SAN FRANCISCO-OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

Progress Report-- May 2000

BACKGROUND

The east spans of the San Francisco-Oakland Bay Bridge are vulnerable to damage and possible collapse during earthquakes that are likely to occur in the San Francisco Bay Area. As shown in Figure 1, the bridge sustained a partial collapse during the Loma Prieta Earthquake of 1989. Studies show that a replacement structure is of better value compared to rehabilitation of the existing bridge. Therefore, the State of California is designing a new east span bridge in partnership with the Metropolitan Transportation Commission and the Federal Highway Administration.

DESIGN

In January 1998, the Caltrans project team with its consultants T.Y. Lin International, Moffatt & Nichol, Parsons Brinckerhoff and others initiated the design with preparation of the 30 percent design variations.

Figure 2 shows a plan and elevation of the proposed bridge. Bridge components include a cable-supported segment, a skyway segment, the Yerba Buena Island (YBI) transition structure and an Oakland approach structure. The bridge alignment selected is consistent with the MTC 1997 recommendations and legislation signed into law in August 1997. Factors considered in identification of the alignment include:

- Vertical profile needs to match the existing YBI viaduct;
- Horizontal alignment of proposed west span needs to join the existing alignment approximately 110 meters east of YBI tunnel portal;
- Construction economy and aesthetics;
- Desire to maintain the main span tower close to YBI due to geologic considerations;
- Preference to keep the east end of the new bridge close to the existing Bay Bridge structures due to progressively poorer soils northward of the existing structure; and
- Highway geometry needs to provide for design speed of 100 kph.

A large striking asymmetric self-anchored suspension bridge has been chosen for the cable-supported segment. Figure 3 is a computer rendering of the cable-supported segment. The structure is supported by double column bents at both the west and east ends of the segment and by a single large multi-legged tower that supports the main cables which in turn support the deck throughout the length of the segment. The cable-supported segment has a 385 meters forward span and a 180 meters back span. The tower and orthotropic deck are steel.

The skyway segment of the bridge is comprised of side-by-side long span, haunched prestressed concrete box girder bridges separated by 15 meters. The spans are 160 meters, gradually

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1 MTC Memorandum to Bay Bridge Design Task Force from L.D. Dahms, Executive Director, Metropolitan Transportation Commission, re: EDAP Recommendations, June 4, 1998.
decreasing to 120 meters toward the Oakland approach structure. Figure 4 is a computer rendering of the skyway segment.

For the YBI transition structure, the eastbound and westbound structures are carried on separate single-column bents, except near the viaduct end where they are supported on outrigger bents. The separate transition structures merge into the existing double deck viaduct structure at the YBI portal. Figure 5 shows a cross-section of the YBI transition structure.

During construction of the YBI transition structure a YBI detour structure is required. For the 30 percent design, three alternative detour structures were presented. Figure 6 shows the detour option eventually selected where westbound traffic is detoured to the north and eastbound traffic is detoured to the south of the new YBI transition structure.

For the Oakland shore approach structure, an elevated structure is used. The elevated structure consists of cast-in-place, prestressed concrete box girder supported on reinforced concrete piers, reinforced concrete footings and small diameter pipe piles. Figure 7 is a section view of the Oakland approach elevated structure.

In addition, EDAP recommended that the new east span be designed in accordance with Caltrans’ proposed design loading which accommodates the possibility of future light rail service.

These design alternatives are more fully described in the 30% Design Report and the Phase I Report.

Since completing the 30 percent design, the design has advanced. Significant design issues include:

- Suspension cable redesign;
- W2 steel pier;
- Skyway cast-in-place segmental option;
- Skyway modified framing scheme;
- Skyway pile cap redesign;
- Steel bicycle/pedestrian path option; and
- Addition of belvederes to the bicycle/pedestrian path.

These refinements have been included in the 85 percent completion design and are described below.

**Suspension Cable Redesign**

The cable-supported segment is a single tower, two-span asymmetrically self-anchored suspension bridge. For the 30 percent design, the suspension cable is anchored at each pier, piers W2 and E2 (see Figure 2). Such conventional anchorage systems require a large cable anchorage, which in this case is provided by the W2 pier. The project team believes that a better anchorage

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system is a monocable system in which the strands of the main cable are anchored within the deck itself at the east transition box girder only. The cable is looped around at the west anchorage (Figure 8) and supported by one twin-trough deviation saddle at the tower top. The monocable system has the advantage of simplifying the west-end anchorage and reducing the construction cost of the bridge.

Also, cable replacement for this bridge would be extremely difficult. In fact, replacement should be avoided due to the complicated three-dimensional cable geometry and the nature of the self-anchorage system. The quality of the cable strand, wire manufacturing, cable assembly, corrosion protection, and maintenance are important design considerations. Studies undertaken by the project team\(^5\) suggest two things. First, the main cable should be prefabricated parallel wire strand (PWS) cable. Such cable is more resistant to stress corrosion and water-induced corrosion when compared to cable made of individual wires and erected by the aerial spun (AS) method. Second, a corrosion inhibiting system should be implemented. It should use zinc galvanizing, grease application, S-wire wrapping, elastic oxide primer and paint, and possibly dehumidification.

W2 Steel Pier Redesign

A redesign of the west pier has been developed to study the feasibility of a passive tie-down system in lieu of the active system used in the 65 percent design, and a steel cap beam in lieu of a concrete cap beam as used in the 65 percent design\(^6\). The studies show that the redesign improves the overall seismic performance of the pier. The redesign is described below.

**Passive Tie-Down System.** For the 30 percent design, the W2 steel pier uses an active tie down system where pre-stressed cables transfer the uplift load from the suspension cable to the rock anchors. The seismic demand induces tensile load on the anchors. Conceptual redesigns studied here use a passive tie-down system where the pier shafts are structural steel and are anchored to a steel grillage structure embedded in a massive gravity footing. Such a system eliminates the permanent tensile load on the pile anchors. The active pile anchors are no longer used to resist the seismic uplift force.

**Recommendations.** The study shows that the better design is one with a gravity footing (without tension piles), steel composite piers, and a counterweight at the pier bent cap. Figure 9 shows an elevation and plan of the recommended west pier design.

Skyway Cast-In-Place Segmental Option

For the 30 percent design, the EDAP recommended design was the pre-cast (with cast-in-place joints) segmental concrete haunched box girder.

After taking this recommended design to the 65 percent design, Caltrans suggested that a cast-in-place segmental concrete haunched box girder (balanced cantilever construction) variation also be taken to the final design. The cast-in-place design with balanced cantilever construction avoids the need for extensive marine work, and may realize some cost savings.


Skyway Modified Framing Scheme

For the 30 percent design, the skyway is divided into five frame segments to alleviate large creep and shrinkage moments in the piers. A superior scheme is to divide the skyway into four frames to reduce the number of expansion joints and hinges and to improve seismic performance.

Skyway Pilecap Redesign

The 30 percent design used concrete pile caps. Seismic design forces necessitate a massive concrete pile cap with very dense pre-stressed steel reinforcement. Caltrans and the design team suggested an alternative design. Instead of an all reinforced concrete pile cap, a composite steel-concrete pile cap is used. The prefabricated steel plate pile cap resists most of the design load. The voids are filled with lightweight concrete. The pile cap is covered with a cast-in-place reinforced concrete cover all around it. The redesigned pile cap weighs less compared to the 30 percent design, thereby reducing foundation seismic loads. Also, the redesign is easier to construct as compared to the massive heavily reinforced concrete pile cap.

Steel Bicycle/Pedestrian Path Option

EDAP recommended a concrete skyway with a concrete bicycle/pedestrian path. When taking this to a 65 percent design, the project team considered using a steel bicycle/pedestrian path due to its lighter weight. Since the bicycle/pedestrian path is placed at one edge of the box girder, a significant torsional moment is induced in the girder. The steel design reduces the torsion in the box girder; therefore, the steel design is the preferred design and is being taken to the final design level.

Addition of Belvederes

During the 65 percent design of the bicycle/pedestrian path, the MTC recommended that the project team design belvederes (five on the skyway and two on the main span) along the path. Figure 10 shows a rendering of the designed skyway belvedere.
Figure 1  COLLAPSED SPAN OF SAN FRANCISCO-OAKLAND BAY BRIDGE AFTER LOMA PREITA EARTHQUAKE 1989
Figure 2 BRIDGE PLAN AND ELEVATION
Figure 3 RENDERING OF EDAP RECOMMENDED CABLE-SUPPORTED SEGMENT
Figure 4 RENDRING OF EDAP RECOMMENDED SKYWAY—Haunched Concrete Box Girder
Concrete barrier type 732 (mod) typ
Cast-in-place reinforced conc box girder
Cast-in-place prestressed conc box girder

Figure 5 YBI TRANSITION STRUCTURE--Cross Section
Figure 6 DETOUR STRUCTURE AT YBI—North South Option (Aerial view looking north-east)
Figure 7 OAKLAND APPROACH STRUCTURE--Cross Section
Figure 8  REDESIGNED ANCHORAGE FOR SUSPENSION CABLE AT PIER W2
Figure 9  REDESIGNED W2 PIER--Elevation and Plan
Box 7, Folder 6

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