuation relationship at the direction of the Peer Review Panel. Two sets of three-component acceleration time histories were developed for the Hayward event. The first set developed using the 1993 procedures was conservatively not attenuated along the length of the bridge and was judged deficient in the long period energy. Learning from the 1994 Northridge earthquake, the second set was developed to include sufficient amount of long-period energy and the recommended composite attenuation relationship. These modifications increased the target response spectra by 12% at periods greater than 1 second. The initial time histories used as a seed for the Hayward event were the Corralitos recording from the 1989 Loma Prieta earthquake. The initial seed records were then modified to be compatible with the target spectra.

Three sets of three-component acceleration time histories were developed for the San Andreas event. Again, the first set developed using the 1993 procedures was conservatively not attenuated along the length of the bridge and was deficient in the long period energy. The second and third sets developed after the 1994 Northridge earthquake were modified to include sufficient amount of long-period energy and the recommended composite attenuation relationship. The long-period energy was increased up to a period of 3 seconds for the second set and up to a period of 10 seconds for the third set. Since there are no recordings at close distances from a magnitude 8 strike-slip event, numerical simulation procedures were used to generate initial seed motions for the San Andreas event. The initial seed motions were then modified to be compatible with the respective target response spectra.

The response-spectrum-compatible time-histories at Pier E23 for the Hayward event and at Pier YB1 for the San Andreas event were further modified using the spatial variation effects to generate rock motion time histories at the location of each pier. For each event, the resulting multi-support sets of time histories are similar in waveforms and frequency contents and only differ with respect to long-period energy and attenuation along the length of the bridge.

2.D. Site Response Effects

The rock motions discussed above were further modified by propagating through soil columns to obtain site-specific ground motions at appropriate foundation levels for the structural analysis. Three-component free-field acceleration and displacement time histories were generated at Piers E1 to E23 and YB1 to YB4 using the program SHAKE. The soil properties were based on 10 borings and were interpreted for piers between the test borings. For E6 to E23, the ground motions for pile foundations were developed at the bottom of pile caps. Where the pile caps were located in the Bay Mud, the ground motions were generated at a depth just beneath the Bay Mud. The ground motions for spread footings at YB2 to YB4 were generated at the bottom of the footing. The motions at caisson piers E3 to E5 were generated at dense sand directly underlying the Bay Mud. The ground motions at pier YB1 were computed at a depth of 23 feet from the ground surface. The resulting acceleration time histories were then used to develop acceleration and displacement response spectra at these locations for the response-spectrum analysis of various segments of the bridge.

It should be noted that the foundation ground motions developed in this manner do not account for the kinematic interaction effects of the pile foundation. The kinematic interaction analysis was conducted only for existing caissons beneath the cantilever section as discussed below. The kinematic interaction analysis was also not performed for the retrofit pile foundations, which are substantially larger than the existing timber piles.

2.E. Soil Structure Interaction

The first step of the soil structure interaction analysis consisted of the performance of seismic soil response analysis for the soil profile specific to each pier location, in the absence of the foundation structure, i.e. it constituted an analysis of the free field conditions. Our review of these analyses indicated that they were performed using reasonable assumptions and a commonly used computer program (SHAKE). Specifically the shear wave velocity profile assumed at each location was consistent with field-measured values, which are reasonable for the soil types present at each pier. The earthquake records used in the analysis were consistent with the bedrock motions selected for the SFOBB project and were appropriately input at the bedrock level.

For piers E2 through E5, which are supported on caissons, an analysis of the seismic interaction of the caisson with the adjacent soils was performed. A stick model was used for the caisson, connected to the adjacent soils by means of a series of both horizontal and vertical springs (referred to as p-y and t-z respectively). The vertical and horizontal ground motions computed from SHAKE were then applied to the end of the corresponding springs opposite the caisson at various elevations. The movements obtained for the top of the caissons were then used as input to the bridge piers with springs representing the caisson foundation. The springs were uncoupled (e.g. coupling between horizontal and rocking modes was not considered). The analyses indicated overstressing of the caissons and thus a discussion was presented on alternatives for strengthening the caisson foundations. However, an actual design for retrofitting the caissons was not included in the information available to us.

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For piers E6 through E23, which are pile supported, we found no information as to whether a seismic soil-structure interaction (SSI) analysis was performed. It appears that the seismic input to the superstructure was chosen as the SHAKE output at the base of the pile cap elevation. Thus the potential change in the seismic motion caused by the presence of the piles was ignored. While this assumption would be reasonable if only the existing timber piles were present, it is not apparent that the presence of the much stiffer 60-in. diameter piles included in the retrofit can be ignored.

There was no information available to us that indicated an analysis was performed of the stresses in the piles due to the ground movements computed from SHAKE, often referred to as kinematic effect. In our opinion, these effects may be significant for the 60 in diameter piles and for any batter piles.

Permanent ground movements. The potential for permanent ground movements associated with accumulation of seismically induced strains in the soils surrounding and/or beneath the caissons and the pile foundations was not specifically addressed in the documents made available to us. Note that if such movements were to occur they may be additive to the tectonic differential movements that occur between piers. In response to this issue, the Caltrans seismic advisory board offered an estimate of less than 1 cm differential permanent bedrock movement between two adjacent piers. Although this estimate is appropriate for supports founded on rock, it may not be suitable for a situation where one support is founded on rock (Pier E1) and another on soil (Pier E2).

2.F. Appropriate Criteria

The Caltrans criteria for the maximum earthquake magnitudes and rock ground motions are appropriate. The criteria follow standard procedures that were available at that time and were later modified to account for the long-period energy observed in the 1994 Northridge earthquake. However, the effects of possible differential permanent displacements that could occur between the adjacent piers were not considered.

3. Geological and Geotechnical Site Investigations

3.A. Description

Subsurface investigation and field and laboratory testing was performed to provide data for evaluation of retrofit schemes and design. The historic data (prior to Loma Prieta) was supplemented by investigations in 1994 through 1996. Downhole geophysical measurements were made to establish and/or confirm the seismic soil properties. Additional and more extensive investigations were performed starting in 1998 for the replacement structure, but these were not available during the retrofit study.

Except for the portion of the bridge on Yerba Buena Island, the generalized subsurface profile consists of the following stratigraphic sequence: Young Bay Mud underlain in succession by the Merritt/Posey/San Antonio Formation, the Yerba Buena (Old Bay) Mud, the Upper and Lower Alameda Formation, and lastly the Franciscan Complex (bedrock). Bedrock slopes steeply from the east side of Yerba Buena Island to

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approximately elevation -300 ft and then slopes gently down to the east to approximately elevation -440 ft. in the vicinity of the Oakland touchdown. Yerba Buena foundation conditions consist of alluvial deposits over the Franciscan Formation or just the Franciscan.

3.B. Geotechnical Considerations [Documents 27, 267, and 363]

Sufficient subsurface exploration, insitu testing and laboratory testing exists to adequately characterize foundation conditions along the SFOBB alignment. The subsurface and physical property investigation appears adequate to support a retrofit design, including new larger and longer piles and seismic characteristics.

3.C. Condition of Existing Foundations

Only the condition of the exposed portions of the foundations was apparently checked following the Loma Prieta earthquake. No documentation of the condition of the buried foundations, in particular the timber piles, was found in the documents. Research and load tests of old timber piles was planned but was abandoned due to deterioration of the wood outside of its saturated environment [Document 2]. Caltrans notes speculate that some battered timber piles may have been damaged during the Loma Prieta earthquake [Document 373].

The assumption of minimal or insignificant deterioration of the timber after 65+ years is not unreasonable based on experience in Bay Area and previous timber pile research. Whether physical damage to the piles has occurred as a result of excess lateral loads is unknown. Caltrans apparently assumed no damage. This is a potentially significant data gap in the retrofit scheme since the intent was to add new Cast-In-Steel-Shell (CISS) piles to supplement the capacity of the timber piles. The net effect of confirmed or assumed damage to the timber would likely be to increase the cost of the retrofit.

4. Global Model

4.A. Description

Documentation of the ADINA global baseline model is incomplete and vague [Documents 72, 325]. It includes a computer-generated plot of the model, a few presentation viewgraphs, and some notes, but no description of the assumptions and discussion of the results. The notes indicate four global models, which are a fixed base model, a rocking model, a spherical isolator model, and a cylindrical isolator model. The isolators are friction pendulum bearings with a period of 5 seconds and friction coefficient of 6%. The purposes of the various global models and their relationship to local models were not defined. This was identified as Data Gap No. 9 in our Phase 1 report. From the limited output data it appears that the global model was intended to provide an estimate of the maximum displacements and the maximum loads exerted on the footings to assess the base isolation retrofit scheme. Apparently, displacement histories from the global model were used as the input for a more detailed analysis of the 504' truss system.

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The superstructure, in the global model, was represented using frame elements with lumped masses. The properties of the frame members and masses were derived from separate GTSTRDL models developed for 288', 504', and cantilever truss spans. The lumped properties of the superstructure included axial and bending stiffness, and total mass of the truss. The mass of the truss was located at superstructures center of gravity.

The effects of pile foundation were represented by uncoupled translational and rotational springs included at the base of towers. The tower was fixed in the vertical direction, thus no vertical and torsional foundation springs were included. Mass of tremie, pedestal, and enclosed water was represented as a point mass at the center of gravity. Tremie and pedestal were considered rigid due to expected retrofit.

It appears that contact surfaces were included at the tower-foundation interface for towers YB2-YB4 and E2-E16 to model rocking response. Expansion joints at towers YB3, E4, E11, and E17-E23 were modeled using gap elements. Elements to represent friction pendulum bearings were included at Piers E4 to E23, but the adequacy of these elements in capturing the actual behavior of the bearings was not discussed.

4.B. EQ loading and Application

Earthquake loading consisted of multi-support displacement histories. The input displacement histories were obtained from the SSI analysis. Such a SSI analysis was not referenced, but we assume it is referring to the kinematic interaction analyses conducted for the caissons [Document 325]. We did not find any kinematic interaction analysis for the timber piles, which implies that input at Piers E6 to E23 were free-field displacement histories from the SHAKE analyses.

4.C. Sound Analysis

Nonlinear time-history analysis using multi-support excitation was performed for the global model. Initially a Rayleigh damping of 5% with an 8-second isolator having a friction coefficient of 6% was used, which resulted in a maximum isolator displacement of 60 in. at Pier E5. In a subsequent analysis a 5-second isolator having a friction coefficient of 6% with a 10% Rayleigh damping was employed, resulting in a reduced maximum displacement of 40 inches at Pier E4 [Document 325]. At 5% damping, the computed maximum transverse displacement (60 in.) exceeds the isolator displacement capacity of 44 inches, while at 10% damping, the maximum displacement drops below the isolator capacity. A nonlinear dynamic analysis, which explicitly models the isolators and gaps, does not justify increasing the elastic structural damping from 5% to 10%. The energy dissipation due to sliding of isolators and opening and closing of the gaps has already been accounted for through their nonlinear force-displacement relationship, and that the foundation damping effects were considered separately in development of the seismic input using SHAKE and SSI analyses.

The results of analysis are limited to tables of maximum displacements for superstructures, isolators, towers, soil springs, gaps, and footing reactions [Document 325]. No plots of displacement and force histories were provided to examine the results. The isolator permanent displacements, possible steel yielding, and the demand-capacity

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ratios of pile foundations were not determined. The computed force-displacement relationships for the isolators were not provided to check the accuracy of the ADINA modeling procedures.

In summary, the validity of the global baseline model and its results could not be determined. The foundation springs and the seismic input used in the model are those developed for the existing timber pile foundation and not for the retrofitted pile foundation. At a reasonable level of 5% damping, the maximum displacement demand of 5 ft exceeds the isolator displacement capacity of 44 in. It appears the isolator retrofit would work only if a damping value of 10% can be justified. Possible permanent displacements of isolators were not determined.

5. Base Isolation Considerations

5.A. Description

Seismic isolation bearings were proposed and incorporated into the retrofit scheme in response to concerns with the superstructure steel truss elements. The intent was to reduce relative horizontal displacements between each corner of a truss span thus relieving stresses caused by warping of the truss as well as reducing inertial forces of the truss mass [Documents 59, 72, 98, 146, 168].

Seismic isolation bearings were to be located at the top of each column (leg of tower) at all piers with the exception of the original support points of the cantilever structure, E1, E2, E3, and E4. The final retrofit concept that was being considered prior to termination of the retrofit project was to add two new piers, E2A and E2B, between E2 and E3. These new piers would support the joints attaching the drop-in truss segment between the two cantilever sections. The retrofit scheme is to separate the two superstructure types with the end of the cantilever sections fixed to the new pier and the drop-in section supported by isolation bearings.

5.B. Sound Analysis

The computer program ADINA was used for the overall global modeling of the SFOBB. This program has the capability of evaluating nonlinear (such as bearing stiffness and friction) and one directional effect (such as expansion joint gaps) under a dynamic time history. Typically in such an analysis, a global damping of 5% is used for the elastic range of behavior, and damping due to the nonlinear behavior is accounted for by explicit modeling of the nonlinear mechanisms.

Caltrans increased damping for the global ADINA model from 5% to 10% [Document 325]. This increase of damping reduced displacements across the bearings from about 60 inches to about 40 inches. The bearings are designed for a maximum displacement of 44 inches [Document 146] and, therefore, it is assumed the isolation design is based on the 10% damped model. The justification to increase the damping is apparently based on using a higher global damping that is attributed to soil yielding, sliding of bearings (friction pendulum type), concrete cracking, and steel yielding [Document 72]. This is

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inconsistent with the expected linear-elastic performance of the structural members and other considerations discussed below.

As stated in the "Description" above, the isolation strategy was to reduce stresses in the superstructure spans, caused by warping of the truss geometry and due to the inertial forces of the truss mass. As such the superstructure elements, towers and foundations, were designed to remain within the elastic range and should not be analyzed for greater than 5% damping.

The bearings were intricately modeled using the friction and restoring characteristics of the bearings. The isolator damping, whatever its value, was therefore directly accounted for in the nonlinear ADINA model. No additional damping based on isolator bearings can be justified.

Damping generated by soil deformations also seems to have been accounted for in the SHAKE and kinematic interaction analyses that generated seismic input motion and foundation springs for the ADINA model. The SHAKE analyses employed strain-dependent damping curves to produce free-field motions. Kinematic interaction analyses were based on nonlinear p-y and t-z springs to account for the nonlinear soil behavior. Therefore, no further damping for the soil-pile foundation is warranted.

In conclusion, an increase in damping above the typically accepted global application of 5% is not prudent for the retrofitted structure designed to respond elastically. An increase of damping based on inclusion of isolation bearings for the soil structure interaction effects has not been adequately justified in the documents provided.

5.C. Seismic Reliability - Lifeline Criteria or No Collapse:

The use of seismic isolation bearings is an attempt to increase the overall reliability of the structure by reducing damage to the members and joints of the existing steel truss elements. However, the bearings themselves cannot be directly evaluated under this criterion. One must look at the results of their use on various portions of the structure and evaluate the various portions as to their seismic reliability. One such area of concern is the expansion joints between the superstructure spans. Seismic isolation bearings trade off a reduction in force for increased displacement. It was noted in the "Description" above that the bearings would reduce the relative displacement within a truss span. However, the inter-truss displacement at expansion joints would increase. Therefore, the extent of damage to the expansion joint elements may dictate the overall time delay in allowing safe passage of emergency vehicles. Another concern is that the isolation scheme works for a 10% damping but not a 5% damping. Overall the seismic isolation strategy may not be as effective for a long period bridge as it is for short period structures, as described in 4.D. In fact the notes of the 30 October 1995 Peer Review Meeting reference a statement by Professor James Kelly of UC Berkeley, an expert in base isolation, stating "Caltrans may be making a mistake using the isolation strategy for SFOBB." We could neither find a Caltrans response to Professor Kelly's concerns nor any documentation that would support the effectiveness of such a large isolation unit for

SFOBB. Similar concerns were also raised by the seismic advisory board on several occasions [Document 372].

5.D. Validity of Isolation Strategy

Seismic base isolation is typically used to reduce seismic force demands by shifting the period of structure away from the peak of the earthquake response spectra and providing additional damping through friction or other means. As such the base isolation concept is both cost effective and technically sound for stiff structures, where seismic force demands are high.

The as-built periods of vibration for the long-period piers such as Piers E7 [Document 115] and E13 [Document 106] of the East Span of SFOBB are 6.3 and 4.2 sec, respectively. At these periods of vibration the seismic force demands for most of the as-built truss systems are not much different from those for the retrofitted bridge with the 5-sec friction pendulum isolators. On this basis the validity and effectiveness of isolation strategy is questionable because the as-built flexible steel piers transmit approximately the same level of seismic forces to the truss system. Shortening the period of vibration by stiffening piers with the concrete encasement, and then using isolators to elongate the period approximately to the same level of the as-built condition does not appear prudent.

6. Summary of Retrofit Contracts

The proposed retrofit includes work between pier YB1 on Yerba Buena Island and Pier E23 in Oakland. The SFOBB East bay span retrofit project was divided into various separate contracts organized by Caltrans. Each of these contracts is described and discussed in the following sections. The overall retrofit strategy was to reinforce the piers and foundations to provide pure elastic response, and to isolate the superstructure from the substructure by replacing the existing bearing shoes with isolator bearings. In all portions of the bridge except the cantilever, such a scheme was followed. The proposed retrofit as interpreted by the COE design team (the proposed retrofit is not defined anywhere for the bridge as a whole) is summarized by the following.

- (1) Span between Pier YB1 and Pier E1 (Contract No. 2 and Contract No. 10). The YB2, YB3 and YB4 foundations were to be reinforced by enclosing the existing spread footing foundations with a new pile cap and new cast-in-drilled-hole concrete piles placed around the perimeter of the existing spread footing. The existing steel towers were to be encased in concrete and a bearing support was to be constructed at the top of the tower. Isolation bearings were to be installed, and various truss members and connections of the four 288' superstructure trusses were to be reinforced or replaced. Expansion joints were to be modified to accommodate differential truss displacements.
- (2) Span between Pier E1 and Pier E4 (Contracts No. 3 and 8). This portion of the bridge includes the cantilever superstructure and supporting piers. Various strategies had been considered, and it is not clear that a final retrofit strategy had been selected for this portion of the bridge. The retrofit design was not complete

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for either the superstructure or the foundations (see Sections 6.D and 6.G below). It appears that the following scheme was the selected retrofit used for cost estimating purposes.

- New piers were proposed to support the structure where the cantilever and suspended spans join. Foundations had not been designed for these piers.
 - The suspended span was to be separated from the cantilever and was to be supported on isolation bearings mounted on top of the new piers. The ends of the existing cantilever spans were to be pinned to the new piers.
 - The anchor span anchorages at Pier E1 and Pier E4 were to be modified such that the superstructure would be tied down and damped transverse and horizontal release would be provided.
 - Superstructure retrofit was to involve reinforcement of various members and connections and a stiffening edge truss were to be added to the outside faces of the trusses (details are not known).
 - Foundations at E2, E3 and E4 were to be reinforced with large diameter concrete filled steel pipe piles surrounding the caissons and precast concrete pile caps.
 - Towers were to be modified by removing the lateral bracing and encasing the existing steel towers with new concrete box towers. A large concrete crossbeam was to be constructed between the tops of the box towers.
 - Articulated joints were to be necessary to accommodate large differential displacements between truss segments.
- (3) Span between Pier E4 and Pier E23 (Contract Nos. 4, 5, 6, 7, 9 and 10). This portion of the bridge includes five 504' truss spans (between Pier E4 and Pier E9) and fourteen 288' truss spans. The overall retrofit strategy is to stiffen the substructure and isolate the superstructure.
- The retrofit strategy for all of the foundations excluding E5 includes the installation of large diameter steel pipe piles around the perimeter of the existing foundations and pile caps and construction of new pile caps. The piles will be driven open ended, partially reamed, and the upper ends will be backfilled with reinforced concrete.
 - The foundations at E5 will be reinforced with large diameter concrete filled steel pipe piles surrounding the caissons and precast concrete pile caps.
 - For towers E5 through E16 (with exception of Tower E9), tower members (legs, cross braces, joints) will be encased with a reinforced concrete jacket, and a permanent concrete platform will be provided at the top. Tower E9 will include strengthening of various members by replacing lacing with perforated plates, and adding jacking platforms.
 - Isolation bearings will be installed at each pier.
 - Various members and connections of the 288' trusses will be reinforced or replaced.
 - Various members and connections of the 504' superstructure trusses will be reinforced. In addition, an edge beam will be constructed and mounted to each

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truss. The beam is a box beam that is mounted horizontally along the entire length of each truss just below the mid panel points.

6.A. Contract 2, YB2-YB4 Towers.

Description: This contract includes YB2, YB3, and YB4 towers and foundations supporting the 288' trusses on the east side of the Yerba Buena Island. YB2 and YB4 are single towers; YB3 is a double steel tower. The tower legs are made of built-up steel sections and all of the cross bracing are laced members. All of the towers are supported on spread footings. [Documents 310, 354]

The existing steel tower will remain in place and will be encased in concrete. The isolator bearings will be installed on a large ledge at the top of the towers. The new pile cap and cast-in-drilled hole concrete piles will enclose the existing footings. All existing loads and expected seismic loads will be transferred to the new foundations.

Appropriate Criteria: Caltrans established a seismic retrofit performance objective for this contract. The objective was to keep the foundation for all the towers in the elastic range during the Safety Evaluation Seismic Event. Meets lifeline criteria as stated in Section 1, Criteria.

Geotechnical Considerations: Sufficient subsurface exploration, insitu testing and laboratory testing exists to adequately characterize foundation conditions along the SFOBB alignment. Information was obtained from historical sources as well as recent project specific data acquisitions.

Yerba Buena foundation conditions consist of alluvial deposits over the Franciscan Formation or just the Franciscan. Adequate foundation conditions exist to support the retrofitted SFOBB.

Existing foundations for YB1 through YB4 and E1 are shallow or deep footings bearing on rock (YB1, YB4 and E1) and soil (YB2 through YB3). Notes indicate the existing foundation capacities are not adequate and will be replaced. The new foundations at YB2 through YB4 consist of five and six-foot diameter drilled piers (CIDH piles) that will develop the required vertical (tension and compression) and lateral capacities. Detailed evaluation of existing foundation capacities and design of new CIDH piles was not found. The retrofit scheme for E1 and YB1 was not found except notes indicating the need for increased uplift capacity.

Rock slope stability on YBI at Piers E1 and E2 was evaluated using field mapping, borings, and laboratory data. A two-dimensional analysis was performed using bridge loads and earthquake accelerations. A static three-dimensional analysis was performed using a Steronet. Some of the input data for the stability analyses was not contained in the document we reviewed. Thus, we can evaluate general conclusions and not detailed results. We could not determine if a sensitivity analysis was performed. Caltrans concluded the rock slopes at Piers E1 and E2 will be stable during a maximum credible

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earthquake with factors of safety against sliding of about 3.5. The scope of the study and the conclusions appear reasonable.

Seismic Considerations: Refer to Sections 2.B. Earthquake Ground Motion Criteria, and 2.C. Rock Motions for seismic and earthquake considerations on this contract. Due to proposed installation of isolation bearings, it was assumed the isolation device would only transmit 0.1g longitudinally and 0.2g transversely at the top of the towers.

Sound Analysis: The SFOBB retrofit design is complex. The design presents numerous challenges and requires considerable engineering judgement for this contract. Decisions were based on a sound design strategy and appropriate analyses.

From the review of various documents, it was assumed that computer modeling was accomplished using recognized software (WFRAME, XSECTION, GTSTRUDL). Analyses were performed using typical methodology and common references and procedures. An equivalent static analysis was coordinated with a global dynamic nonlinear analysis (ADINA model).

The as-built baseline model was developed using foundation springs. The as-built model revealed that the tower legs, the laced member bracing, the anchor bolts, and the concrete pedestals and footing did not have sufficient capacity to meet the established performance criteria of D/C of less than 1.0 the D/C greater than 3.0 was reported for various structural elements.

A "Push Over" model was used to determine the seismic demand on the retrofitted towers. A Caltrans in-house program was used in the push over analysis. The towers were assumed fixed at the base and allowed 1 to 1.5 inches movement of the foundation. The results from static analysis compared favorably with results from the ADINA global model analysis

Seismic Reliability: The foundation retrofit design is essentially elastic and damage to towers and foundations would not be expected. Therefore, design meets lifeline criteria.

Other Alternatives: There were two seismic retrofit alternatives considered for the existing towers and foundation. Alternative 1 was a steel strengthening and Alternative 2 was concrete encasement of the existing tower.

Cost Analysis: The cost estimates were developed to GP level. This included 10% mobilization and 20% contingencies as is standard with GP estimates. At the time the retrofit study was discontinued the cost estimate was realistic and accurate for the design level completed. It was not complete. There is adequate pricing data with backup. The towers were at a PS&E level and the foundations were at a GP level.

6.B. Discussion of Contract 3, E2-E5 Caissons

Description: This contract includes the retrofit of caissons at Piers E2 to E5. The foundations for the two new piers, E2A and E2B, supporting the cantilever spans, were apparently to be designed by the Contract 8 team.

E2 is basically a large spread footing founded on rock at the edge of Yerba Buena Island. E3 to E5 are deep caissons extending into the bay mud. The concept for the new piers, E2A and E2B, is to use large diameter steel pipe piles protruding down into the bay mud and underlying soils, with a reinforced concrete cap at the Bay's water surface.

Appropriate Criteria: Refer to Section 1. Criteria.

Geotechnical Considerations: The generalized subsurface profile consists of the following stratigraphic sequence Young Bay Mud underlain in succession by the Merritt/Posey/San Antonio Formation, the Yerba Buena (Old Bay) Mud, the Upper and Lower Alameda Formation, and lastly the Franciscan Complex (bedrock). Bedrock slopes steeply from the east side of Yerba Buena Island to approximately elevation -300 ft and then slopes gently down to the east to approximately elevation -440 ft. in the vicinity of the Oakland touchdown. Adequate foundation conditions exist to support the retrofitted SFOBB. See Contract 2 for geotechnical comments for E2.

Seismic Considerations: Refer to Section 2. Seismic Evaluation.

Sound Analysis: For Caissons of Piers E3, E4 and E5 - The as-built baseline model was developed using Com624P to provide an initial rough look at the behavior of the caissons. Patran and ADINA were then used to provide more refined analysis. Existing bearing capacities and settlement behavior were determined to be unacceptable in order to add load to caissons E2 through E5.

It is stated in the calculations that the resulting displacement time histories from the local caisson ADINA models were then used as the input for the global (entire bridge including superstructure) model. This poses a problem in that this procedure would not have resulted in the capture of the actual behavior of the caissons as the effect of the pier (towers) and superstructure mass were not included in the local caisson model.

The initial concept of using post-tension tendons anchored into the underlying rock layer was rejected by Caltrans Office of Structural Foundations (Geotechnical engineering). This concept would relieve stresses induced by overturning moments by redirecting the overturning forces via tension into the rock. However, the additional prestressing forces resulted in an effective increase in the vertical loading on the caissons to the point of overstressing the underlying soil. This scheme was abandoned [Document 375]. The revised and current scheme is to internally stress the caisson by coring through the outer concrete walls of the caissons, installing prestress tendons, and locking the bottom end of the tendons off against the bottom of the caissons. This would add moment capacity to the existing concrete structure but would not reduce the rocking displacements, as would the rock anchors. In addition, this alternative had several remaining concerns. First, a

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construction method for locking off the tendon end against the bottom of the caisson had not been developed. Second, this alternative would not be adequate to support additional dead load from retrofits of the towers and superstructure. It was the designers' conclusion that an additional external support system, perhaps using large diameter pipe piles would have to be developed to carry these additional forces. No calculations or plans were provided for this concept.

In summary, it is apparent that a valid retrofit scheme had not been reached. For Caissons of Pier E2: The analysis procedure and initial retrofit scheme is similar for that described above for Piers E3, E4, and E5. However, this pier is founded on the outcropping rock of Yurba Buena Island and the prestress force of the tiedowns was not a problem. Actually the inverse was determined in that if the pier were allowed to rock, the edge stresses under the footing could overstress the rock. Therefore, the use of rock anchors to prevent rocking and control stresses at the edge of the footing was acceptable. The analysis and details provided indicate that the rock anchors would be placed around the exterior perimeter of the existing foundation. They would be attached to the existing caisson with a reinforced concrete cap surrounding the caisson.

The ADINA models provided indicate that for this pier, the towers and superstructure mass were included.

Additional Foundation for new Piers E2A and E2B: Refer to the section covering Contract 8.

Seismic Reliability: A viable solution had not been obtained as of the date the retrofit project was abandoned in favor of the complete bridge replacement alternative.

The foundations (caissons) for E2, E3, E4, and E5, with the internal prestress retrofit, are designed to remain fully elastic:

$$\text{Demand} < \text{Elastic Capacity}$$

Therefore, damage to the caissons would not be expected, which could be interpreted as meeting lifeline criteria at least for these elements. However, this is irrelevant as the internal prestressing represents only a partial retrofit. It does not address other concerns such as excessive rocking which could result in excessive displacement at the top of the towers, and settlement caused by the additional weight of the tower and superstructure retrofits.

Other Alternatives: There were two general retrofit alternatives considered for the existing caissons. Alternative one is to internally strengthen the caisson for overturning moments by installing tiedown anchorages. Within this scheme, several different methods ranging from internal stressing of the existing reinforced concrete caisson to external (protruding below the bottom of the caissons) tiedown anchorages into bedrock.

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Alternative two is similar to that used for piers 6 through 23, which is an external strengthening using large diameter pipe piles around the perimeter of the existing caisson with a concrete cap tied to the caisson to produce monolithic behavior of old and new.

Alternative one, using external tiedowns into bedrock was the original concept chosen. All calculations and plans supplied by Caltrans are for this scheme. However, late in the design process a geotechnical review concluded that the additional vertical load induced by the additional tiedowns may result in unacceptable settlement due to overstressing of the underlying soils. At this point Alternative one was modified to eliminate the rock anchors and use internal prestressing. After it was concluded that this was insufficient to address all of the deficiencies associated with the existing structure, Alternative two was discussed. No calculations or plans were provided regarding this alternative.

Cost Analysis: The cost estimates were developed in a GP level. This included 10% mobilization and 20% contingencies as is standard with GP estimates. At the time the retrofit study was discontinued the cost estimate was realistic and accurate for the design level completed, GP. It was not complete.

6.C. Discussion of Contract 4, Contract 5 and Contract 6 E6-E23 Foundations.

Contract 4 Description: This contract includes the retrofit of the existing foundations at Piers E6 through E9 supporting the 504' trusses and towers. The existing steel towers will remain in place and will be encased in concrete under separate contract. The footing block rests on top of an existing non-reinforced concrete seal/pile cap and consists of numerous timber piles.

The retrofit strategy is to isolate the 504' superstructure spans from the towers with isolation bearings. Thus the substructure was designed to withstand the seismic force of approximately 20% of the superstructure mass and 100% of its self-weight.

The retrofit consists of constructing a sheet pile cofferdam, dredging mud from within the cofferdam, driving a single row of large diameter piles to a specified tip elevation around the perimeter of the existing foundation, and constructing a pile cap enlargement. A reinforcement cage will be inserted in shells and the shells will be concrete filled. The new piles were to be designed to a strength and stiffness criteria sufficient to provide composite load and displacement resistance in combination with the existing timber piles [Document 354].

Data Gap: A significant data gap exists (Data Gap 5) for Contracts 4 and 5. Without this information it is difficult to determine if sound analysis and appropriate criteria including lifeline were used for this portion of the bridge. However, it is reasonable to assume that the criteria and analysis for these contracts were similar to that used for Contract 6. Therefore, for the purpose of this study we have assumed the same conclusions on geotechnical consideration, seismic and earthquake consideration, appropriate criteria, sound analysis, seismic reliability - lifeline criteria or no collapse, and other alternatives as those concluded on Contract 6.

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Contract 5 Description: This contract includes the retrofit of the existing foundations at Piers E10 through E16 supporting the 288' trusses and towers. The existing steel towers will remain in place and will be encased in concrete under separate contract. The footing block rest on top of an existing non-reinforced concrete seal/pile cap and consist of numerous timber piles.

The retrofit strategy was to isolate the 288' superstructure spans from the towers with isolation bearings. Thus the substructure was to be designed to withstand the seismic force of approximately 20% of the superstructure mass and 100% of its self-weight.

The retrofit consists of constructing a sheet pile cofferdam, dredging mud from within the cofferdam, driving a single row of large diameter piles to a specified tip elevation around the perimeter of the existing foundation, and constructing a pile cap enlargement. A reinforcement cage will be inserted in the shells and the shells will be concrete filled. The new piles will be designed to a strength and stiffness criteria sufficient to provide composite load and displacement resistance in combination with the existing timber piles.

Data Gap: A significant data gap exists (Data Gap 5) for Contracts 4 and 5. Without this information it is difficult to determine if sound analysis and appropriate criteria including lifeline were used for this portion of the bridge. However, it is reasonable to assume that the criteria and analysis for these contracts were similar to that used for Contract 6. Therefore, for the purpose of this study we have assumed the same conclusions on geotechnical consideration, seismic and earthquake consideration, appropriate criteria, sound analysis, seismic reliability - lifeline criteria or no collapse, and other alternatives as those concluded on Contract 6.

Contract 6 Description: This contract includes the retrofit for existing foundations and pedestals at Piers E17 through E23, which support the 288' trusses. The towers and footings are hollow walls three to four feet thick. The footing block rest on top of an existing 12.5 ft. thick non-reinforced concrete seal/pile cap, supported by approximately 300 timber piles.

The retrofit strategy is to isolate the 288' superstructure spans from the towers with isolation bearings. Thus the substructure was designed to withstand the seismic force of approximately 20% of the superstructure mass and 100% of its self-weight.

The retrofit includes the construction of a cofferdam, excavation to the bottom of the existing seal course, driving large diameter steel piles, partially filled with concrete to limit the deflection in the timber piles to acceptable levels. The construction of footing and buttress walls are to connect the retrofitted and existing footing together.

Due to the reduced clearances below the trusses, dredging was planned to precede the cofferdam construction. The cylindrical steel piles will be driven to the side of the existing pile cap. The piles were to be filled with reinforced concrete. The isolation bearings will isolate the 288' superstructure spans from the towers. The foundation and

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tower at E17 would no longer act as an anchor pier for spans E11 through E16 [Documents 323, 354, 152, 36].

Appropriate Criteria: Caltrans established a clear seismic retrofit performance objective for this contract. The objective was to keep the foundation for all the towers in the elastic range during the Safety Evaluation Seismic Event. Localized exceptions to the “totally elastic” philosophy would be acceptable as long as the serviceability goal was not compromised. The serviceability goal is the often referred to “lifeline criteria” of being able to accommodate immediate post earthquake emergency relief access and public access within a short time frame.

Capacities of timber piles were determined using soil data at each tower, published properties of wood piles, and plans/specifications for the original construction. Vertical capacities were based on skin friction using the minimum specified pile butt and tip diameters. Some calculations used nominal pile diameters rather than the minimum [Document 74]. No uplift (tension) capacity was recommended because of the lack of a good structural connection of the pile to the cap [Document 73]. However, some calculations assumed tension capacity. We do not know if these discrepancies were resolved. Lateral capacities were determined using p-y curves. Supplemental CISS piles were designed to augment the existing timber piles by limiting deflections and bending [Document 323]. No reduction in the timber pile capacities appears to have been taken to account for possible historic structural damage.

Vertical, 5-foot diameter steel pipe piles were selected to augment the timber pile foundation capacity and control loads and deflection in the timber piles. Lateral capacities were determined using p-y curves. Drivability studies for these piles were performed and pile load tests were planned to confirm capacities. Various retrofit schemes were selected. The selected scheme appears reasonable.

Geotechnical Considerations: The generalized subsurface profile consists of the following stratigraphic sequence: Young Bay Mud underlain in succession by the Merritt/Posey/San Antonio Formation, the Yerba Buena (Old Bay) Mud, the Upper and Lower Alameda Formation, and lastly the Franciscan Complex (bedrock). Bed rock slopes steeply from the east side of Yerba Buena Island to approximately elevation -300 ft and then slopes gently down to the east to approximately elevation -440 ft. in the vicinity of the Oakland touchdown [Documents 27, 74, 89, 189].

Adequate foundation conditions exist to support the retrofitted SFOBB.

Seismic Considerations: A significant effort was exerted in defining the seismic setting for the SFOBB. Rock motions were determined and propagated through developed soil columns to provide a series of site specific time histories and response spectra at appropriate foundation levels. Rock motion was propagated using equivalent linear (SHAKE) and nonlinear analysis. Soil-Foundation-Structure Interaction analyses were not performed on retrofitted foundation. Foundation stiffness and force-deflection and

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moment-rotation curves were developed for each foundation. The kinematic interaction analysis was not performed for as-built and retrofit foundation.

Sound Analysis: The SFOBB retrofit design is complex. The design presents numerous challenges and requires considerable engineering judgment. Decisions were based on a sound design strategy and appropriate analyses. From the review of various documents, it was assumed that computer modeling was accomplished using recognized software (ADINA, COM624, GROUP, SHAKE, GTSTRUDL, etc.). Analyses were performed using typical methodology and common references and procedures. The COM624 and GROUP programs were used for the analyses of both as-built and retrofitted foundations. The demand and capacity were calculated from the above and equivalent static analysis for lateral displacement, axial, moment, shear. These results were coordinated with a global dynamic nonlinear analysis. The closing of Data Gap 9 would have confirmed our assumptions.

The stresses in the timber piles to the ultimate capacities, $F_b = 5000$ psi and $F_v = 450$ psi were used in the design of the retrofit foundation [Document 323]. The foundation needs to be retrofitted to withstand the seismic force of approximately 20% of the superstructure mass and 100% of its self weight. The large diameter steel piles were used to limit the deflection in the timber piles to acceptable level.

Design assumption for timber piles, footing stiffness, design assumption for the concrete pier foundations were reviewed [Document 152].

Strut and tie were analyze and designed using AASHTO LRFD bridge design specifications.

Seismic Reliability: The foundation retrofit design is essentially elastic and damage to towers and foundations would not be expected. Therefore, design meets lifeline criteria.

Other Alternatives: Alternative foundation retrofit strategies were considered. These alternatives included ground improvement (grouting) schemes, small diameter piles, and large diameter vertical and battered steel piles with a new pile cap / load transfer structure above the water surface.

Micropiles [Document 323] – This retrofit concept was to drill through the lightly reinforced footing block and concrete seal (elevation +8 to -45) and install micropiles to take uplift and compression. Caltrans determined the micropiles would not significantly increase the lateral capacity of the foundation and therefore this strategy was dismissed.

Floating Cofferdam - This retrofit concept was to dredge out to the bottom of the footing block and float precast concrete cofferdams into place. Then the precast units would be connected, the bottoms knocked out and large diameter steel piles driven. After the piles were driven, a new pile cap would be stressed to the existing footing block. Due to large amount of dredging and the uncertainty involved in construction, this option was not selected.

Cost Analysis: The cost estimates were developed by Caltrans represented PS&E level estimates. At the time the retrofit study was discontinued the cost estimate was realistic and accurate for the PS&E level of design. However, 100% plans and specification and estimates were not complete.

6.D. Discussion of Contract 7, E5-E16 Towers

Description: Contract 7 includes the steel towers supporting the 504' and the 288' truss spans from piers E5 to E16, with the exclusion of the steel tower at pier E9. All steel towers are supported on concrete pedestals. The steel towers at piers E5 to E8 have double X-braces that are 120 ft to 140 ft tall, whereas steel towers at piers E10 to E16 have single X-braces that are 60 ft to 90 ft tall (see Contract for E9). In addition, pier E11 has double steel towers to allow for thermal expansion and contraction. All steel towers consist of built up steel sections and rest on timber pile foundations with the exception of the steel tower at pier E5, which is supported on a concrete caisson foundation [Document 354].

The isolation retrofit strategy involves decoupling the top of the towers from the trusses by installing friction pendulum isolation bearings in between at each existing truss shoe location. First, the tower members (tower legs, X-braces and joints) are encased with a reinforced concrete jacket, and a permanent concrete jacking platform is constructed at the top of the towers [Document 354]. The trusses are then to be jacked from the top of the towers, and the top of the tower members are to be cut. This would be followed by attaching the isolation bearing to the top of the tower members and to the bottom of the existing shoe base plate. For the low height towers at piers E13 to E16, the space between members is to be filled to form a solid in-fill wall [Documents 38, 354].

Appropriate Criteria: The portions of the criteria referenced in Section 1 that pertain to the evaluation and design of the steel towers include discussions on the allowable tensile, compressive, and shear capacities of the steel and concrete members, as well as gusset joint, shear and tensile rivet capacities. Acceptable D/C for both evaluation and design of steel and concrete members were also defined.

In 1995, more refined guidance for the evaluation and retrofit design of latticed members, rivet and gusset plate connections were published by Caltrans, based on the work of its Steel Committee and other researchers (see also "Seismic Design of Components of the East Bay Crossing" by A. Astaneh, 1995) in the so called white paper report [Document 373].

Geotechnical Considerations: Refer to Section 3. Geological and Geotechnical Site Investigations.

Seismic Considerations: See Section 2, Seismic Evaluation, for general considerations. For the local tower models, ARS curves (see Caltrans Bridge Design Specifications) were generated for each pier by Caltrans' Structure Foundations Section for pushover analyses [Documents 38, 311].

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Sound Analysis: Caltrans' analysis approach is to start with a simple model and then add complexity to it gradually until the model captures all of the system's response to an acceptable degree [Document 357]. For the stand alone steel tower analysis, this involves a simple plane frame model with in plane and out of plane motions in both the longitudinal and transverse directions. If required, foundation flexibilities, plastic deformations, rocking motions, softening of soil modulus and etc. can also be included in the analysis.

For all steel towers in this project, some or all of the following types of the analysis were performed,

- static push over analysis;
- linear elastic 3D response spectrum modal analysis;
- linear elastic time history analysis;
- nonlinear time history analysis with geometric and/or material nonlinearities.

Modeling Assumptions: Global baseline GTStrudl and ADINA models of all the existing East Bay Bridge spans were created to assess the overall seismic behavior and to capture interactions between adjacent spans, using different (rocking, fixed, soil spring) boundary conditions [Documents 180, 197]. The global results are useful for comparison with results from the local tower models. In some cases, global data were extracted and used as input for the local tower models.

For the stand alone tower models, the steel tower legs were assumed to be connected to the foundation by rigid links with translational and rotational springs. Rigid links were also used to account for connection stiffness (gussets). The contact surfaces were included at the bottom of the tower legs to allow for rocking motions. The pedestals supporting the tower legs were modeled as beam elements using actual stiffness. The masses of the foundation, pedestal, tremie, and enclosed water were modeled as a point mass, and this mass was attached to the end of a vertical rigid link. Gap elements were used at the top of the towers to model expansion joints. For retrofit analysis, base isolation bearings were modeled as springs with additional masses placed at the top of the piers.

Damping is used to dissipate energy through deformation during seismic motions. The values used for the SFOBB studies range from 5% to 15% of the critical damping depending on the type of system being analyzed and the level of peak deformation assumed [Document 72]. Each tower model was subjected to full static and dynamic loads with 3 dimensional (fault normal, parallel, and vertical) time histories. Time history analyses were carried out to 10, 20 and/or 40 seconds, with 0.02 increments. Different displacement time histories were applied to the base of each tower, accounting for wave passage, coherency, attenuation, and other local effects. Questions on the validity of global analysis regarding damping and verification of the selected strategy are discussed in Section 4, Global Model.

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In analyzing the retrofitted steel towers, the demand loads were obtained from the worst case of two methods, which were the global model using ADINA with foundation springs and displacement time histories applied at each support, and the stand alone local pushover models using GTStrudl and ADINA, with assumed isolation bearing transfer loads of 10%-20% g applied at the top. Member geometric properties were based on the cracked section, and the inertia forces were based on maximum accelerations from ARS curves generated by Caltrans' Structure Foundations Section.

Capacities of retrofitted tower members were analyzed using computer program "X-Section" and are based on the combined existing steel section and the new reinforced concrete encasement as a composite section [Document 122]. Capacities of the concrete encased joints were analyzed with "X-Section" using the combined yield capacities of the existing gusset plates and the new joint reinforcement. The main steel, which would be continuous across the jacking platform, was checked using the strut and tie method as suggested by the peer review panel [Document 311]. Buckling and slenderness of gusset plates were not considered since the joints are fully encased in concrete [Documents 161, 311].

Analyses conducted by Caltrans indicated that many members of the existing steel towers are overstressed. Some of these have the potential to buckle and induce instability. Connections were identified as possessing capacities below the capacities of the adjacent members. Given the large demand-to-capacity ratios reported in Caltrans' as-built analyses, Caltrans felt that it would not be economical to retrofit all deficient bridge members such that they will behave elastically during major seismic events.

The soundness of analysis cannot be determined independently by the COE Team. All analysis and design calculations are scattered in different documents provided by Caltrans. Most of these are incomplete and unorganized, with few narratives, figures, or tables describing what was actually done. Given the limited amount of time and the large volume of material that are available, it is not possible to thoroughly review each of these documents. However, it can be stated qualitatively that, in general, the analyses and design follow accepted current procedures and practice.

Seismic Reliability: Given acceptance of the propose retrofit (not justified by analysis as described in Section 4, Global Model), retrofit work of this contract satisfies the lifeline criteria.

Other Alternatives: Different ways to strengthen the deficient structural members were evaluated by Caltrans to various degrees. Some of those that were considered are listed as follows [Document 311].

- boxed section steel strengthening - remove lacings and rivets and replace with steel plates and high strength bolts and strengthen existing gusset plates and connections;
- hollow concrete encasement - encase existing tower with hollow concrete pier wall;
- solid concrete encasement - encase existing tower with solid concrete pier wall;

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- solid X-bracing encasement - encase individual tower members with reinforced concrete jacket.

The following are reasons listed by Caltrans, however many “lessons were not substantiated by analysis and the COE Team does not necessarily agree with justification. Concrete encasement was chosen by Caltrans as the preferred method for member strengthening after comparing different alternatives. The biggest advantages are to provide increased stiffness of the tower and reduce rotation at the top; minimize local buckling problems of the existing steel members, lacings, and gusset plates; avoid structural solutions for which little physical testing exists; eliminate the need to retrofit the existing steel tower anchorage by providing a continuous connection between the new base of tower longitudinal steel and the new foundation retrofit steel; provide a permanent jacking platform at the top of tower for jacking the trusses for the installation of the isolation bearings or for future replacement, and to eliminate lead paint removal and future painting and maintenance costs [Document 161]. Retrofit of the existing steel members, on the other hand, will require replacing the existing rivets with high strength bolts in addition to building up the existing steel tower legs in the longitudinal direction, which would also require staging the retrofit process in order to remove existing rivets and lacings while maintaining traffic on the bridge [Documents 311, 354].

Cost Analysis: The cost estimates were developed by Caltrans in a PS&E level estimate. At the time the retrofit study was discontinued the cost estimate was realistic and accurate for the PS&E design level completed. It was not 100% complete as design was not completed, finalized, checked, or stamped.

6.E. Discussion of Contract 8, Cantilever Towers and Superstructure.

Description: Contract 8 consists of three separate contracts. Contract 8A consists of installation of two new towers and foundations supporting the suspended span between the east and west cantilever spans (Document 188). The towers are reinforced concrete moment frames with inclined legs. The foundation consists of a precast hollow cellular pile cap with large diameter pipe piles. The piles at pier E2A are anchored 10 feet into bedrock while piles at pier E2B are driven into dense sand. Tie-downs are included to reduce tension loads on piles due to longitudinal loads. The towers support isolator bearings installed on top of the tower cross beams.

Contract 8B consists of separating the cantilever spans into 3 independent, long period structures and retrofit of towers E1, E2, E3, and E4. The proposed retrofit of pier E1 includes installing a reinforced concrete jacket around tower columns and web wall, and installing prestressed tie-down anchors through the piers into rock. Retrofit of the remaining piers includes encasing tower columns in reinforced concrete, removing tower cross bracing, installing a stiff prestressed bent cap between top of tower columns, and strengthening the connection between tower legs and pier. Connections of the suspended spans at piers E1 and E4 are released and replaced with a vertically restrained bearing.

Contract 8C consists of seismic retrofit of the three-span steel truss superstructure spanning from Pier E1 to Pier E4 to include installation of edge trusses, minor retrofit of

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suspended spans, Pier E1 knee joint strengthening, Pier E1 and Pier E4 release and hold-down strategies, extensive deck joint construction possibly with large dampers where joint impact cannot be avoided, installing tiedown bearings (to keep I-bars in tension) at Piers E1, E2A, E2B, and possibly E4, strengthening connections (rivet and gusset plate replacement), strengthening portal frame members, top lateral members, top and bottom cross bracing, vertical truss members, floor beams, and, anchor shoes, and extending stringer seats with steel plates [Document 227]. The investigations were in various stages of completion when the cessation directive was issued.

Appropriate Criteria: Design criteria were presented in the form of allowable stresses, material strengths, strain limits, capacity equations, and acceptable demand-capacity ratios. Performance criteria were presented in the form of expected performance of the retrofitted bridge. The initial performance criterion (1994) was to achieve full serviceability (full access to traffic immediately following the earthquake) after the design earthquake. This was to be achieved by limiting stresses to or below the elastic limit and demand-capacity ratios to unity. This goal became increasingly difficult to achieve as the analyses progressed and complexity and cost of the retrofit increased. Acceptable performance at the time the project was terminated included allowing some damage and yielding of material (1997) [Documents 224, 354]. Under this scenario, it was expected that three lanes would be serviceable in six months, and full service would be available in one year. Documentation identifying the level of exceedance (D/C) of the affected components of the respective alternatives has not been identified to date.

Member capacities were based on an upper bound yield strength, e.g. F_y of 37 ksi for steel yield strength of 33 ksi. Capacities for steel members in combined axial bending or compression, flexure, shear, and torsion were based on AISC or AASHTO LRFD design criteria with increased resistance factors. Acceptable stresses in as-built truss members were limited to 60% of yield [Documents 44, 230]. This limiting value was to account for the expected controlling mode of failure (buckling) of compression members. It was reported that 94% of truss members failed under this limitation. Concern was also expressed regarding behavior of riveted connections and their impact on the capacity of truss members. Concrete and reinforcement strains for concrete towers were limited to 0.003 and 0.002 respectively. Concrete and reinforcement strengths for concrete towers were limited to 5 and 60 ksi respectively.

Geotechnical Considerations: Not applicable.

Seismic Considerations: Several computer models were developed to analyze the components of Contract 8. A global baseline model was developed for the entire structure using the ADINA computer program. A detailed model of the cantilever span trusses (from pier E1 to Pier E4) was developed using GTSTRUDL [221] and ADINA [224]. Several local models, including the E1 anchorage [Documents 222, 224], vertically restrained bearings, truss portal frames [Document 228], and pier towers and foundations [Documents 97, 116], were also developed. The separate ADINA and GTSTRUDL results were compared to develop a level of accuracy and confidence in the models [Documents 215, 228]. The documents reviewed did not indicate that a level of

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confidence required for this type of analysis was achieved in the models. Source of input loads was never well defined [Document 219].

Earthquake loads were represented in the form of time history displacements and accelerations used in linear and non-linear dynamic analyses and acceleration-response spectra used in linear static pushover analyses. It appears that for the time-history analyses, input loads are applied at the foundation (at least for tower and foundation analyses). Loads are applied to tops of towers for tower and foundation analyses and to truss members in the superstructure analyses (in three dimension) for pushover analyses. The origin of loads was not clear in the documents reviewed, except that accelerations of 0.1g and 0.2g for longitudinal and transverse directions respectively were generally applied to tops of towers with isolation bearings to account for bearing effects.

Sound Analyses: Reasonable procedures using well-established criteria were employed in the evaluation of steel member capacities. Material properties appear reasonable. An upper bound material strength and resistance factor is a reasonable approach. Computer modeling, analysis, and design efforts were undertaken using commercially available software and recognized procedures.

Confidence in model development and performance did not appear to be fully achieved. The requirement to achieve fully elastic behavior may have been too restrictive for a loading event expected to occur no more than once in the life of the structure. The relaxation of this requirement further into the evaluation process seems more reasonable and perhaps would lead to different conclusions if this strategy were pursued in the beginning. Results from testing of lattice members may have provided more confidence in structural performance of the existing members.

Several advantages of concrete encasement over steel retrofit of towers were presented. However, little support for these contentions was provided. The argument that concrete towers can be sized for strength and ductility, does not require testing, does not require highly specialized labor and careful staging, requires shorter construction time, and provides easier installation for isolation bearings can be made for steel as well.

Seismic Reliability: The seismic reliability of the retrofit of the cantilever superstructure cannot be assessed because Caltrans did not conclude their efforts to establish a viable retrofit strategy prior to the cessation of work on the retrofit effort.

Other Alternatives: Several other strategies for support of the cantilever truss spans were evaluated including a cable system, an edge arch system, and external strut truss system. These alternatives included retrofitted towers and in some cases additional towers. These alternatives were evaluated qualitatively, with minimal analysis, and eliminated from further study.

Cost Analysis: Not applicable.

6.G. Discussion of Contract 9, 504' Trusses From E4 to E9, Tower E9 and 50 ft Long Deck Slabs Above E9

Description: The East Span of the SFOBB includes five 504' truss spans between Pier E4 and Pier E9. Project 9 includes retrofit of the 504' trusses, tower E9, and deck slabs above tower E9, and installation of isolation bearings. All five of the trusses are to be connected to form a truss train. Tower E9, 50-ft slab supports, and truss heel areas must be modified to accommodate installation and support of the isolation bearings. The proposed retrofit for the 504' spans is shown by the General Plan – 504' Span plans (Document 31).

The proposed retrofit of the trusses involves installation of a horizontal edge beam along the length of each truss, reinforcement of vertical members, strengthening of the heel area adjacent to bearings, and strengthening of floor beam connections. The edge beam is located at approximately mid-height of the truss and is composed of a built-up 2'-8" by 2'-5" box beam. The beam is to be installed in the same plane as truss members, so the beam intersects each vertical and lower diagonal member requiring a significant bolted connection at each intersection. Four vertical members on each truss will be retrofitted by replacing the existing lacing with new perforated cover plates. Rivet removal and temporary support of "un-laced" members will be required. Significant reinforcing of the heel area with plates and stiffeners and local strengthening of adjacent end posts and diagonal members is required. All connections between floor beams and the supporting truss will be strengthened.

Tower E9 would have to be modified to provide a platform for jacking the trusses and installing the isolation bearings. Upper connections at each corner are to be strengthened by adding gusset plates and stiffeners resulting in significant bolted and welded connections. Tower diagonals are also to be reinforced by replacing lacing with perforated cover plates.

Due to overall structural modifications, an alternate support system is to be provided for the 50 ft span deck slabs located above tower E9. Cantilever corbels are to be mounted to the adjacent floor beam to provide an extended seat for the stringers. In addition, deck expansion joints must be installed at each end of the upper and lower deck slabs, and sidewalks must be modified.

Prior to installation of the isolation bearings, the top portion of the existing towers must be removed, anchor bolts for the bottom portion of the bearing must be installed, and adjacent truss heels must be connected. After the truss is jacked, the bearings are to be slid into position and the upper portion of the bearing is to be attached to the truss heels, and the lower portion bolted and grouted to the towers. Much drilling and specialized construction is involved.

Appropriate Criteria: Although a formal statement of criteria is not provided by a single document, there is evidence in several documents [Documents 60, 61, 79, 309] that specific criteria for capacity determination and D/C limits were developed for retrofit of the 504' spans. The criteria have evolved over time with the most recent criteria

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[Documents 61, 354] supporting a near lifeline condition (fully elastic response in the 504' trusses to a maximum event with some offsets expected at the ends of isolated trusses). As outlined in Section 1, qualitative definitions of performance criteria have been provided. It is also evident that member capacities were well defined using appropriate criteria and capacities were calculated for all primary structural members in the 504' trusses. Concise and well-defined analysis guidelines, however, are not included.

Criteria for determining capacity of tension, compression and flexural members were developed through an extensive effort [Document 61]. Design criteria of AISC, AASHTO and CALTRANS were each considered in development of guidelines. In addition, a specific study on the strength of latticed members [Document 373] was carried out to determine truss member strengths. Extensive efforts were undertaken to determine the capacities and section properties of each structural member. The need for retrofit was determined based on a D/C limit of 1.0.

Geotechnical Considerations: Not Applicable.

Seismic Considerations: For the superstructure, earthquake loads are based on accelerations of 0.2g in the transverse direction and 0.1g in the longitudinal direction. This is justified on the basis that friction pendulum isolation bearings are used to support the structure.

Sound Analysis: It is stated in various documents that linear, nonlinear and time-history analyses (THA) have been conducted. A global model of the entire east portion of the SFOBB, local truss models and detailed finite element models of various connections were developed and utilized. It is not clear, however, how these analyses were coordinated. The documentation does not provide a clear statement on specific requirements on analysis type, description of required sequence for type of analysis, or how various analyses are inter-related.

In a December 1996 presentation to the pier review panel, it is stated that linear (GTSTRUDL), nonlinear (ADINA), and dynamic time history analyses (THA) were conducted to determine the as built and retrofitted performance of the structure [Document 61]. A single span space frame model and a plane frame model of all five spans were developed. Additionally, several detailed models of various connections were developed. The time-history analysis (THA) is not described and no summary of results is provided.

Special analyses were conducted for jacking and temperature. Finite element models were developed to model gusset plates at the truss support heel [Document 309]. Additionally, a temperature analysis was conducted. In the temperature analysis, it was assumed that the truss was fully expanded when the towers were retrofitted, and then after retrofit of the towers, the truss was allowed to contract with temperature. Shears at support points were checked to determine if sliding of the joint would occur. The document states that all shears were under the limit of 0.7 times the dead load reaction, so

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sliding would not occur. This is inconsistent with the friction value of the isolation bearings, which is between 0.1 and 0.2.

Static push analyses using a 3-D model were conducted for longitudinal and transverse loading [Document 58]. Static loads that are equivalent to 0.2 times the dead load were applied at end nodes for longitudinal analysis and at truss panel points for lateral analysis. Member force results were provided; however, the results do not correspond with any other results presented. Push analyses were not used to determine ultimate capacity and failure mechanisms of the truss.

Analysis Results: In a January 1996 strategy meeting, existing structure and retrofitted D/C plots for a general 504' truss model were presented [Document 309]. In a December 1996 peer review meeting plots for a general 504' model and for models that represent spans E4, E6 and E8 were presented [Document 61]. These apparent most recent results show that the retrofitted structure would have all members with a D/C of less than 1.0 with exception of four vertical members in span 8 (all are less than 1.3). In early to mid 1996, results for capacity calculations and demand to capacity ratios are shown by spreadsheet type printouts [Document 57]. Results in each document are consistent for the general case 504' model; however, results for spans E4, E6 and E8 are not consistent. In no case are the input loads described. This presents some confusion in the interpretation of results and it is not clear exactly what type of analysis was conducted to determine the demands used in formulation of the results.

There is evidence that appropriate analysis was carried out, but due to the inconsistencies and lack of summary, a definite conclusion cannot be made.

Seismic Reliability: The retrofit strategy involves isolation of the superstructure so the superstructure demands are dependent on the performance characteristics of the isolation bearings. The reported analysis loads have been based on these characteristics; however, displacement demands are not well summarized. Given the conservative definition of capacity and conservative D/C limit, high seismic reliability is likely considering force effects on the structure. Regarding displacement effects, however, a solution to account for the effects of displacement demands and interaction with adjacent truss trains (impact between unattached segments of structure) has not been developed or is not documented appropriately. Furthermore, the global analysis was not conducted using retrofitted tower and foundation properties, so the isolation strategy was not verified.

Considering only the structural aspects of the 504' truss spans (not including end of truss displacements), a lifeline condition is apparently met. The D/C limitation of 1.0 ensures elastic behavior in the superstructure trusses.

Other Alternatives: Document 60 presents two alternative schemes. Both schemes would employ additional towers placed adjacent to existing towers. In the first alternative, the truss would be isolated from the existing tower and new additional towers would be constructed to catch an un-seated truss. These towers would be located under the bridge to the east and west of each pier. The second alternative would include a set of towers

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placed on either side of the bridge adjacent to each existing tower. These would not support the trusses, but would restrain lateral movement of the trusses during an earthquake. Analysis of towers was conducted and a planning budget level design was completed. These alternatives were examined to provide cost information for alternative schemes.

Cost Analysis: The cost elements were developed by Caltrans in a GP level. Included are 10% mobilization and 20% contingencies as standard at the GP level. At the time retrofit study was ordered discontinued, the cost estimates appear to be realistic and accurate for the GP level. It was not complete.

6.H. Discussion of Contract 10, 288' Trusses

Description: Contract 10 includes all the superstructure work from piers YB1 to E1 and from piers E9 to E23. These spans include four 288' trusses between pier YB1 and pier E1 on Yerba Buena Island and fourteen 288' trusses between pier E9 and pier E23.

The retrofit strategy selected by Caltrans is to substitute isolation bearings for existing bearing shoes at various locations from pier E9 through pier E23 to reduce excessive relative truss displacements and to reduce shock due to impact. The trusses from pier E9 to pier E11 and from pier E11 to pier E17 are to be connected as in the existing condition. The trusses from E17 to E23 are also to be connected in similar manner. The thermal expansion joints at piers YB1, E1, E9, E11, E17, and E23 at the ends of the truss train will be modified to allow for the significant displacement associated with the isolation bearings [Documents 146, 354, 360].

The truss vertical hanger members are to be strengthened to prevent excessive drift. New lateral bracings will be added and existing diagonal and vertical bracings will be strengthened to increase load carrying capacity and to allow load transfer to deck without inducing bending of the floor beams about their weak axes. Existing knee bracings will be upgraded to improve shear and torsion resistance. In addition, longitudinal bracings are to be added, reinforcement of connections between stringers and floor beams, diagonals, lower chords, upper chords, gusset plates, sidewalks, barriers, floor beams are to be strengthened, I-bar assemblies are to be added and new diagonal kickers will be installed to restrain upper deck floor slab movement [Documents 29, 79, 155, 158, 159, 360].

Appropriate Criteria: The portions of the criteria referenced in Section 1, Criteria, that pertain to the evaluation and design of the 288' span superstructure include discussion on the allowable tensile, compressive, and shear capacities of the steel members, as well as gusset joint, shear and tensile rivet capacities. Acceptable D/C for both evaluation and design of steel members were also defined.

In 1995, more refined guidance for the evaluation and retrofit design of latticed members, rivet and gusset plate connections were published by Caltrans, based on the work of its Steel Committee and other researchers (see also "Seismic Design of Components of the

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East Bay Crossing" by A. Astaneh, 1995) in the so called white paper report [Document 373].

Geotechnical Considerations: Refer to Section 3, Geological and Geotechnical Site Investigation.

Seismic Considerations: Refer to Section 2, Seismic Evaluation.

Sound Analysis: Caltrans' analysis approach is to start with a simple model and then add complexity to it gradually until the model captures all of the system's response to an acceptable degree [Document 357]. For the stand alone segment analysis, this involves a series of simple plane frames with beam elements in between subjected to seismic motions in both the longitudinal and transverse directions. If required, lumped masses, foundation flexibilities, plastic deformations, rocking motions, softening of soil modulus and etc. can also be included in the analysis.

For all segment models in this project, some or all of the following types of the analysis were performed,

- static push over analysis;
- linear elastic 3D response spectrum modal analysis;
- linear elastic time history analysis;
- nonlinear time history analysis with geometric and/or material nonlinearities.

Modeling Assumptions: Global baseline GTStrudl and ADINA models of all the existing East Bay Bridge spans were created to assess the overall seismic behavior and to capture interactions between adjacent spans, using different (rocking, fixed, soil spring) boundary conditions [Documents 180, 197]. The global results are useful for comparison with results from the local segment models. In some cases, global data were extracted and used as input for the local segment models.

The 288' spans in the stand alone segment models were modeled by interconnected beam elements with lumped masses at the quarter points along the superstructure length between steel towers [Documents 76, 113]. The steel tower legs were assumed to be connected to the foundation by rigid links with translational and rotational springs. Rigid links were also used to account for connection stiffness (gussets). The contact surfaces were included at the bottom of the tower legs to allow for rocking motions. The pedestals supporting the tower legs were modeled as beam elements using actual stiffness. The masses of the foundation, pedestal, tremie, and enclosed water were modeled as a point mass, and this mass was attached to the end of a vertical rigid link. Gap elements were used at the top of the towers to model expansion joints. For retrofit analysis, base isolation bearings were modeled as springs with additional masses placed at the top of the piers.

Damping is used to dissipate energy through deformation during seismic motions. The values used for the SFOBB studies range from 5% to 15% of the critical damping

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depending on the type of system being analyzed and the level of peak deformation assumed [Document 72]. Each segment model was subjected to full static and dynamic loads with 3 dimensional (fault normal, parallel, and vertical) time histories. Time history analyses were carried out to 10, 20 and/or 40 seconds, with 0.02 increments. Different displacement time histories were applied to the base of each tower, accounting for wave passage, coherency, attenuation, and other local effects. Questions on damping and verification of selected strategy regarding the validity of global analysis are discussed in Section 4, Global Model.

In analyzing the retrofitted superstructure, the stand alone local structural models were extracted from the global baseline model with all spans assembled as trains, assuming that all the 288' trusses are coupled both transversely and longitudinally [Document 146]. These segment models were analyzed as a series of lollipops, including refinements such as material nonlinearities, banging between adjacent spans and superstructure damping [Document 113]. Member geometric properties were based on the cracked section, and the inertia forces were based on maximum accelerations from ARS curves generated by Caltrans' Structure Foundations Section.

The basic steps in the analysis procedures are:

- establish demands using results from the global baseline model and perform stand alone analysis on the segment models;
- establish member capacities using criteria discussed above;
- strengthen member or redistribute loads to other members when the demand is greater than its capacity.

Analyses conducted by Caltrans indicated that many members of the existing steel superstructure are overstressed. Some of these have the potential to buckle and induce instability. Connections were identified as possessing capacities below the capacities of the adjacent members. Given the large demand-to-capacity ratios reported in Caltrans' as-built analyses, Caltrans felt that it would not be economical to retrofit all deficient bridge members such that they will behave elastically during major seismic events.

The soundness of analysis cannot be determined independently by the COE Team. All analysis and design calculations are scattered in different documents provided by Caltrans. Most of these are incomplete and unorganized, with few narratives, figures, or tables describing what was actually done. Given the limited amount of time and the large volume of material that are available, it is not possible to thoroughly review each of these documents. However, it can be stated qualitatively that, in general, the analyses and design follow accepted current procedures and practice.

Seismic Reliability: Given acceptance of the isolation strategy (not justified by the global analysis, see Section 4, Global Model), retrofit work of this contract satisfies the lifeline criteria.

Other Alternatives: Different ways to strengthen the deficient structural members were evaluated by Caltrans to various degrees. Some of those that are listed below were eventually incorporated into the project:

- "surgery" - remove existing members and joints one by one and replace with new ones [Document 358];
- modification - attach new plates, angles, beams and/or other structural shapes to stiffen existing members;
- addition - add new, but separate plates, angles, beams and/or other structural shapes to existing structural system to redistribute demand loads.

Cost Analysis: The cost elements were developed by Caltrans in a GP level. Included are 10% mobilization and 20% contingencies as standard at the GP level. The cost estimates appear to be realistic and accurate for the GP level achieved at the time retrofit study was ordered discontinued. It was not complete.

6.I. Other Alternatives

Even though significant additional work would be necessary to complete the proposed retrofit scheme, Caltrans has adequately considered other retrofit alternatives. There is no other global retrofit alternative defined using a consistent retrofit strategy for the entire bridge. There are, however, many local alternatives that were explored in the development of each individual contract. Many of these alternatives were disregarded for various reasons prior to developing a detailed alternative design. In many cases, it was not possible to develop a complete and accurate cost estimate, and it is not possible to determine whether or not many of these alternatives would satisfy lifeline criteria. The design process is an evolving process in which many alternatives are given due consideration without completing a design and cost estimate. Because many factors control design decisions, complete and accurate cost analysis is not always necessary in the decision process. Some of the considered alternatives are summarized below.

- (1) Regarding the towers, a steel strengthening and various concrete encasement seismic retrofit alternatives were considered. Concrete encasement was selected based on several factors.
- (2) Alternative foundation retrofit strategies were considered. These alternatives included ground improvement (grouting) schemes, small diameter piles, and large diameter vertical and battered steel piles with a new pile cap / load transfer structure above the water surface.
- (3) For the 504' span trusses, two alternative schemes that employ additional towers placed adjacent to the existing towers were considered. In the first scheme, the additional towers serve to restrain lateral movement of the trusses, and in the second scheme, the towers provide platforms to catch an unseated truss.
- (4) Several strategies for support of the cantilever truss spans were evaluated including a cable system, an edge arch system, a superstructure frame, a

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substructure frame, and an external strut truss system. These alternatives included retrofitted towers and in some cases additional towers. These alternatives were evaluated qualitatively, with minimal analysis, and eliminated from further study.

- (5) There were two general retrofit alternatives considered for the existing caissons (E2 to E5). Alternative one is to install tiedown anchorages and the second alternative was to add large diameter pipe piles around the perimeter of the existing caisson with a concrete cap tied to the caisson.

Appendix 5. Review of Originally Proposed Replacement Alternative (Skyway or Viaduct Type Bridge)

Purpose of Review: Review of this design alternative assists in answering Question 2 from the scope of work. Question 2 as stated in the scope follows:

Was Caltrans' cost-benefit analysis comparing the originally proposed replacement alternative vs. the proposed retrofit alternative reasonable -- i.e., was it based on appropriate criteria and sound analysis, including consideration of realistic, accurate and complete cost figures?

This alternative essentially is the least cost replacement alternative that provides the required seismic performance (lifeline). It was used by Caltrans in late 1996 and early 1997 to compare cost of the retrofit alternative to a replacement alternative and was the primary basis for recommending replacement over retrofit. Replacement was recommended by Caltrans and the State of California in early 1997. **This review primarily focuses on the appropriateness of the design effort as related to the alternative costs that were used in the comparison. A discussion of lifecycle costs is also given.**

Documents Reviewed and Chronology of the Skyway Design

| Doc No. | Provided by | Description or Title | Date |
|---------|-------------|--|-------|
| 371B | Caltrans | Skyway Design Calculations – 300ft spans | 03/96 |
| 371C | Caltrans | Skyway Design Calculations – 500ft spans | 08/96 |
| 169 | Ventry Engr | Value Analysis Summary of SFOBB Replacement | 08/96 |
| 252 | Caltrans | “The Gray Report” Cost Estimate Investigation for the East Spans Replacement | 09/96 |
| 170 | Ventry Engr | Value Analysis Summary of SFOBB Replacement Bridge Retrofit Project – “Structural Report” | 09/96 |
| 23 | Ventry Engr | San Francisco-Oakland Bay Bridge East Bay Crossing Replacement Value Analysis Findings | 12/96 |
| 249 | Caltrans | “The Yellow Report” Replacement Study for the East Spans of the SFOBB Seismic Safety Project | 12/96 |
| 329 | Caltrans | Governor’s Action Request (GAR) | 02/97 |
| 250 | Caltrans | RETROFIT VS. NEW BRIDGE | 04/97 |
| 263 | Caltrans | 30% Type Selection | 05/98 |
| 276 | Caltrans | Draft Environmental Impact Statement (DEIS) | 09/98 |
| 267 | Caltrans | Replacement vs. Retrofit | 04/00 |

Description of Alternative: The originally proposed replacement alternative is generally described as haunched girder skyway structure and would follow the same alignment as any other replacement bridge. This type of structure makes up a significant portion of the SAS and Cable Stayed alternatives with the difference being in the main span. Document 276 describes the Skyway Design as a structure constructed of either concrete or steel, supported from under the bridge by piers. With this structure type, each bridge would be constructed as a separate, independent structure. Under the skyway design alternative, spans over the navigation channel area could be a maximum of 490-550 feet in length which would require 3 spans as compared to the 2 spans for the self anchored suspension and cable-stayed alternatives. It is noted that there were several variations of the skyway alternative over time and subsequently several different cost estimates. Indeed, the cost estimate used in two of the primary reports (docs 249 and 250) that demonstrated the lifecycle cost superiority of the replacement over the retrofit approach was a composite of several different replacement alternatives including cable stayed.

Geotechnical Consideration: Geotechnical information for the 1996 designs was extrapolated from the retrofit alternative. Site-specific geotechnical data was developed for the 1998 design.

Seismic and Earthquake Consideration: Site-specific seismology for the retrofit alternative was utilized for the 1996 replacement designs. This essentially included the response spectras for six different ground motions. The 1998 design also utilized the retrofit ground motions as the updated ground motion data was not yet complete. A significant effort was exerted in defining the seismic setting for the SFOBB. Rock motions were determined and propagated through developed soil columns to provide a series of site-specific time histories and response spectra at appropriate foundation levels. Rock motion was propagated using equivalent linear (SHAKE) and nonlinear analysis. Soil-Foundation-Structure Interaction analyses were also performed.

Sound Analysis/Design Criteria: The following documents were reviewed that contain design information and/or calculations related to the originally proposed replacement alternative (skyway/viaduct).

- 1) Documents 371B and 371C contain design calculations that appear to be for the viaduct designs contained in document 252 with 371B including designs of 300 ft spans and 371C including designs of 500 ft spans.
- 2) Document 252 contains design criteria, drawings and cost estimates for the preliminary replacement alternatives. The originally proposed replacement alternative is not actually included in this document though a similar skyway/viaduct alternative is.
- 3) Document 170 contains seismic design calculations (pushover analyses, column design, foundation evaluations), drawings and cost estimates for the VA alternatives.
- 4) Document 263 contains 30% design level drawings, design criteria, costs, geotechnical data and selected analysis results and discussions. The Skyway was analyzed using a SAP2000 global model that included nonlinear springs and

beams to represent the pile foundations. Response spectrum analysis was used with this model. ADINA was used to perform 2D and 3D parametric analyses of the pile foundations (soil-foundation-structure interaction). This included nonlinear soil properties and inelastic properties of the piles and columns.

The design and analysis for the originally proposed replacement appears to be reasonable and appropriate for the level of design. The more detailed 1998 design confirms the adequacy of the earlier designs.

Seismic Reliability - Lifeline Criteria or No Collapse: The design intent of the originally proposed replacement alternative was to meet lifeline criteria, with seismic events defined and the expected performance for the events given [Document 252]. Ductility and displacement goals are also given [Document 252]. The 1996 versions of this alternative were based on preliminary design efforts (appropriate) and therefore the design to lifeline criteria is not actually demonstrated; however, based on the provided design documents it is clear that Caltrans and various consultants felt very comfortable that this bridge type could be designed to lifeline standards and that this bridge type would provide the best seismic performance, i.e. better than cable stayed or suspension bridges. Caltrans' 30% design (1998) describes a more refined design effort with performance criteria, site-specific data and selected design/analysis results though no actual calculations/analyses were provided [Document 263]. It is concluded, based on the documents provided and engineering judgment, that this bridge type would provide better seismic performance than the other alternatives due to its relatively simple design and construction. The designs used for the comparison to the retrofit are reasonable and appropriate for the intended purpose and are representative of a lifeline bridge. The skyway design, which was completed after the replacement versus retrofit decision, appears to confirm the earlier designs and cost estimates [Document in 263].

Cost Figures – Realistic, Accurate and Complete: Though there were variations in the alternative over time and different reported costs, it does appear that reasonable first cost figures were developed for the originally proposed replacement alternative and the cost figures used in the primary decision reports may have actually been conservative.

Reported Costs for Skyway/Viaduct Alternative

| Doc No. | Provided by | Description or Title | Date | Reported Cost (1) |
|---------|-------------|--|-------|-------------------|
| 169 | Ventry Engr | Value Analysis Summary of SFOBB Replacement | 08/96 | 605 |
| 252 | Caltrans | "The Gray Report" Cost Estimate Investigation for the East Spans Replacement | 09/96 | NA (2) |
| 170 | Ventry Engr | Value Analysis Summary of SFOBB Replacement Bridge Retrofit Project – "Structural Report" | 09/96 | 660 |
| 23 | Ventry Engr | San Francisco-Oakland Bay Bridge East Bay Crossing Replacement Value Analysis Findings | 12/96 | 797 |
| 249 | Caltrans | "The Yellow Report" Replacement Study for the East Spans of the SFOBB Seismic Safety Project | 12/96 | 987 (3) |

Appendix 5

| Doc No. | Provided by | Description or Title | Date | Reported Cost (1) |
|---------|-------------|---|-------|-------------------|
| 329 | Caltrans | Governor's Action Request (GAR) | 02/97 | 1,075 |
| 250 | Caltrans | RETROFIT VS. NEW BRIDGE | 04/97 | 990 |
| 263 | Caltrans | 30% Type Selection | 05/98 | 1,100 (4) |
| 276 | Caltrans | Draft Environmental Impact Statement (DEIS) | 09/98 | 1,200 (4) |
| 267 | Caltrans | Replacement vs. Retrofit | 04/00 | 1,170 |

- (1) Millions of \$, Includes Construction and design costs, including approaches, demo, interim retrofit, temporary structures.
- (2) Report did not include original replacement alternative, however a similar viaduct structure was presented with a \$531/SF cost.
- (3) Average of 4 different replacement alternatives including 2 cable-stayed and 2 viaduct types.
- (4) 1998 dollars, DEIS included rounding otherwise the same as 30% Type Selection

Life-Cycle Cost: Documents 23, 249 and 250 address the life-cycle costs of the retrofit alternative and the originally proposed replacement alternative. These documents all make the same conclusion, i.e. that the replacement approach is much more desirable from a lifecycle cost standpoint. Based upon the data received it is difficult to confirm some of the actual numbers (and methodologies) used in the economic or lifecycle analyses; however the analyses appear to address the significant issues and costs. The lifecycle analysis appears to be reasonable and realistic. Given the initial costs of the proposed retrofit and the originally proposed replacement being similar, from a qualitative point of view it appears, even without performing the actual lifecycle/economic analysis, that the replacement would be preferred. (Seismic reliability, operations and maintenance, traffic issues, etc.)

The lifecycle cost as presented suggest that the decision to select a replacement alternative may have been made even if the retrofit alternative costs were substantially less.

Summary: The design for the originally proposed replacement was based on appropriate criteria and sound analysis, which results in realistic, accurate, and complete costs.