SAN FRANCISCO AND OAKLAND, CALIFORNIA

San Francisco-Oakland Bay Bridge New East Span Skyway

After the 1989 Loma Prieta earthquake damaged the original East Span of the San Francisco-Oakland Bay Bridge, Caltrans determined that the safest, most cost-effective solution was a total bridge replacement. The new, 2.2-mile-long East Span of the San Francisco-Oakland Bay Bridge opened to traffic on September 2, 2013, and is one of the busiest toll bridges in the United States. The bridge is also a designated Lifeline Structure with a 150-year design life, and must be operational for emergency vehicles shortly after the strongest ground motions engineers can expect in a 1,500-year period.

Constructed using the balanced cantilever method, the Skyway incorporates the latest seismic-safety technologies. Each viaduct consists of four structural frames joined together by special hinges that can transfer shear and moment during seismic motion while allowing longitudinal movement. The Skyway decks are composed of precast concrete segments, the largest segments of their kind ever cast.

Innovation of Design and/or Construction

The East Span comprises four interconnected structures: the 2,047-foot-long Self-Anchored Suspension Span (SAS); the 6,900-foot-long segmental concrete box girder Skyway viaducts (Skyway) that sweep up from the Oakland shoreline to connect with the SAS; the 4,229-foot-long Oakland Touchdown, which links the Skyway to California's Interstate 80; and the 1,542-foot-long Yerba Buena Island (YBI) Transition Structure that connects the SAS to the YBI tunnel.

The Skyway portion of the East Span is the bridge's longest component. The parallel eastbound and westbound viaducts carry 10 lanes of traffic in each direction, with 10-foot-wide shoulders to maintain traffic flow and a new bicycle-pedestrian path that enables users to enjoy panoramic views of the region.

The viaducts of the Skyway are three-cell, variable-depth, precast segmental box girders, erected in balanced cantilever, with a typical span of 525 feet. The 452 concrete segments for the Skyway box girders were cast in a special precasting yard and are the largest of their kind ever cast, each weighing up to 750 tons.

After being match cast and stored up to six months to reduce the effects of creep and shrinkage, the segments were barged about 70 miles to the Skyway construction site. Once on site, Self-Launching Erection Devices (SLEDs) were used to lift the massive segments up to 135 feet above the water and into place on the cantilevers. The SLEDs were set up and anchored to the cast-in-place pier tables. The first precast segment was hoisted up from a float barge and a cast-in-place closure was made between the pier table and the first segment. Once the pier table and segments were post-tensioned together, the SLEDs advanced onto the leading segment and were re-anchored. The next pair of segments were then erected and post-tensioned together. The process repeated, with the SLEDs advancing outward from the pier table until all pairs of segments of a typical cantilever were erected.

The balanced-cantilever method of construction was used for the Skyway to compensate for the high cost of constructing seismically-resistant foundations in the soft bay mud. Using this method, the variable-depth segments were erected in both directions, working outward from the piers, and allowed longer span lengths. While this method increased the cost of the superstructure, it reduced the number of spans and lowered the cost of the foundations.

The Skyway superstructure is divided by expansion joints into four frames, three with four piers and one with two piers. The frames are typically connected at midspan by a large hinge pipe beam measuring 6.5 feet in diameter and 60 feet long and are supported on circular bearings. The pipe beams are designed to not unseat during an earthquake, and are constrained against longitudinal movement in one cantilever and free to slide in the adjacent cantilever. This permits the bridge frame to expand and contract at the hinge locations. During an earthquake, the hinge pipe beams constrain the two parts of the structure to move together transversely and vertically, thereby limiting damage to the expansion joint above. In case of overstress, the midsection of the hinge pipe beam absorbs the strain, minimizing damage to the remaining length of the pipe beams.

Carrying 300,000 vehicles per day, the Skyway viaducts also required specially-designed expansion joints that could carry heavy traffic and reduce lane closures during repair procedures. While the expansion joints on the original bridge could only accommodate up to a few inches of movement during an earthquake, the expansion joints used on the new structure can handle up to several feet of movement.

Jury Comments

Truly a landmark structure that is sleek, yet robust, and establishes a new gold standard in seismic performance for lifeline structures. With a 150 year design life it will impress generations to come. Massive precast segments, long spans, and durable post-tensioned concrete all within the most severe of seismic environments-absolutely impressive.

A battery of mock-ups was performed to verify constructability and circumvent challenges in the field, thereby maintaining and/or accelerating erection operations and reducing the risk of impacts to the schedule. While this method has been used to create secure foundations for offshore oil rigs, this is the first time the technology has been used for bridge construction of this scale.

Aesthetics and/or Harmony with Environment

The structure has a sleek aerodynamic form that minimizes its visual mass. The Skyway that ascends gracefully from the Oakland shoreline connects seamlessly with the parallel roadways of the SAS.

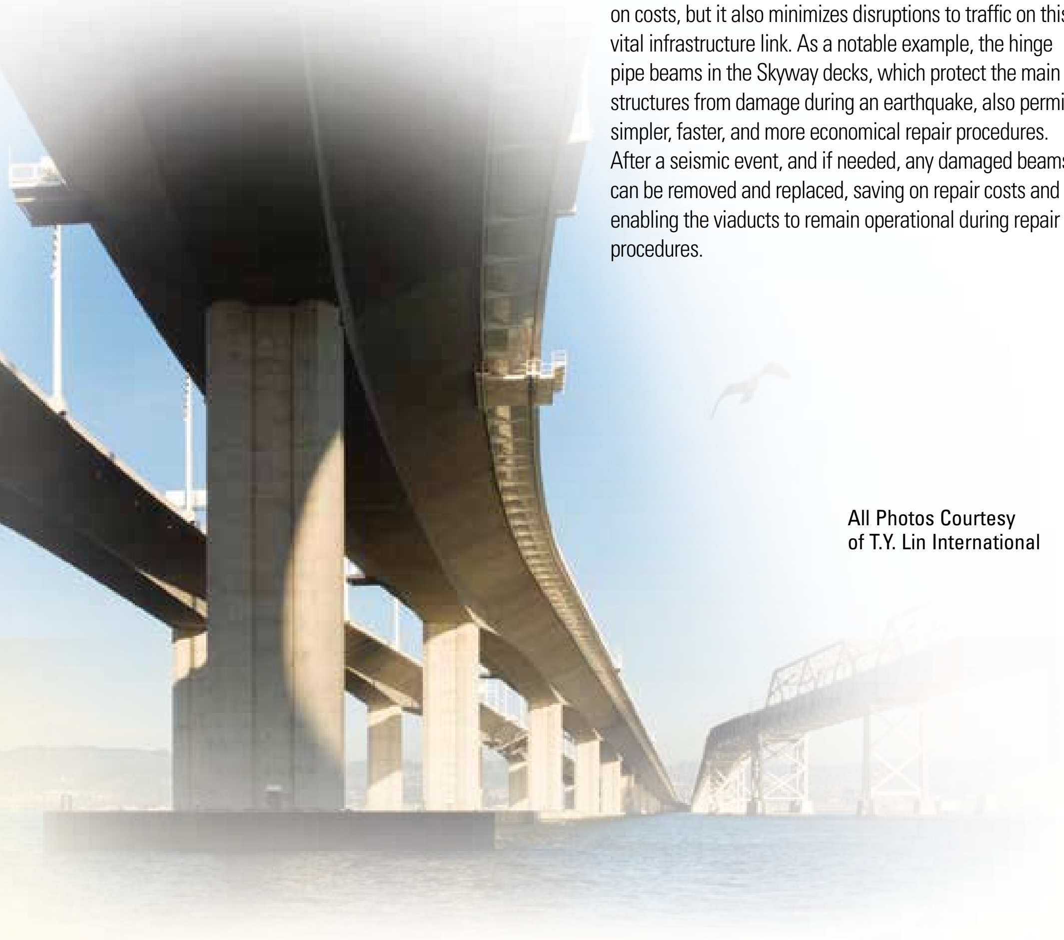
Aesthetic design flow can also be seen in the shape of the piers and the profile of the new bicycle-pedestrian path that "floats" alongside the eastbound Skyway structure. The 15.5-foot-wide path currently offers a scenic, 4-mile round-trip at steady 2 percent climb across the Skyway to the SAS, where the trail stops just west of the tower. The path also has benches at wider belvedere locations where users can enjoy panoramic views of the Bay Area without blocking traffic.

Because the San Francisco Bay is home to large, diverse communities of plant, fish and marine mammal life, the project team developed and implemented a comprehensive program to safeguard the environment during construction activities. One innovation used during Skyway construction was the marine pile driver energy attenuator, which creates a dense shower of underwater bubbles. This "bubble curtain" protected fish and other marine life by enveloping the Skyway pilings and dissipating the shock waves produced by the energy from the pile-driving hammer. In addition, since certain bird species have roosted on the original bridge for decades, the team designed special nesting platforms under the Skyway, nicknamed "Cormorant Condos," to provide nesting habitat in the same general area.

Minimization of Construction Impact on the Traveling Public

Although the East Span was a seismic engineering project, the structure also addresses local and regional transportation needs in several ways. From the onset, one of the most important project considerations was the need to keep traffic moving during construction. For this reason, the original bridge was kept operational until the new structure opened on Labor Day 2013. Major construction and demolition work was also scheduled during nights and weekends in order to minimize disruption to peak commute hours.

The design team also provided effective solutions for bridge repair after an earthquake. Not only does this save on costs, but it also minimizes disruptions to traffic on this vital infrastructure link. As a notable example, the hinge pipe beams in the Skyway decks, which protect the main structures from damage during an earthquake, also permit simpler, faster, and more economical repair procedures. After a seismic event, and if needed, any damaged beams can be removed and replaced, saving on repair costs and enabling the viaducts to remain operational during repair procedures.



All Photos Courtesy of T.Y. Lin International

CREDITS

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Construction Engineering Services: **Parsons Transportation Group**

Constructability Review/ Estimating Services: **California Department of Transportation (Caltrans)**

Construction Engineering Inspection: **California Department of Transportation (Caltrans)**

Precast Producer: **Kiewit** / FCI / Manson, A Joint Venture

Formwork for Precast Segments: **Deal**

Form Travelers for Cast-in-Place Segments: **Schwager Davis, Inc.**

Erection Equipment: **Schwager Davis, Inc.**

Post-Tensioning: **Schwager Davis, Inc.**

Bearings: **D.S. Brown Company**

Expansion Joints: **D.S. Brown Company**

Epoxy Supplier: **Sika USA**

Prepackaged Grout: **Sika USA**