Tour Guide

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The Bus Tour
Orthotropic Steel
Bridges OBC 2008
Saturday
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1. Summary

This paper describes seventeen Orthotropic bridges built and in operation in California, plus one under construction and two innovative bridges designed, but never built. Orthotropic steel decks in North America are very rare with about 51 out of 650,000 inventoried bridges. California has 25,000 bridges or 4% of all USA bridges, but more than 25% of the orthotropic bridges. Bridges discussed are the North 680 to West Connector Bridge of Dublin CA [1965]; Ulatis Creek I-80 wearing test bridge, Vacaville [1966]; San Mateo - Hayward [1968]; San Diego Coronado [1969]; Queensway Twin Bridges [1971]; BART Weathering Steel Twin Steel Bridges – Berkeley [1972]; the Miller-Sweeney bascule bridge on Alameda Island; [1974]; Sacramento River Bridge at Colusa [1980]; Golden Gate Bridge Redecking [1985]; Maritime Off-Ramp [1997]; are the Carquinez Straits [2003] and the SFOBB San Francisco Oakland Bay Bridge [2007].

Map: The Orthotropic Bridges on Tour – Seven Bridges

A small pedestrian bridge at Braille Trail [1977], and a patented slab bridge [1998] design by Advanced Bridge Systems of Redding California has been approved by Caltrans are discussed. Innovative orthotropic bridges that were not constructed, due to cancellation of funding, such as the Southern Crossing [1972] Viaduct's 304.8-M signature span tied basket handle arch, and the Ruck-A Chucky curved cable stayed bridge [1976] are described.

Keywords: Orthotropic steel decks; Orthotropic, Bridges, Wearing Surface, Weathering Steel, California, Movable Bridges, bascule bridge, and fatigue resistant detailing
2. Introduction

**ORTHOTROPIC BRIDGES OF CALIFORNIA**

by Alfred R. Mangus

#2 Ulatis Creek Test Lane Bridge West Bound I-80
Bridge Number 35-0054

#10 Suspension Bridge at Carquinez Straits I-80
[2003]

Ruck-A-Chucky - Curved Cable Stayed [ unbuilt]

Auburn

Slab Bridge Advanced Bridge Systems, Redding

Four BART Bridges Berkeley [1972]

#9 Maritime Off-Ramp Bridge Number 33-0623S
Oakland [1997]

#6 MillerSweeney Bascule Bridge [completed 1974]
Bridge Number 33C-0147

Map: The Orthotropic Bridges of California [numbered order built]

In the 1920's, American engineers began using steel plate riveted to steel beams for large movable bridges [1]. The purpose was to minimize the dead mass load of the lift span. In 1938, the American Institute of Steel Construction began publishing research reports on the steel-deck system. The AISC called this the “Battledock floor” since they felt the steel-deck had the strength of a battleship. The Germans began to use steel-deck bridges as grade separation bridges for their “autobahn” in 1934. After the war, the Germans developed better analytical methods to analyze this “Orthotropic” system in the 1950’s. One German Company “MAN” created a manual. In 1963, the AISC funded and published
the pioneering work *Design Manual for Orthotropic steel Plate Deck Bridges*, authored by Roman Wolchuk [2]. This prompted the states of California, Illinois, Michigan, Missouri and Oregon to create prototype bridge systems. AISI, American Iron and Steel Institute, sponsored funding of the documentation of the various wearing surface test bridges built across North America. Caltrans purchased German design manuals, which documented the design procedures that occurred in Europe. The James F Lincoln Arc Welding Foundation has promoted the use of welded Orthotropic bridges with their publications and design contests. Dr. M. S. Troitsky authored *Orthotropic Bridges* in 1967, with minor revisions in 1985 [3]. AISC granted copyright permission to reprint design aids from the 1963 manual by Wolchuk, to encourage the construction of Orthotropic bridges.

**Leave Hotel about promptly @ 8am**

3. **[9-10 AM stopover #1 –exit bus– see map of San Francisco Bay area] The Alfred Zampa Memorial Bridge across Carquinez Straits [2003]**

The steel truss bridge completed in 1927 and designed by David B. Steinman was determined to be in need of a seismic retrofit in the 1990's [21]. The narrowest part of the Sacramento River is at Carquinez Strait, The flow of the water changes with the tide. The suspension bridge offers an obstruction free travel area for the ocean going vessels travelling below these bridges. The descendant firm, Parsons Corporation selected a replacement solution or a Suspension Bridge with an aerodynamic orthotropic superstructure [Bridge No. 28-0352L]. The 1927 truss bridge will be demolished. Dr. John W. Fisher of Lehigh, PA USA, has developed with Parsons Corporation a more fatigue resistant detail for trapezoidal ribs. This detail is described in the AASHTO code & [6] & [22]. The bridge has a 28.96-m wide x 1056-M long = 30,586 sq. meters of Orthotropic deck area. The roadway superstructure is 3.0-M deep. The superstructure was fabricated in 24 full width sections in Japan with bolted splices on the sides and bottom. The top deck is welded. The interior & exterior of the bridge was painted. There are many other papers discussing this complex bridge plus Fig 3. The bridge was named the Alfred Zampa Memorial Bridge. See http://www.franklinnewbridge.org

![Fig. 3 The Alfred Zampa Memorial Bridge across Carquinez Straits](http://www.franklinnewbridge.org)

4. **[10:30 –11 AM stopover #2 –exit bus– see map of San Francisco Bay area] BART = Bay Area Rapid Transit Bridges in Berkeley [1972]**

Four weathering, single track, simple span steel bridges were completed for BART, Bay Area Rapid Transit in 1972, [BART BR. NO. A-096 A & B]. A joint venture of Parsons Brinkerhoff + Tudor Engineers + Bechtel was retained by BART. Tudor Engineers designed these four bridges located in Berkeley, California. Each bridge supports a single track and has a simple span of 33.53-M. Two parallel bridges cross over Golden Gate Ave. and two parallel bridges cross over Chabot Road. The abutments of the Golden Gate Avenue and Chabot Road bridges are separated by about 30-M. One crew of ironworkers built all four bridges. Each deck is divided into ten identical deck panels of about 3.35-M long by the superstructure width. These essentially square deck panels have six trapezoidal ribs that span the 3.35-M. The 40 identical panels were shop welded and field bolted to the transverse floor beams. Gravel ballast for rail track on the weathering steel deck is used to make track
adjustments for grade. The four bridges are 4 x 3.35-M wide x 33.53-M long = 449 sq. meters of total deck area.

![Diagram of a BART Bridge](image)

### Fig. 4 The four BART Bridges in Berkeley

5. [11:30 – NOON stopover # 3– exit bus– see map of San Francisco Bay area]
   - The Miller – Sweeney Bascule Bridge, Alameda Island [1973]

The Miller-Sweeney Bridge [CALTRANS BR. NO. 33C-0147] at Fruitvale Avenue is a four-lane single-leaf Bascule Bridge. Its’ movable span of 18.59-M wide by 38.86-M long crosses the Oakland Estuary [Fig. 5]. This is a navigable waterway between Alameda Island and Oakland, CA, with access to the San Francisco Bay [13]. The bridge was designed by McCreary Koretsky International Inc. for the U.S. Army Corps of Engineers and was opened to the public on December 12, 1973 [15]. In 1989, the Loma Prieta Earthquake caused damage to the bridge inside the machinery pit and it was shut to all vessel traffic until repaired. In 1991 another mishap occurred when a fully loaded sand barge (weighing 3630 metric tons) hit the movable span and caused extensive damage. The Bascule span uses trapezoidal rib with spacing pattern from design aid booklets prepared by the Bethlehem Steel Company [6]. The wearing surface failed by creep when the movable span was in the open position and was resurfaced in 1997 [16]. The bridge is 18.59-M wide x 38.86-M long = 722 sq. meters of deck area. More useful bridge data is available from [http://www.dnai.com/~kenseq/bridges/miller.html](http://www.dnai.com/~kenseq/bridges/miller.html).

![Image of the Miller Sweeney Bascule Bridge](image)

### Fig. 5 The Miller Sweeney Bascule Bridge

**Lunch @ Asena Restaurant Alameda Island [noon to 1pm]**

6. [1:30 pm – 1pm drive over # 4 ] San Mateo - Hayward Bridge across San Francisco Bay [1967]

The State of California San Francisco Bay Toll Crossing was the designer and owner. Caltrans is now the owner and operator of the San Mateo – Hayward. Caltrans Bridge Number is [ Br. No. 35-0054 ] This bridge opened to traffic on Oct 31, 1967 [9] & [10]. This Orthotropic bridge has a two side spans of 115.5-M each counterbalancing the main 228.6-M span. There are 14 approach spans of 89.0-M or 7 per side of the main span. Thus this bridge has the largest total Orthotropic deck area of Any other California Bridge. Statistics are: width of 25.934-M, and length of 1,676.4-M = 43,465 square Meters. It carries six lanes of Route 92 traffic across San Francisco Bay. The two main deck members are
rectangular box girders 3.43-M wide by 4.567-M deep at midspan and 9.135-M deep at supports. Maximum depth is at supports. Fatigue “cut-outs”, were not used at the base of the open rib in all of the crossbeams’ webs. The Orthotropic deck, varies in thickness with deck stresses. The structure was fabricated by Murphy Pacific in Emeryville, CA. The structure was moved and erected in very large pieces by a 453-metric ton floating crane vessel named the “Marine Boss”. Epoxy concrete was used as the wearing surface and it’s still in use after over 37 years of continuous usage. Bay Tolls also built a weight station as an Orthotropic deck prototype for the San Mateo - Hayward Bridge. Testing details plus procedures and this weight station were part of the contract plans for the San Mateo - Hayward Orthotropic Bridge. See www.dot.ca.gov/hq/esc/tollbridge/SMHay/SMfacts.html.

Fig. 6 Hayward San - Mateo Bridge across San Francisco Bay

7. [2:30 pm – 3:30pm stopover #5 –exit bus– see map of San Francisco Bay area] The Golden Gate Bridge orthotropic steel deck replacement [1985]

The Golden Gate Bridge, San Francisco, California, was retrofitted from a reinforced concrete deck built in 1937 to a lighter Orthotropic deck built in 1985 [3] & [6]. This lower deck mass retrofit reduced seismic forces in the suspension bridge towers and other bridge components. Rebar corrosion inside the concrete deck from salt fog was another reason for the deck replacement. The bridge has a 18.288-M wide x 1966-M long = 35,934 sq. meters of Orthotropic deck area. The main span is 1280.2-M with two back spans of 342.9-M. This redecking saved considerable weight reducing seismic loading on the superstructure and tower foundations. Since the roadway deck was a secondary structural component the concrete deck was removed in small pieces at night and replaced immediately with an Orthotropic steel deck panel. See http://www.goldengate.org for more information.

Fig. 7 The Golden Gate Bridge orthotropic steel deck replacement

8. [4pm – 5pm stopover #6 –exit bus – see map of San Francisco Bay area] The East Spans replacement Self-Anchoring Suspension Bridge [2012]

The joint venture firm of T. Y. LIN International + Moffatt & Nichol selected a replacement solution or a Suspension Bridge with a twin aerodynamic Orthotropic superstructure [Br. No. 34-0006 L / R]. The
1936 bridge will be demolished. A variation of Dr. John W. Fisher's fatigue resistant “cut-out” detailing will be used for the “V” shaped deck ribs. Other rib types are also used for this complex structure’s twin superstructure. The detailing of this superstructure is totally different than the Carquinez Bridge [6]. The bridge will use “dehumidification”, so the bridge’s interior will not be painted. The standard Caltrans wearing surface will be utilised. The bridge is divided into two superstructures x 24.08-M wide x 674.83-M long = 32,500 sq. meters of Orthotropic deck area. This steel portion is shown in Fig. 8. See http://www.baybridgeinfo.org/

**Fig. 8 The Self-Anchoring Suspension spans for the East portion of SFOB Bridge**

**Fig. 8b The Self-Anchoring Suspension spans for the East portion of SFOB Bridge**

9.  [5:15pm to 5:30pm – drive over # 7 – see map of San Francisco Bay area ]
**The Maritime Off-Ramp Bridge [1997]**

Shown in Fig. 9 is the Maritime Off-Ramp [ BR. NO. 33-0623S ] a curved "horseshoe" shape bridge crossing over I-80 in Oakland, California, which was completed in 1997 as part of the I-880 Replacement Project. This superstructure has a very sharp radius of 76.20-M and a very shallow web
depth of only 2.13-M for 57.91-M spans. The bridge is 11.03-M wide x 718.1-M long = 7921 sq. meters of deck area. The bridge has two lanes of traffic that create large centrifugal forces. The box girder superstructure is divided into 3 separate cells to resist the torsional forces. Trapezoidal ribs were welded to the top and bottom box girder flanges since this was a continuous structure. The bridge sections were erected over busy I-80 on two different Saturday nights creating an instant superstructure. The bridge was fabricated in 13 segments weighing as much as 318 metric tons and erected with two special hydraulic jacks supported by special multi-wheeled trailers [6] & [19]. The Orthotropic superstructure has a wider top deck plate with a 16-mm thickness and narrower flange plate of 19-mm thickness. In each of the three cells there are four ribs for the top deck and two for the bottom flange. There are two exterior inclined webs and two interior vertical webs [19].

Fig. 9 The Maritime Off-Ramp Bridge

Dinner  [6pm 7pm] @??

Drive by Alfred Zampa Memorial Bridge
Return to Hotel about 9pm

[Other California Bridges not on Bus Tour]

10. Wearing Surface Test Bridge at Dublin [1965]

The North 680 to West connector bridge at Dublin, CA [Br. No. 33-371G] [Dec 1965] was built as an experimental bridge to check the accuracy of Caltrans’ design software “Orthotropic Plate Design” [4]. This software uses the actual capacities, various trapezoidal ribs, and deck plate thicknesses. The California Department of Transportation (Caltrans) built the I-680 over I-580 Bridge as their test structure. This bridge has two totally different rib and deck systems including two different wearing surfaces [5]. This bridge’s two-lane cross-section is similar to a test bridge built by the Michigan Department of Transportation [6], [7]. The four span [22.87-M + 25.91-M + 25.91-M + 22.87-M] bridge uses trapezoidal ribs as shown in Fig. 10. The rigid steel bent is comprised of three-welded steel box members aesthetically shaped. This short span Orthotropic deck bridge is still in use after 30 years of service, but the wearing surface has been replaced on the thin section [8]. The bridge is 10.36-M wide x 97.54-M long = 1011 sq. M of deck area. Therefore 505.5 sq. M is thin and 505.5 sq. M is thick. The deck and ribs were built of [American Society of Testing Materials] ASTM A-441 Steel, while girder webs and bottom flanges are ASTM A-36 steel [25,311 kg/ square mm].
11. Wearing Surface Test Bridge at Ulatis Creek [1966]

The State of California Division of Highways designed the Ulatis Creek experimental bridge lane in 1965. Construction of Caltrans Bridge Number [ Br. No. 23-0052R ] was completed in 1966. It is only the two outside lanes of a 5-span bridge for eastbound Interstate I-80. All spans are 8-M long and the Orthotropic deck has "Split-T" ribs that support eastbound traffic on the outside [truck traffic] lanes. The engineers wanted to test the durability of five types of wearing surfaces. State of California San Francisco Bay Toll Crossing engineers supervised this testing, since the most practicable material was later selected for the wearing surface of the San Mateo–Hayward Orthotropic Bridge. Both State organisations were combined to form Caltrans in the mid-1970's. Ulatis Creek was repainted and a single replaced wearing surface was installed after testing [see Fig. 11]. The Ulatis Creek experimental bridge lane is still in service. This bridge is 10.36-M wide x 39.63-M long = 411 sq. M. of Orthotropic steel deck area. The original wearing surface for the San Mateo Hayward Bridge is still in place after over 38 years and carries some truck traffic, so this bridge is successful in several ways [8].

12. San Diego – Coronado Bridge across the South San Diego Bay [1969]

The San Diego–Coronado Bridge, which was completed in June 1969 [ BR. NO. 57-0857 ]. This California toll bridge sweeps around the harbour area of San Diego. The Caltrans engineers selected a single cell box girder Orthotropic steel deck (continuous length of Orthotropic portion = 573-m). A constant depth box was used for the 182.88-m + 182.88-m + 152.40-m main spans over the shipping channel. Steel plate girders with concrete deck were used on the remaining length of 1690 m. The area is 19.182-M wide x 518.16-M long = 10,266 sq. meters of steel deck. The bridge was erected in large pieces with the "Marine Boss" barge crane. The sections were field bolted together. The bridge is painted on the inside and outside to resist corrosion and carries six lanes of traffic [6] & [11].
Fig. 12 San Diego Coronado Bridge across the South San Diego Bay

13. Queensway Twin Bridges in Long Beach Harbour [1971]

The Queens Way Bridges [ BR. NO. 53C-551 L / R ], identical 3-span twin bridges, were completed in June 1970 and is near the tourist attraction of the decommissioned Queen Mary ocean liner [12]. Each Orthotropic bridge has a main span of 152.4-M. A drop-in span of 88.39-M suspended with steel hanger bars from two cantilever side spans of 32.0-M creates a total of 152.4-M. The side spans are 106.68-M. The two bridges are 2 x 14.02-M wide x 365.76-M long = 10,256 sq. meters of deck area. Each superstructure cross-section is a single cell box with deck overhang. Some components are similar to the completed San Diego –Coronado Bridge. The superstructure was fabricated in 14 pieces and erected in eleven days. Each drop-in span was fabricated as a 560-metric ton piece, in Richmond, California, and floated 1126.5 km south to Long Beach and was lifted up 15.2 meters by the “Marine Boss” barge crane. Minimum deck plate is 13-mm thick. [6].

Fig. 13 The Queensway Twin Bridges in Long Beach Harbour Bay

14. Southern Crossing Tied Arch [1971]

The last concept for a southern crossing was about 22.5 km long and was designed to connect the San Francisco International Airport to the Oakland Airport. Concepts began in the 1950’s. This was the last bridge designed by Bay Tolls. It was not built due to cost and assumed not needed at this time period. The main or Signature Span portion is a tied arch bridge with an Orthotropic steel deck [ see Fig. 14 ]. The two main floor girders were trapezoidal 7.613-M at top x 3.96-M base x 5.538-M deep rather than two large rectangular girders as used on the San Mateo – Hayward Bridge. Fatigue testing of trapezoidal 305-mm at top x 152-mm base x 30-mm depth deck ribs was performed. These were the American Trapezoidal rib shapes developed by Bethlehem Steel Corp. based on the German Krupp Steel ribs. [6]. The bridge was designed to be 35.66-M wide x 396.2-M long = 14,130 sq. meters of deck area.
15. The Colusa Bridge across Sacramento River [1972]

A unique bridge was completed for Colusa County in 1972 [BR. NO. 15C-01]. CH2M Hill Engineers designed this bridge located in Colusa, California [see Fig. 15]. The bridge is 80% prestressed concrete with a 32-M long removable steel orthotropic box section span. The bridge has a 11.63-M wide x 32-M long = 372 sq. meters of Orthotropic deck area. The unique solution cost half as much as a swing bridge. This solution requires truck or barge cranes to pick-up the Orthotropic steel span [13] & [14]. A trapezoidal welded steel box girder with an Orthotropic deck was used to provide a lightweight removable section in a low-level concrete bridge. The weights of several types for the removable bridge section were calculated as follows: normal weight concrete box, 499-metric tons; lightweight concrete box 363-metric tons; steel box with regular weight concrete slab, 363-metric tons; steel box with light weight concrete slab, 272-metric tons; and steel box with orthotropic plate deck, 181-metric tons. Two cranes operating from the bridge, or a single barge mounted crane are needed to lift this removable span. Two truck cranes can provide a comfortable lift for a removable section of steel box girder with an orthotropic plate deck weighing about 181-metric tons. High-strength, corrosion-resistant, weathering steel ASTM A-588 was specified throughout. The 10-mm thick deck plate is stiffened longitudinally by means of closed trapezoidal ribs, spaced about 609-mm on centers. The ribs are cold bent into trapezoidal shape from a 6-mm x 609-mm plate and are 216-mm deep. Transverse supports for the ribs are provided by the floor beams, spaced about 4.27-M on centers. At every other floor-beam there is a cross-frame consisting of two diagonal and one vertical members made of WT 4 x 8.5 [split wide flange 101-mm deep x 11.9 grams/mm]. The overall depth of the removable section is 1.83-M. It consists of 1.75-M steel box with 76-mm epoxy asphalt overlay. The shear in the inclined web is transferred to a vertical web plate at each end by means of two 19-mm thick diaphragm plates. The removable unit has four 152-mm x 305-mm openings through the deck plate for access to lifting pins. Each pair of openings is located at the end of the unit arranged symmetrically about the centerline of the bridge area.

Fig. 15 The Colusa Bridge with removable span across the Sacramento River
16. The proposed Ruck – A – Chucky Bridge [1976]

The most admired bridge that was never built in the USA is the Ruck – A – Chucky Bridge near Auburn, CA [17]. The proposed design directed by the late T. Y. Lin [1912-2003] was completed for the Federal Government assuming that a dam would be built flooding a narrow canyon. To perform a U-turn, the cable-stayed bridge follows a 457.2-M radius and has a chord length of 383.74-M. The bridge was designed to be 15.834-M wide x 383.74-M long = 6,082 sq. meters of deck area. State of the art Orthotropic detailing for that time was used. The superstructure was planned to be site erected as 15.24-M x 15.834-M units assembled from five pieces 15.24-M long. This allowed trucks to reach the site on narrow roads. A shake table model at UC Berkeley simulated seismic loading while wind tunnel testing was done in Colorado. See http://www.ketchum.org/ruckachucky/figures.html

![Fig. 16 The Ruck-A-Chucky Bridge curved cable-stayed bridge hangs from canyon sides](image)

17. The Braille Trail Pedestrian Bridge [1977]

The Orthotropic bridge across Santa Rosa Creek is an integral part of the Braille Trail, built to help the visually impaired and those in wheel chairs to enjoy Spring Lake Park in Santa Rosa, California (see Fig. 17). This bridge is capable of being periodically submerged by floodwater, and aesthetically pleasing as part of a beautiful park [18]. A timber bridge would float and poor soil support discouraged a heavy concrete span; therefore, an Orthotropic steel plate bridge was the economical choice. Engineers with the Sonoma County Water Agency selected an all welded steel Orthotropic bridge to create a minimum weight structure with clean lines for a pleasant appearance and ease of maintenance. The bridge was painted a dark brown acrylic epoxy, which contrasts well with the green park. A sand-wearing surface, bonded to the bridge's deck provides a non-skid surface for wheel chairs and pedestrians. The superstructure was completely shop prefabrication about 240-km from the park. The 1.842-M wide by 18.288-M long has 33.45 sq. meters of deck area. This span was trucked to the site and lifted into place by a crane in 1976 and the photo was taken in 2002 by the author.
18. The proposed Mass Manufactures Slab Bridge [1997]

The modular bridge system was developed by Advanced Bridge Systems Inc., Redding, California and was engineered by Jiri Strasky, Consulting Engineer, Mill Valley, California, for bridges with spans from 6.10-M to 30.38-M. The bridge deck is assembled of steel modules and a composite concrete deck slab (see Fig. 18). The depth \( d \) and number of ribs depend on the span length and loading. The number of modules depends on the total width of the bridge. The width of module shown is 2.515-M. A seven-rib box module forms spans from 6.10-M to 16.76-M; and spans from 18-M to 23-M are formed by six-rib module. Shear studs guarantee a composite action of steel modules, with a concrete deck. Steel stiffeners and concrete diaphragms have been designed at the end of the deck. Static and fatigue loading tests were done at the University of California, San Diego. The "c" shaped Orthotropic ribs are formed quickly from 2-mm coils of flat steel up to 1.829-M wide. These "c" shaped beams are then easily nested and welded together with just 5-mm fillet welds. All welds are quickly and easily made externally. Welding by a patents pending method(s) reduce up to 75% of the effort needed. All exterior welds mean faster production and simpler inspection. Reduced weight saves 10% minimum materials over other systems. Ideal for emergency bridge replacement, since orders can be shipped in seven days. The modules fit on standard trucks and are easily deliverable on all north American highways and most rural roads[20]. A full size mockup of components has been displayed at bridge conferences, and it is not know whether any have been erected in California.

19. Emergency Bridges for replacing damaged bridges. [as needed]

There is need for a replacement “Bailey” Type Bridge. Earthquakes, floods and landslide movements occasional make it necessary to install “temporary” bridge to keep flow of people, goods and services.
flowing. Caltrans owns ACROW type components. This allows the Bridge Investigation & Maintenance Staff of Caltrans to provide a “temporary” bridge for state of California or other government agency use. ACROW uses “chequered” steel deck welded to closely spaced “W-Beam” ribs as shown in Fig 19. Normally wearing surface is not added. This system really dates back to the 1920’s. The only difference was that rivets were used rather than welding as a connection method [1].

![ACROW Components](image)

*Fig. 19 The type of ACROW Components owned by Caltrans for a “Temporary” Bridge*

20. Conclusion Why so few orthotropic bridges in California USA ??

California has about 10% of the population of the USA. It’s economic power is equivalent to that of Japan. The Japanese have more than 250 orthotropic bridges, it is estimated that Europe has more than 1000 orthotropic bridges. The Japanese steel industry has been fabricating many bridges in their own country plus many other countries including the USA. The USA steel bridge fabrication has been shrinking already due to increased use of concrete bridges. The orthotropic bridge is the most expensive to fabricate, normally requiring larger facilities and cranes. The lower initial cost of concrete bridges has placed more competitive economic pressure on the USA steel industry. Thus the USA steel industry finds it difficult to big larger fabrication facilities for an occasional orthotropic bridges. No government agency has decided to fund a new USA orthotropic bridge design manual. There currently is no comprehensive manual dedicated to USA Bridge practices on the subject of orthotropic bridges. None of the private industries or trade associations have upgraded any of the orthotropic manuals or design aids that were created in the 1960’s. Those engineers desiring to design an orthotropic bridge in the USA normally have had to pay for all of their own research. This includes obtaining appropriate bridge codes from other countries, research papers, and any physical testing of actual steel prototype details. Translating technical Japanese articles such as *Orthotropic Steel Decks* that appeared in Japanese *Bridges and Roads*, Oct 1998 and Nov 1999 by Matsui S.; Ohta K. and Nishikawa K. of PWRI Public Works Research Institute will be very expensive, except for figures such as Fig.20.
The largest and best known bridges in California have Orthotropic steel decks. The bridges have been durable and are heavily used by the traveling public. They have performed very well in recent earthquakes. An ASCE, American Society of Civil Engineers’ Conference to be held in August 2004 is being hosted by the Capital Branch of the Sacramento Section of ASCE. One activity will be a site visit to all the bridges located in the San Francisco Bay area to demonstrate their durability and variety of bridge types. Their WWW site is www.orthotropic-bridge.org. Another goal is to inventory Orthotropic bridges across North America to create the sharing of issues by the various owners. It is easy to predict that more of these bridges will be built in California.

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<tr>
<th>Section</th>
<th>Bridge Name</th>
<th>Deck Area (Sq. meters)</th>
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<tr>
<td>4.</td>
<td>Ulatis Creek Test [1966]</td>
<td>411</td>
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</table>
7. Queensway Twin [1971] 10,256
8. Southern Crossing [1971] Not Built
17. Alfred Zampa @ Carquinez [2003] 30,586
18. SFOBB Self Anchoring [2007] 32,500

TOTAL 17 California Bridges 173,937

Millau Viaduct, France [2005] 184,800

Table 1 Compares the Millau Viaduct deck area of all California Orthotropic bridges

21. Acknowledgements

This paper has taken more than four years to collect and personally inspect and photograph most of the bridges. Thank-you to Paul Goryl, PE of Parsons; Chuck Seim, PE of T.Y. Lin International; John Bors of Chemco of California; Dr John W. Fisher, PE of Lehigh University; Jay P. Murphy, the builder of several of these bridges and Ostap Joe Bender, PE by the sharing of papers, photos; etc. Special thanks to staff of the Caltrans HQ Library and Norm Root PE of the Caltrans History and Heritage Committee and my lead Senior Bridge Engineer Carl Huang who translated Japanese captions over many years.

The Authors' thoughts are expressed and not necessarily those of ASCE. The Authors' home e-mail: Mangusalf@aol.com

22. References


