



**Ben C. Gerwick, Inc.**

**NEWS**



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# NEWS

**Published by**

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## Cover Picture

San Francisco-Oakland Bay Bridge - Self-Anchored Suspension  
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New Publications and Presentations

# New Eastern Span of the Bay Bridge

## Self-Anchored Suspension Bridge Alternative

In May, 1997, the Metropolitan Transportation Commission's (MTC) Bay Bridge Design Task Force requested receipt of presentations from interested parties on proposed designs for the new eastern span. An Engineering and Design Advisory Panel (EDAP) had been convened to assist the Task Force in recommending a preferred design. A proposal was developed by the Gerwick/Sverdrup/DMJM Joint Venture, currently working for Caltrans on the seismic upgrading design for the Richmond-San Rafael Bridge. Assistance was provided by COWI, Ben C. Gerwick, Inc.'s parent organization, and Dissing + Weitling (Architects).

The unique setting of the new eastern span was a major consideration in the proposal. A suspended span design echoes the sweeping lines of the western spans as well as the Golden Gate Bridge. The concept of a self-anchored suspension bridge was a consequence of the difficult founda-



Web Site opening page.

ation conditions with deep, soft soils in the Bay. The absence of anchor blocks led to an elegant design with a slender single pylon that pierces a streamlined box girder.

The main structural and construction considerations were:

- High post earthquake performance
- Life line service after an earthquake on either Hayward or San Andreas Fault systems
- Off-site prefabrication to enhance speed of erection, quality and economy

The proposed design of the new span has been performed with sensitivity to environmental concerns to minimize adverse impacts on wetlands and wildlife features.

The users of the bridge, motorists as well as cyclists and pedestrians will experience panoramas of the bridge itself, the broad sweep of the bay, and the interactions of the bridge with the shorelines.

On July 30, 1997, MTC recommended that Caltrans should select two design teams to develop a single tower cable stayed bridge as well as a single tower self-anchored suspension bridge to approximately the 30% design stage before a final decision on design concept is made.

*Paul E. Bach*



Landmark Structure for Oakland.

# Richmond-San Rafael Bridge

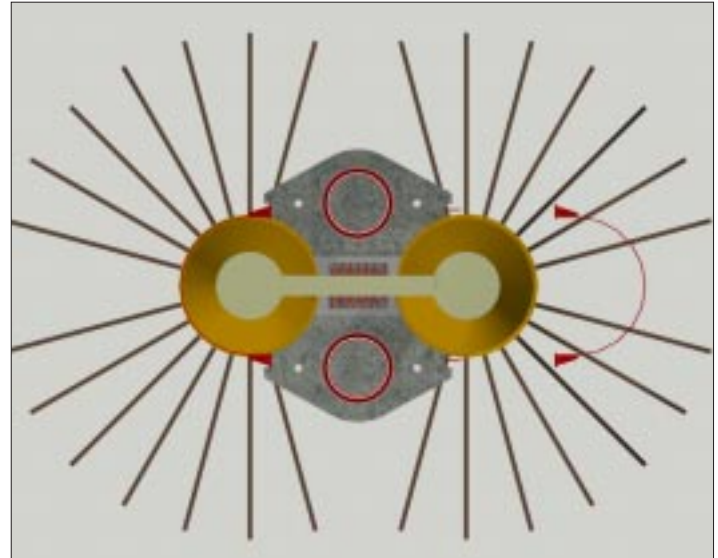
## Innovative Foundation Retrofit

The 4.1 miles long Richmond – San Rafael Bridge, spanning across the northern part of the San Francisco Bay is one of six northern California toll bridges currently being seismically upgraded. Ben C. Gerwick, Inc. is responsible for the final seismic retrofit design of the pile foundations, concrete substructures and steel towers.

The existing concrete substructures consist of two or four concrete shafts interconnected by concrete spandrel beams and diaphragm walls. The concrete shafts are bell-shaped at the bottom to accommodate the large number of HP14x89 steel piles, placed in concentric rings, which make up the underlying foundation. The two outer rows of steel piles are battered 3:12 and 2:12 respectively. Typical water depth is about 50 to 60 feet.

The existing pile foundations experience excessive horizontal displacement demands and will be strengthened by large diameter (10.5 feet to 13.5 feet in diameter) cast-in-steel-shell (CISS) concrete piling installed through new precast concrete pile caps. The existing battered piles limit the location of the new retrofit piling to a central location between the existing belled foundations and underside of the superstructure deck.

As a result of the new large diameter piling the existing H-piles will maintain their capability of carrying overturning forces due to a reduction in lateral displacement demand. The new precast pile cap, through which the new pin-headed piling is driven, is de-coupled from the existing foundation so that only horizontal forces are transferred between the new piling and

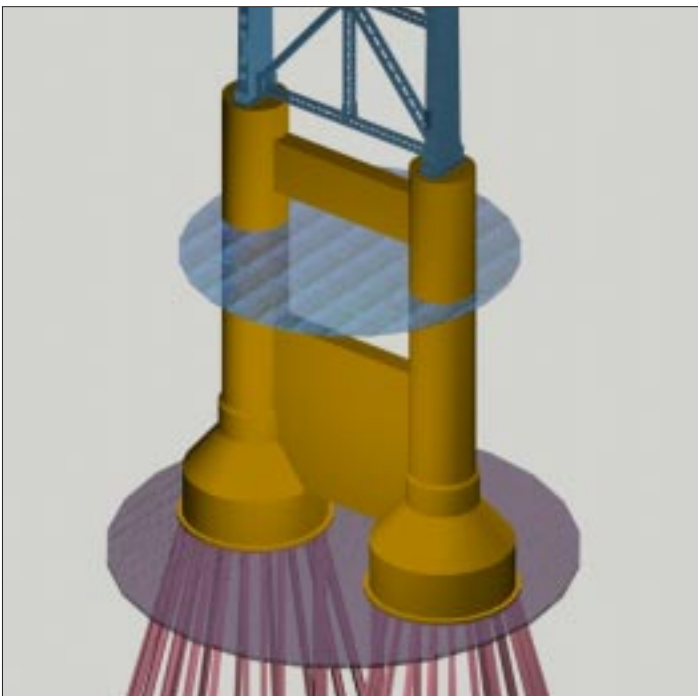


Plan view of foundation retrofit with battered piles indicated.

as-built foundation. This concept has three main advantages; (1) complicated connections sixty feet below sea level between the new pile cap and existing bells are avoided; (2) the thickness/mass of the pile cap is reduced and; (3) additional overturning demand on the battered H-piles is avoided. The inherent rotational fixity of the existing foundation would restrain the rotation of the new pile cap if not de-coupled from the bells and thereby increase the overturning demand on the battered H-piles. All three items above improve the constructibility and reliability of the retrofit.

The four foot thick precast pile cap comprises two identical halves with overlapping reinforcement extending from each half. The precast pile cap halves are each supported by three 14 inches diameter steel pipe piles. Leveling plates with elastomeric bearing pads are placed on top of the pipe piles and adjusted with shim plates to match the elevation of the

existing bell foundations. Tremie concrete is placed in the reinforcement splice pocket to connect the pile cap halves monolithically. Semi-circular steel casings are placed around each of the existing foundation bells and are connected by high strength rods embedded in the precast pile cap. To avoid high local stresses in the steel casing connections, which would result from the rotation of the existing bells relative to the new pile cap, the HS rods are placed in oversized pipe sleeves. Elastomeric bearing pads attached to the sides of the precast pile cap combine with the steel casings to transfer lateral forces between the pile cap and existing foundations. Gaps between the new pile cap assembly and the existing foundation, as a result of construction tolerances, are grouted. In addition to flame sprayed plastic the steel casings are protected by aluminum anodes attached to the casings with galvanized bolts and studs allowing for future



Typical substructure and pile foundation.

replacement if required. Permanent reference electrodes are also attached to the casings with test boxes mounted above the water line. This allows for annual monitoring of the cathodically protected steel elements without the use of divers.

The large diameter steel piles are placed and driven through an oversized steel reaction collar attached to the precast pile cap. The steel reaction collar comprises two concentric circular steel plates separated by a strip of elastomeric bearing pads. After the large diameter piles are installed the gap between the steel reaction collar and the pile cap is grouted. This concept ensures that only horizontal forces are transferred between the pile and the pile cap. The large diameter piling therefore only carries

its self-weight and seismically induced lateral loads. The upper part of the steel pile is finally filled with tremie concrete after the pile has been cleaned out.

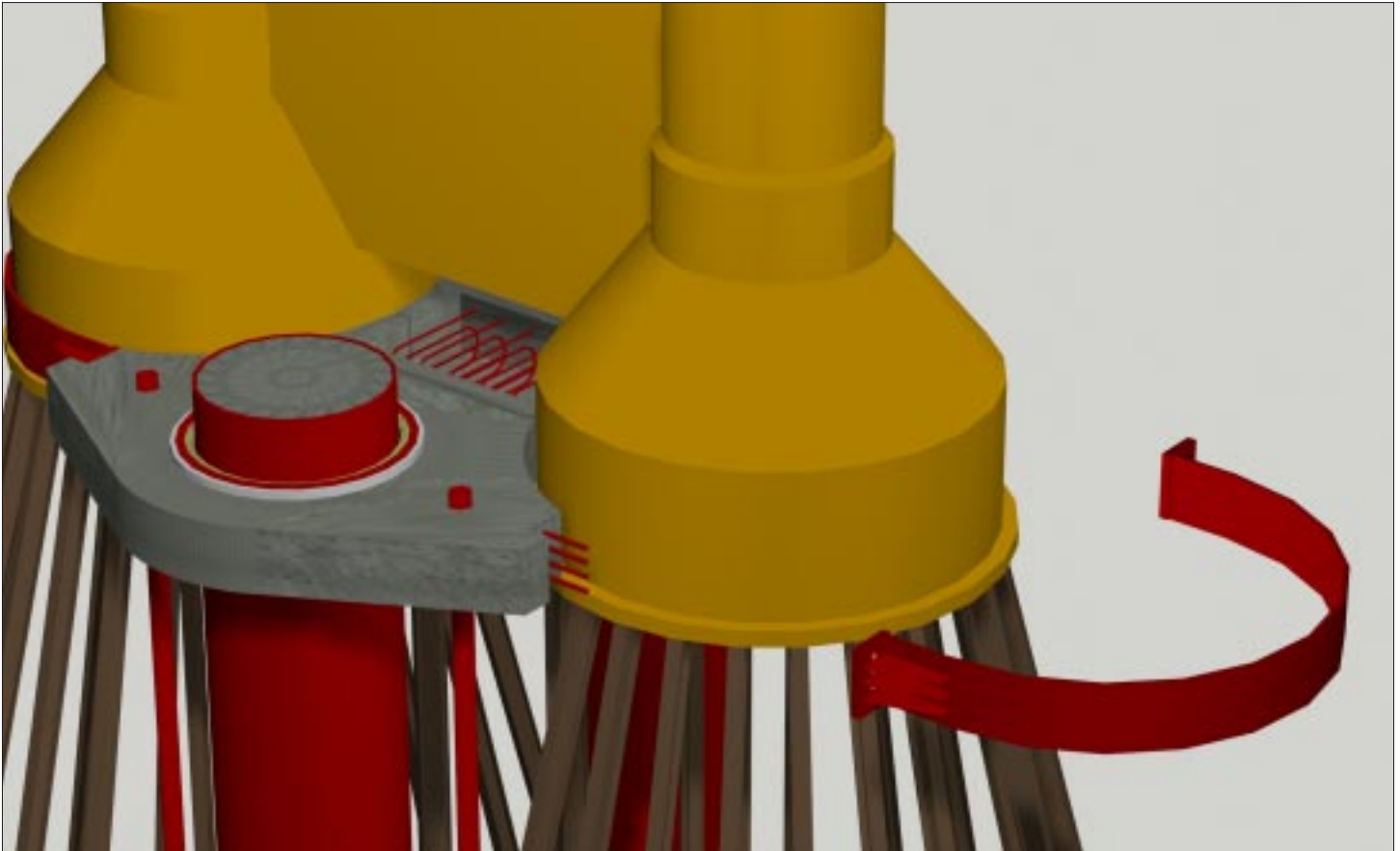
The Gerwick/Kiewit joint venture pioneered the construction method of using precast concrete elements placed underwater without the use of cofferdams and with minimal use of divers during the construction of the existing foundations and substructures. The construction method proved cost-effective and reliable. The use of prefabricated elements throughout the retrofit design will therefore improve both the quality of the retrofitted foundations and the efficiency of the construction and installation.

*Thomas Dahlgren*



*Placing existing precast shaft.*

*Precast pile cap retrofit.*



# Eccentrically Braced Bridge Towers

## Testing Full Scale Frames

Ben C. Gerwick, Inc. developed the concept of using Eccentrically Braced Frames (EBF) to replace the bracing in the existing steel towers supporting the Richmond-San Rafael Bridge. The design provided a reliable means for controlling seismic demands on the superstructure and foundations while preserving the architectural character of the bridge and minimizing the additional mass.

The new EBF towers are central to the seismic performance of the entire bridge. They provide significant lateral capacity but are flexible enough to absorb the earthquake's energy in a ductile manner. They also provide sufficient post-yield capacity to maintain the stability of the bridge after a major earthquake.

EBFs have been used for several years in building frames

and their design, based on American Institute of Steel Construction (AISC) recommendations, have been substantiated by full-scale testing. The Richmond-San Rafael Bridge retrofit, however, required EBF link beams with sizes and proportions well outside the ranges previously tested. As a result, a testing program was implemented to gather the data necessary for accurately predicting the performance of the retrofitted towers. The testing established the amount of post-yield strength gain that could be expected and verified the adequacy of the welding details developed for this project.

### TEST RESULTS

Two beam sizes were tested. The largest was a 30-inch deep built-up section with 12-inch by 14-inch flanges and 3/8-inch web. The second specimen was 16-inch

deep with the same flanges and web thickness. Both specimens had link beam lengths of twelve feet. To be considered successful the specimens had to withstand several post-yield cycles at a link rotation of 0.09 radians. Final fracture should occur in the web rather than the flanges.

The 16-inch beam performed well and met the design requirements for load capacity, ductility, and link beam rotation. The beam was subjected to 19 inelastic cycles until it finally fractured after two cycles at a rotation of 0.10 radians. The beam survived 4 cycles at a rotation of 0.09 radians. Fracture occurred in the link beam web. The link beam continued to carry 100 kips of shear after web fracture. This desirable post-fracture shear capacity was attributed to the relatively large flanges that remained intact.

The 30-inch beam bottom flange fractured after only 12 cycles at 0.09 radians. Flange fracture was adjacent to the toe of the weld connecting the diagonal member flange to the beam flange and directly below the web cope. Metallurgical testing concluded that brittle cleavage fracture initiated near the mid-thickness of the flange and not at the weld. It was concluded that failure was caused by restraint and the high triaxial state of stress at the beam-diagonal joint which prevented the beam flange from necking down in a ductile manner.

The 16-inch and 30-inch specimens exhibited considerable post-yield strength gains with ultimate shear strength to yield strength ratios of 1.68 and 1.82 respectively. With this data the



Dual EBF tower retrofit.

EBFs could be properly sized to control the demands imposed on the superstructure and foundations.

### DESIGN MODIFICATIONS

The large post-yield strength gain demonstrated during both tests allowed designers to reduce the maximum link beam depth from 30 inches to 22 inches. This brought the maximum link beam size closer to the proportions of the 16-inch beam with its superior post-fracture performance.

In addition, the length of the beam web copes were increased to reduce the level of restraint in the flanges.

The test results demonstrate the importance of verifying the post-yield behavior of structural systems, especially when performance-based seismic design strategies are being implemented.

Stephen P. Hardy



Test specimen - built-up beam and diagonal.

# Port of Port Arthur, Texas

## Wharf Expansion Project

The Port of Port Arthur is adjacent to the Sabine Neches Canal at Port Arthur, Texas. The Port is implementing the 1992 Master Development Plan in order to expand its current market share and focus on new market opportunities. The new wharf expansion project includes an approximately 1,700-foot wharf at the west end of its existing 1,200-foot berth. VZM/TranSystems of Oakland and Ben C. Gerwick, Inc. of San Francisco were selected by the Port to design the pile supported wharf structural system to meet the industry standard. The design was completed in October, 1997 and the construction is scheduled for January of 1998.

The site of the new wharf expansion is generally characterized by deep soft soils underlain by dense fine sand. An existing slip area is presently located under the westernmost 400 feet of the

wharf and presents a big design challenge for the pile foundation.

The wharf structure comprises of a 24 inch thick reinforced concrete slab, cast-in-place and supported on 20-inch and 24-inch prestressed concrete square piles. The waterside and landside crane girders are also cast-in-place and supported on 54-inch diameter hollow prestressed concrete piles up to 145 feet long.

The vertical 54-inch diameter hollow prestressed concrete piles are spaced at 20-foot on centers and have been designed by balancing the elastic and plastic responses of the supporting piles with the soil under the design wind loads and ship berthing forces. The piles are filled with concrete near the top to facilitate a rigid moment connection to the cast-in-place concrete girders.

The new Port Arthur wharf

expansion project demonstrates that large diameter cylinder piles are an effective alternative to using the conventional batter piles for wharf structures designed to resist both heavy lateral and vertical loadings in areas with difficult pile driving conditions.

*George C. Fotinos and Yu-Yi Hsu*



New wharf expansion site.



Driving relieving platform piles.

# Tsing Ma and Kap Shui Mun Bridges

## Completion of Hong Kong Airport access bridges



The on-schedule completion of the two airport access bridges from Kowloon to Lantau in Hong Kong was a remarkable achievement by all concerned. Each bridge is a world-class structure. Each is carrying eight lanes of road and two tracks of rail. The Tsing Ma bridge, with a clear span of 1344m is the longest and the heaviest combined rail-road bridge in the world. It spans the main ship channel leading from the ocean and Hong Kong to South China. The Kap Shui Mun cable-stayed bridge is of special technical interest because of its use of composite steel-concrete construction on all three axes. The Ma Wan viaduct, a heavy elevated double deck structure of pre-stressed concrete, joins the two bridges.



The opening celebration was an affair to be remembered, conducted by the cooperative efforts of the outgoing British Commonwealth government of Hong Kong and the incoming Peoples' Republic of China. It featured spectacular fire works including a pyrotechnic waterfall from the entire span of the Tsing Ma bridge.

The author is a member of the Panel of Experts for this project.

*Ben C. Gerwick, Jr.*

## New Publications and Presentations

Analysis and Design for the Inelastic Response of a major Steel Bridge  
National Seismic Conference on Bridges and Highways  
Sacramento, July 1997  
*John Vincent, Tore Abrahamsen, Michael O' Sullivan, et al.*

Jamuna River Bridge, Bangladesh: pile-driving on a vast scale  
FIP, January 1997  
*Ben C. Gerwick, Jr.*

Durability and Design of Marine Structures  
1997, W.R. Grace Engineering Seminar  
*Sam Yao*

Modular Concepts for Rapid Repair of Navy Waterfront Structures  
ASCE Ports, 1998  
*Sam Yao*

Applications of Service Life Prediction in Durability Design  
1997 ACI Fall Convention  
*Sam Yao*

Design of Inland Waterways Structures Using Prefabricated Concrete Units  
XIII FIP Congress, Amsterdam Proceedings  
May 23-29 1998  
*Ben C. Gerwick, Jr. and Dale E. Berner*