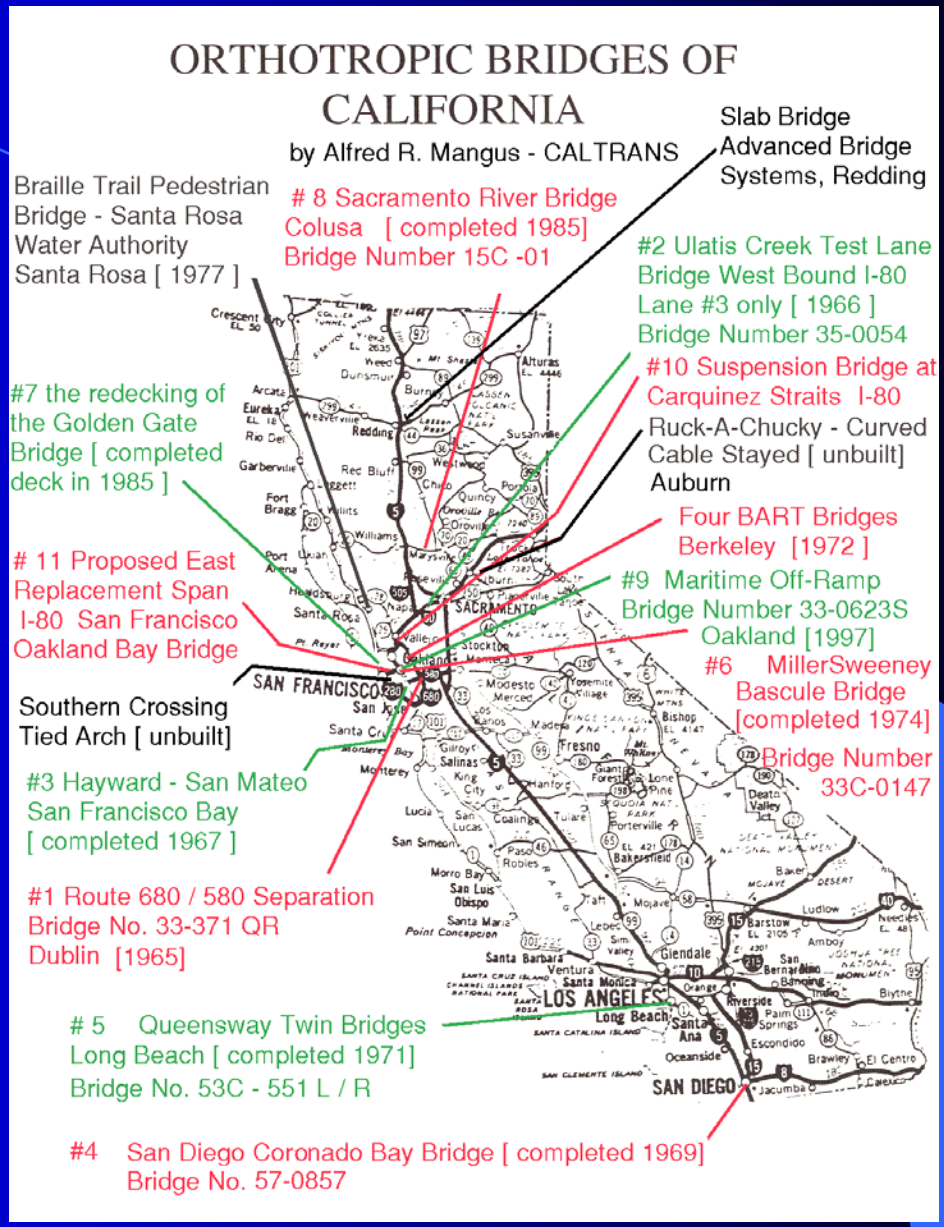
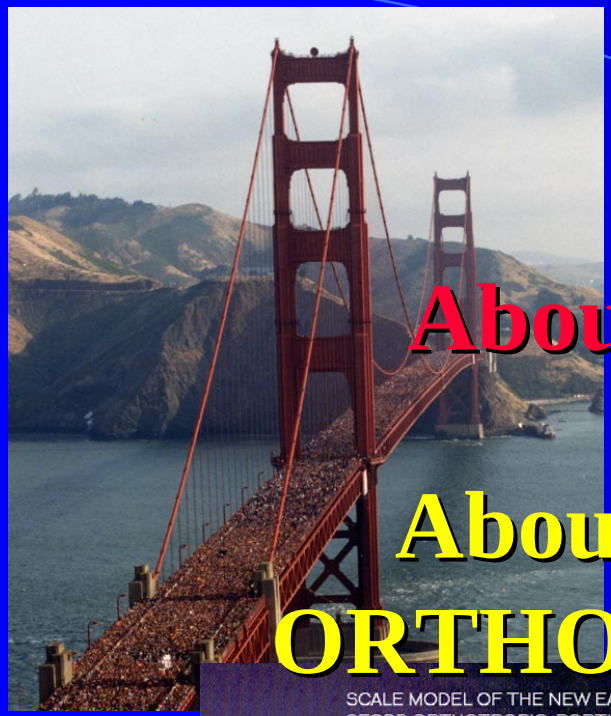
Orthotropic Steel Deck Bridges Landmarks of Our Infrastructure in California 1965-2009

A quick tour !

Monday, September 21, 2009
at 2:00 pm session title
"Steel Bridge Topics"

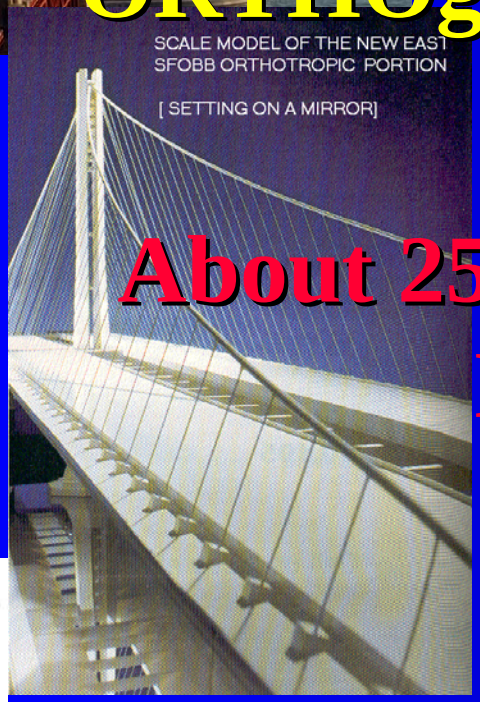


Alfred R. Mangus, PE - Caltrans, USA



About 650,000 Bridges = USA

About 100 ORTHOTROPIC ORTHOgonaly +AnisoTROPIC = in USA

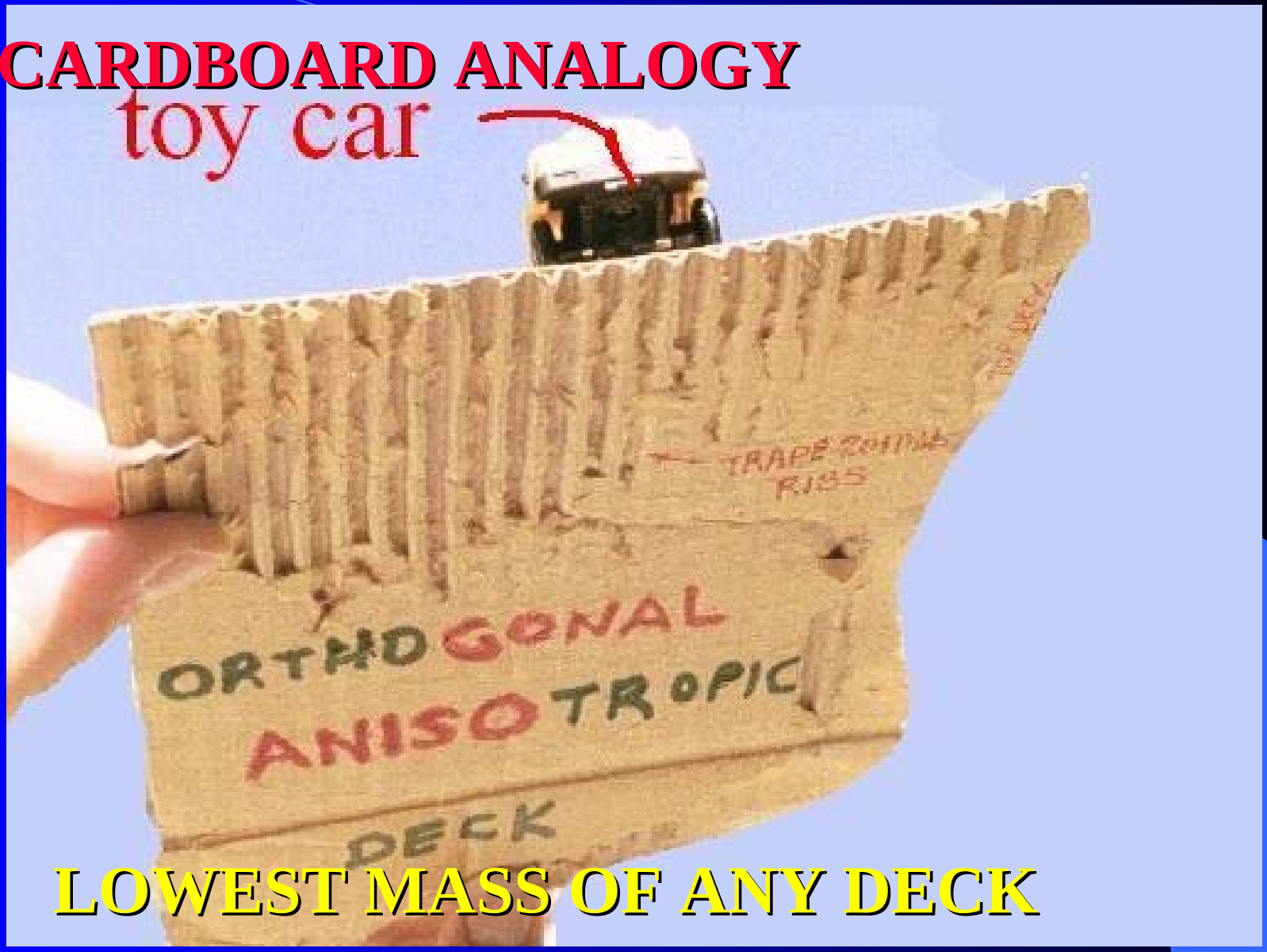


About 25% of USA's Orthotropic Bridges are in CA

Caltrans

STRUCTURAL BEHAVIOR

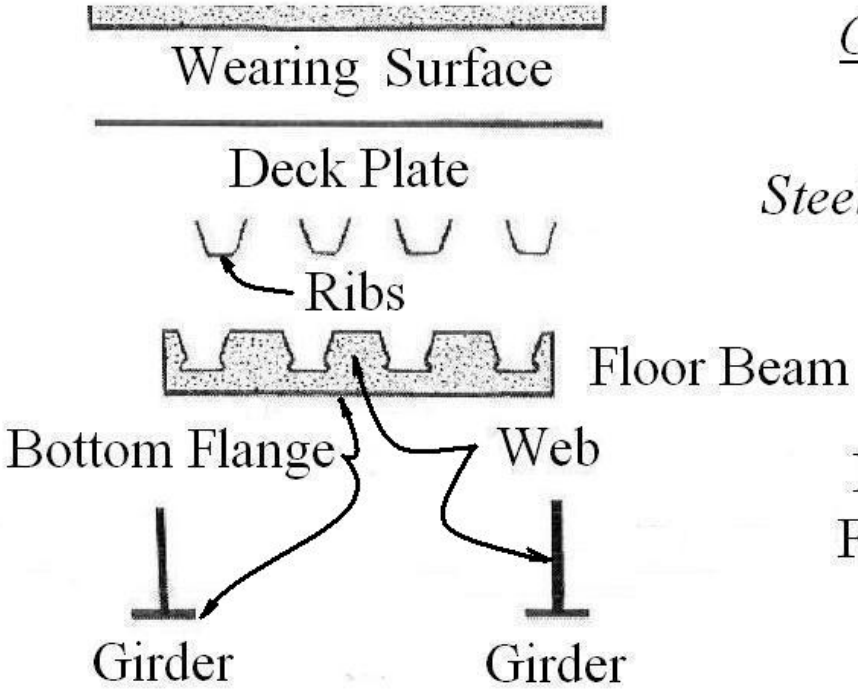
CARDBOARD ANALOGY



LOWEST MASS OF ANY DECK

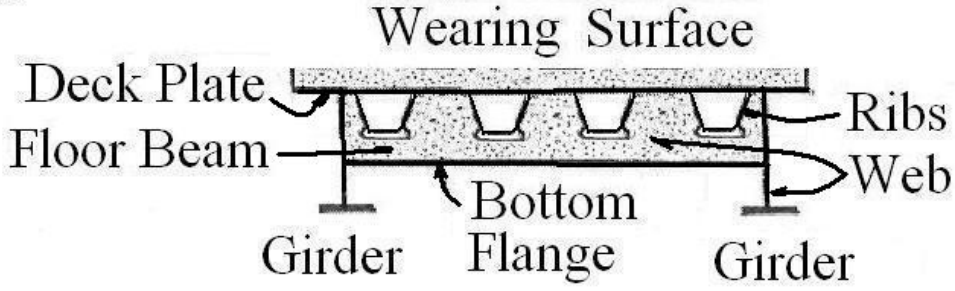
[used in high Seismic Zones; Movable Bridges]

STRUCTURAL BEHAVIOR
DESIGN CONSIDERATIONS



ORTHOTROPIC STEEL DECK EFFICIENCY

Steel Deck is: top flange of the ribs
top flange of the floor beams
top flange of the girders



LOWEST MASS OF ANY DECK

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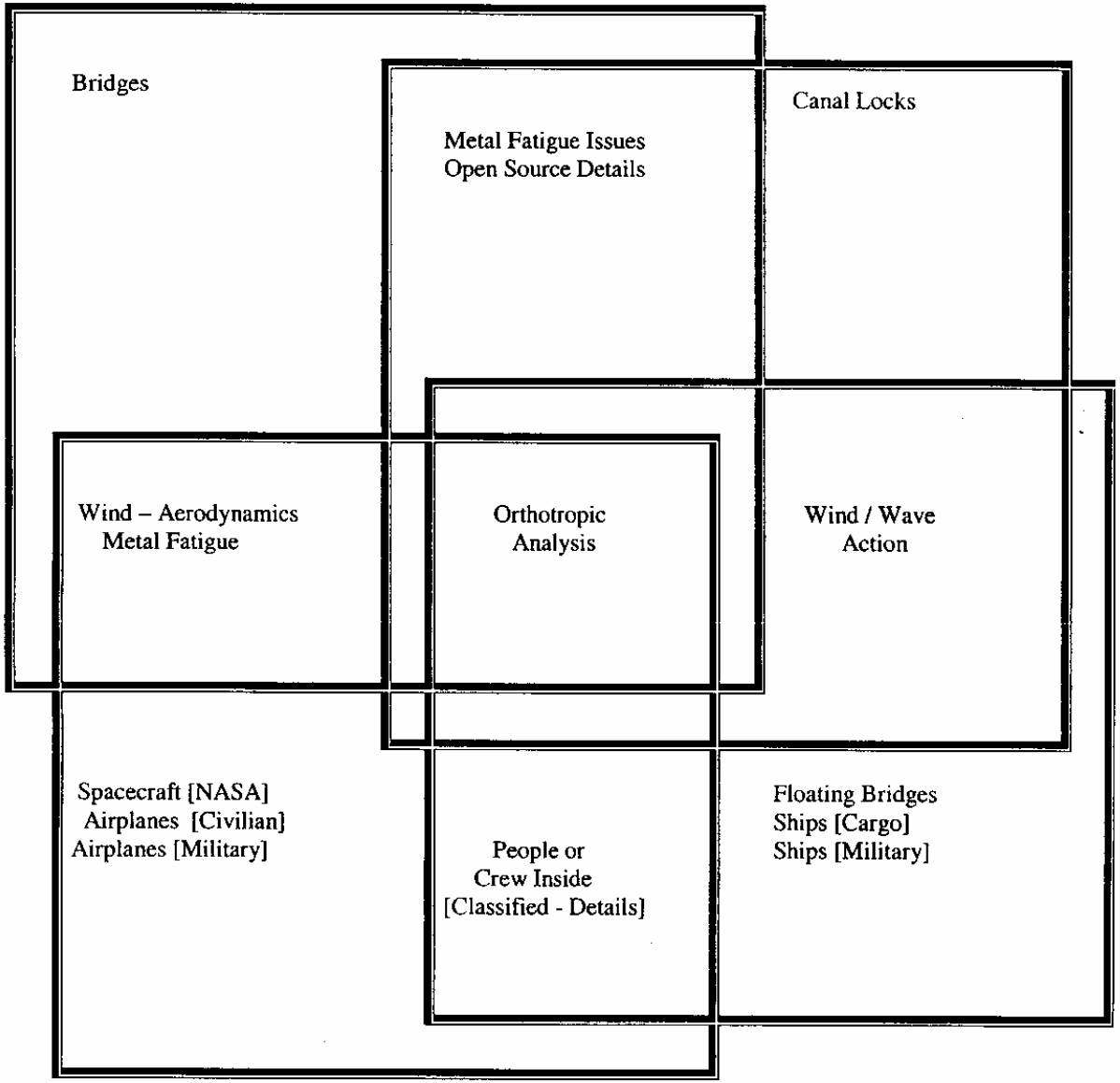
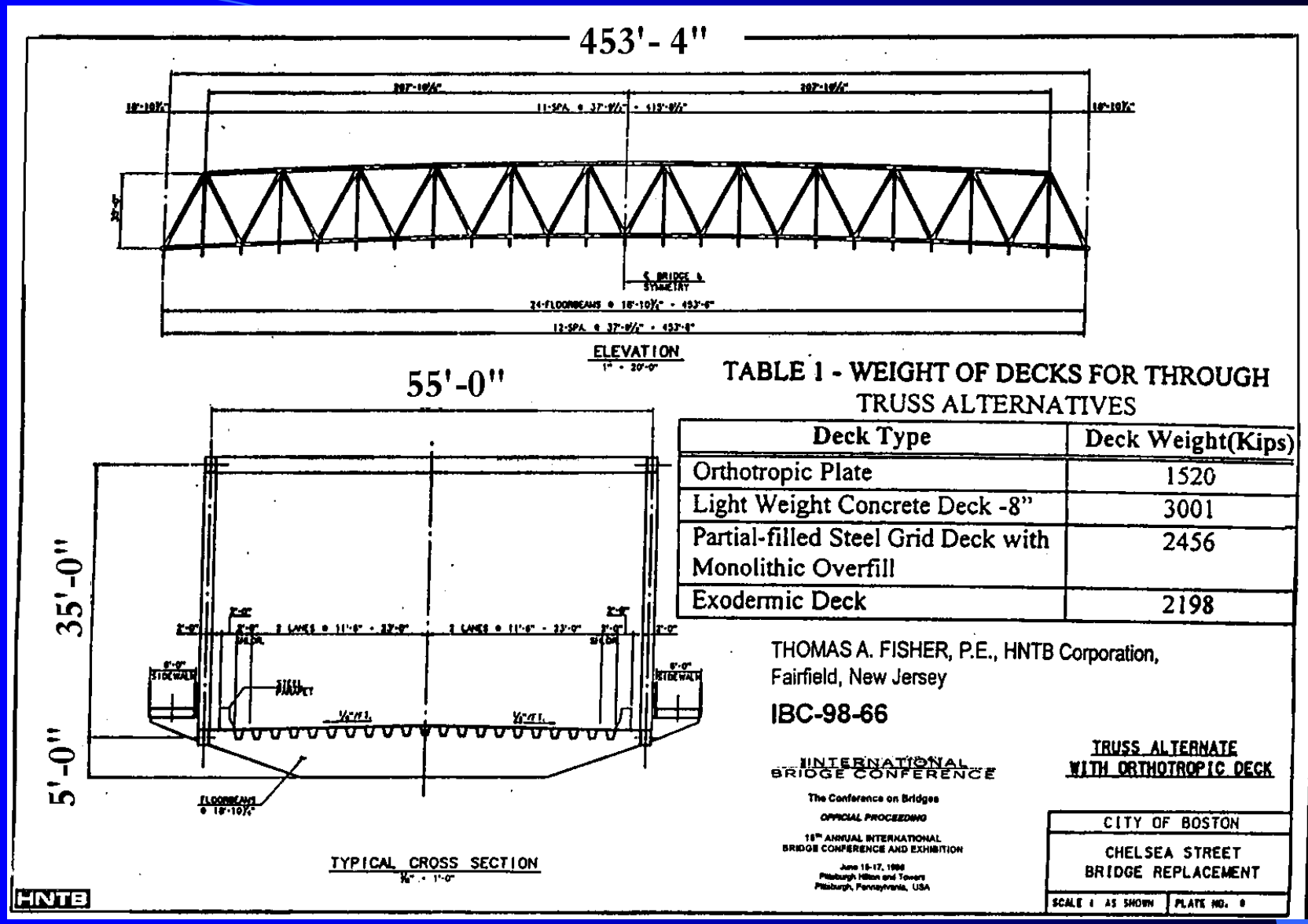


ORTHOTROPIC BRIDGES VS OTHER USES



TYPE SELECTION

ORTHOTROPIC STEEL DECK VS OTHER SYSTEMS

TYPE SELECTION

ORTHOTROPIC STEEL DECK VS OTHER SYSTEMS

Deck Type 453-ft x 55ft	Deck Weight(Kips
Orthotropic Plate	1520
Light Weight Concrete Deck -8"	3001
Partial-filled Steel Grid Deck with Monolithic Overfill	2456
Exodermic Deck	2198

THOMAS A. FISHER, P.E., HNTB Corporation,

CHELSEA BRIDGE BOSTON

Deck Type Analyzed and fully engineered for comparison	Lift Span Total Weight (tons)	Advantages	Disadvantages
Orthotropic Steel Deck	760	Lowest self-weight results in cost savings for towers, foundations, motors, cables etc.	Lack of current codes, designers required to do their own research and develop their own design software
Exodermic Deck (Patented system)	1099	Owner does not have to worry about design, which is provided by manufacturer	Patent holder becomes a "sole supplier", which requires a waiver from FHWA
Partially-filled steel grid deck with monolithic overfill	1228	Older historic system where lifespan has been up to 75 years	Has a much higher dead load than orthotropic decks
Lightweight (100 pcf) Concrete Deck – 8 inches thick	1501	Non-proprietary system	Limited number of suppliers for lightweight aggregate. Not much dead weight savings

This table is based on one originally created and published by Dr. Thomas A. Fisher of HNTB Corporation

TYPE SELECTION

ORTHOTROPIC STEEL DECK VS OTHER SYSTEMS

Re-Decking Statistics by Roman Wolchuk, PE

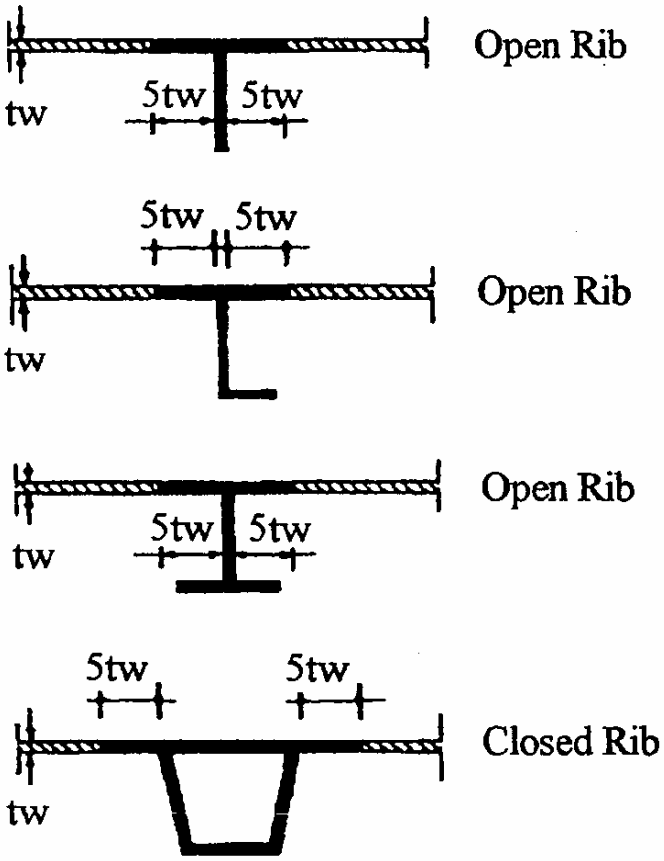
Table 1. Selected Completed Orthotropic Redecking Projects in the U.S. and in Canada

Bridge	Lions Gate Vancouver [a]	G. Washington N.Y.C.	Golden Gate S. Francisco	Throgs Neck V. N.Y.C.	Ben Franklin Philadelphia	Champlain Montreal
Year	1975	1978	1985	1986	1987	1993
Old deck weight (psf)	100	106	104	107	123	110
New deck weight (psf)	61	60	79	83	89	82
Redecking cost ($/sf) [b]	47	40	70	72	79	110
Deck integration with main members	Yes	No	No	No	Yes	Yes
Redecking work	Night	Night	Night	Night	Day	Night

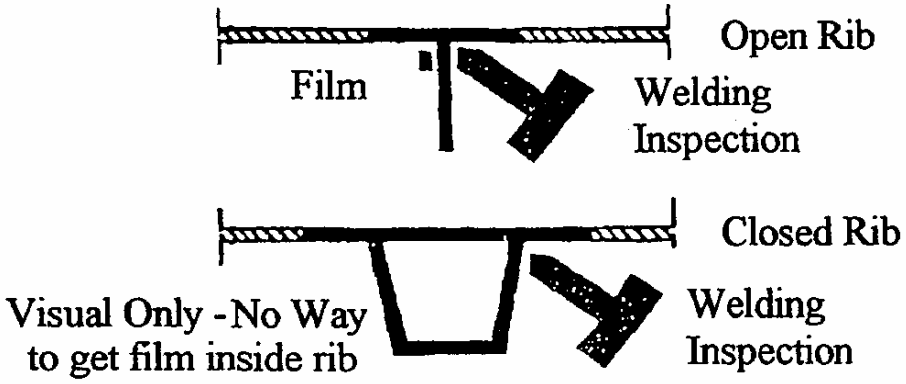
[a] The 1975 orthotropic roadway is currently being replaced by a new widened orthotropic deck.

[b] Excluding bridge repairs, inspection walkways, utilities relocation and other items not related to roadway redecking

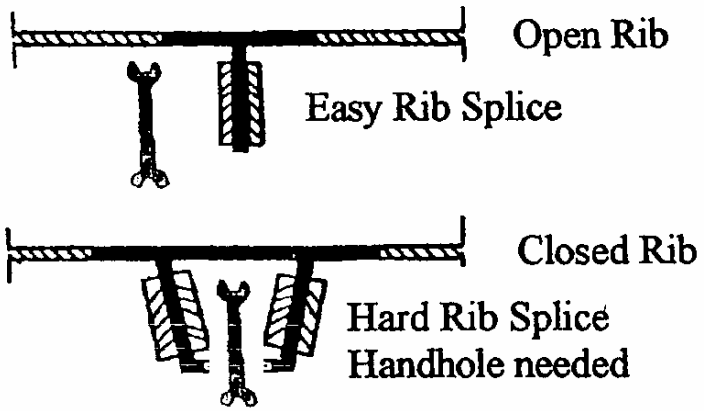
20 % TO 40% weight reduction on deck



Design Issues - Efficiency



Fabrication Efficiency

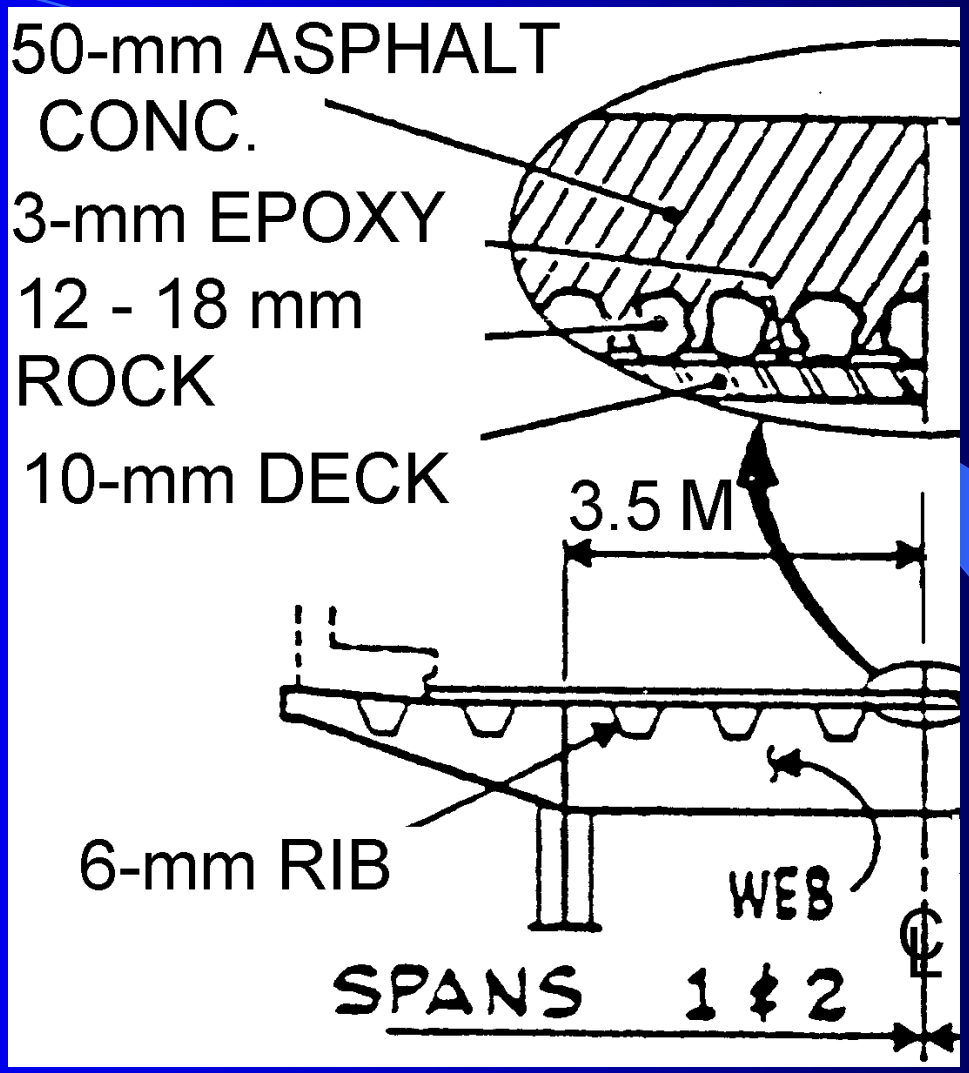


Construction Efficiency

- **Three issues in choosing a rib**
- **Design – Fabrication – Construction**

33-0371G

680 / 580 TEST BRIDGE DUBLIN - 1965

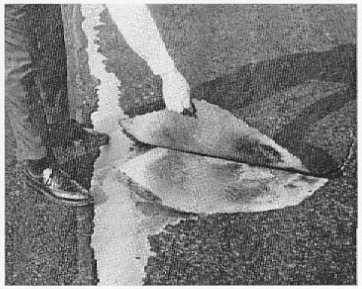


33-0371G

680 / 580 TEST BRIDGE DUBLIN - 1965

WEARING SURFACE TEST MATERIAL FAILURE

Both photos Courtesy of AISI American Iron and Steel Institute & CALTRANS

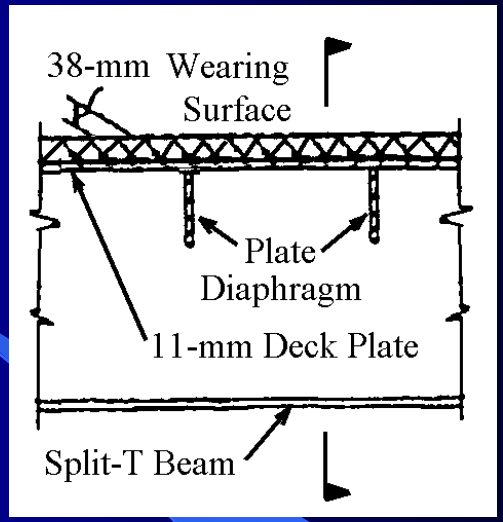


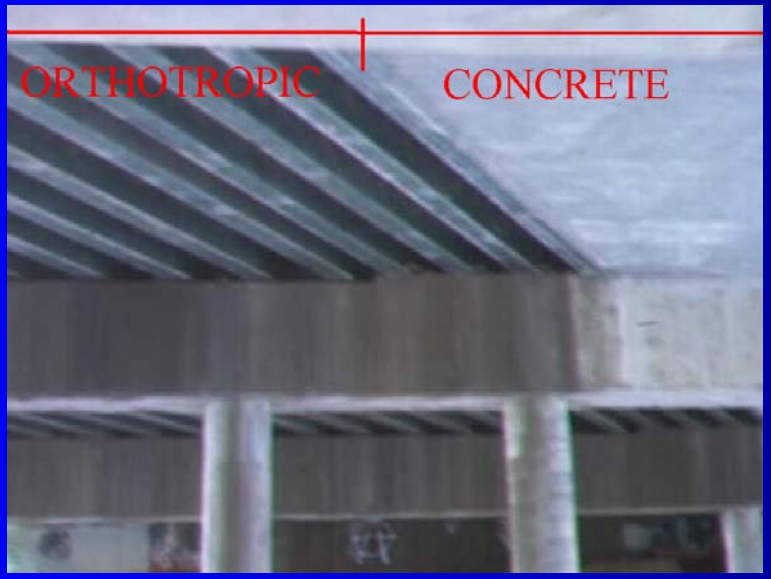
The I-580 Grade Separation over I-680 Bridge, Dublin, CA
CALTRANS is the designer & owner

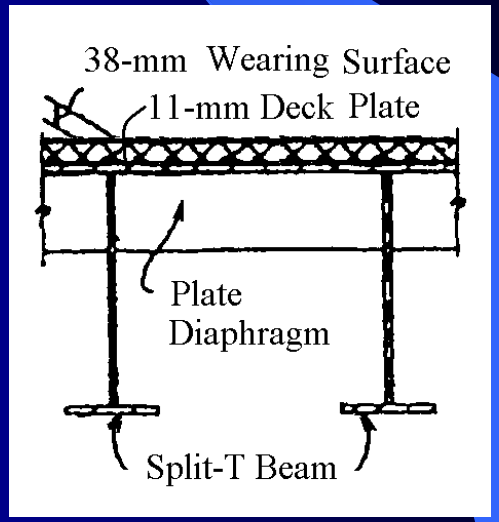
REMOVAL OF FAILED WEARING SURFACE MATERIAL

33-0371G

680 / 580 TEST BRIDGE DUBLIN - 1965

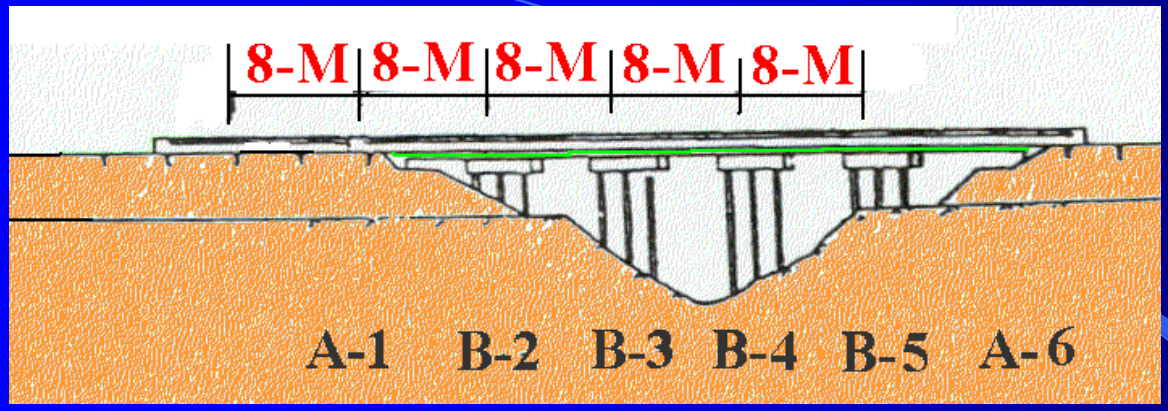


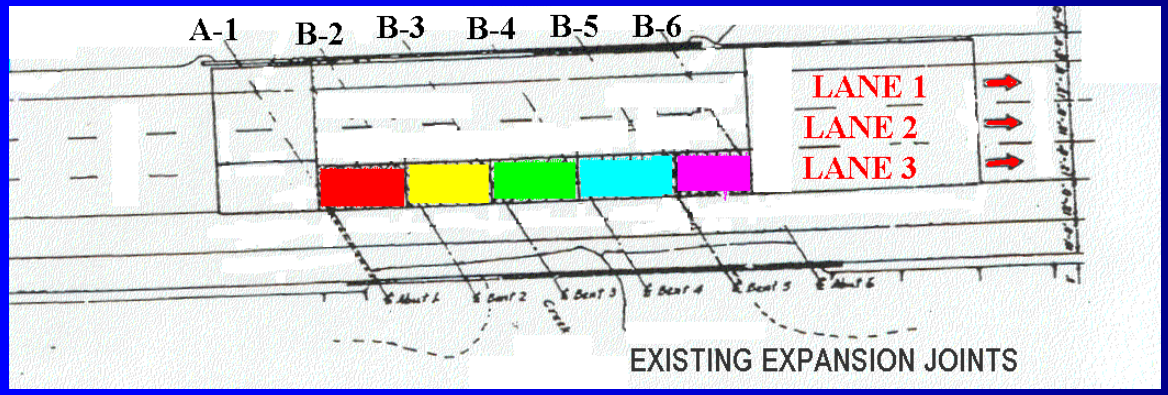




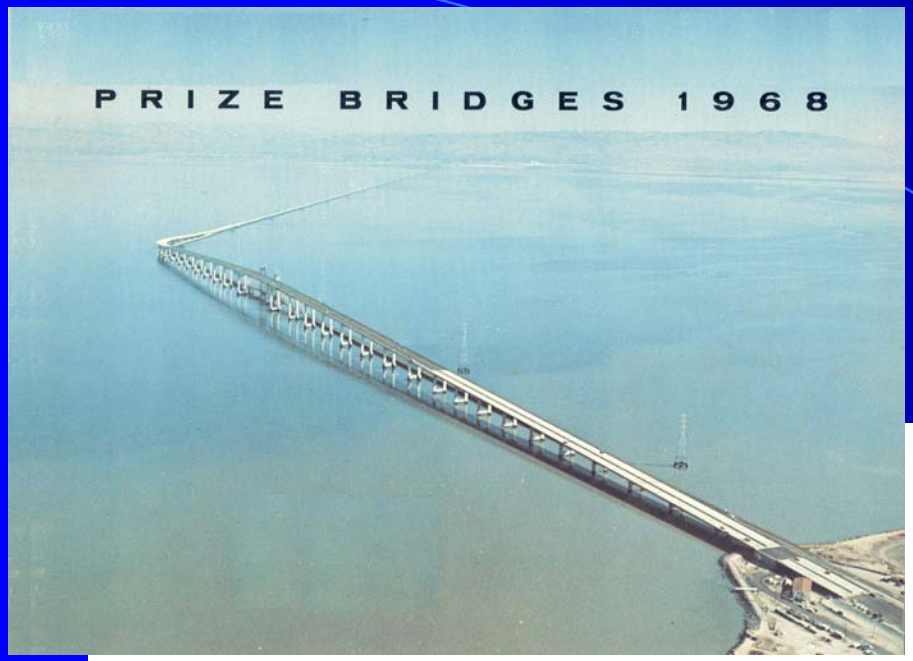
LATIS CREEK TEST BRIDGE #23-0052R

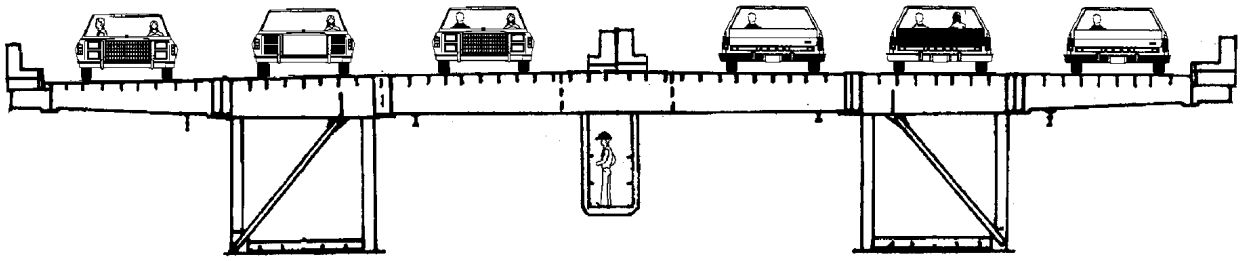
VACAVILLE - 1966





ULATIS CREEK TEST BRIDGE #23-0052R
VACAVILLE - 1966





STATE OF CALIFORNIA
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Division of
San Francisco Bay
Toll Crossings

SAN MATEO - HAYWARD BRIDGE

-0054, Opened OCTOBER 31, 1967

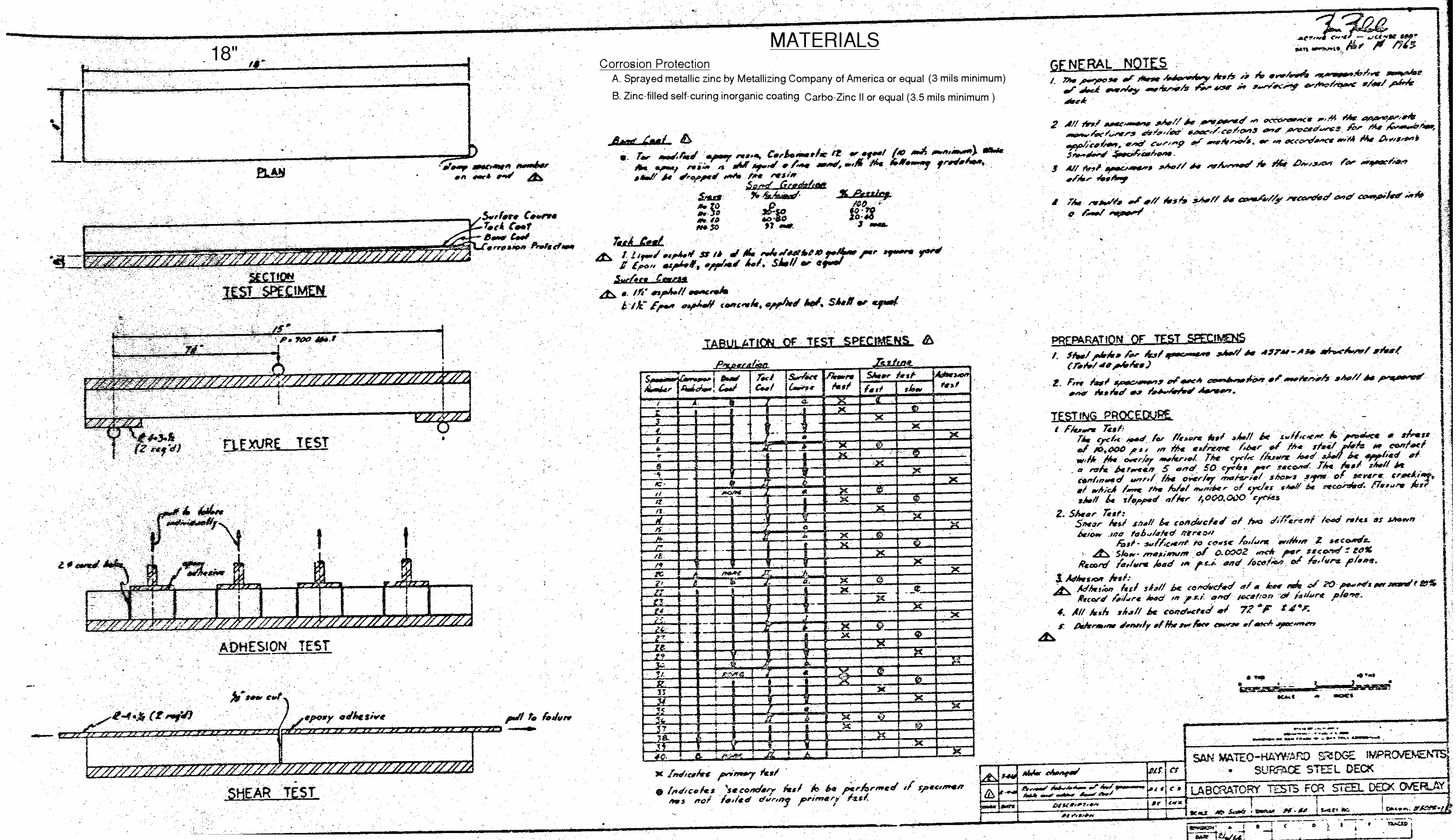
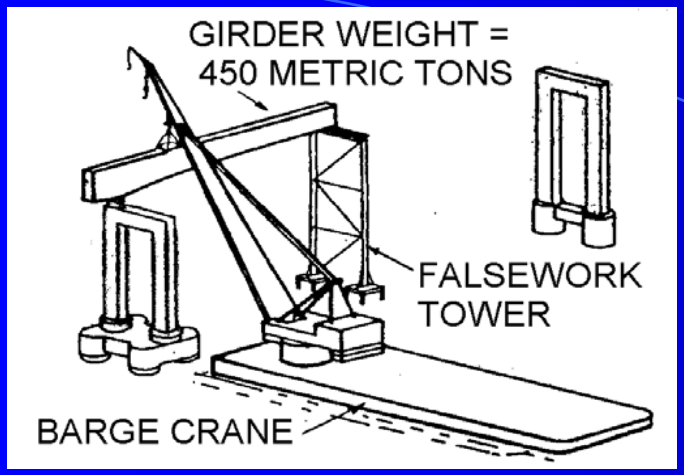
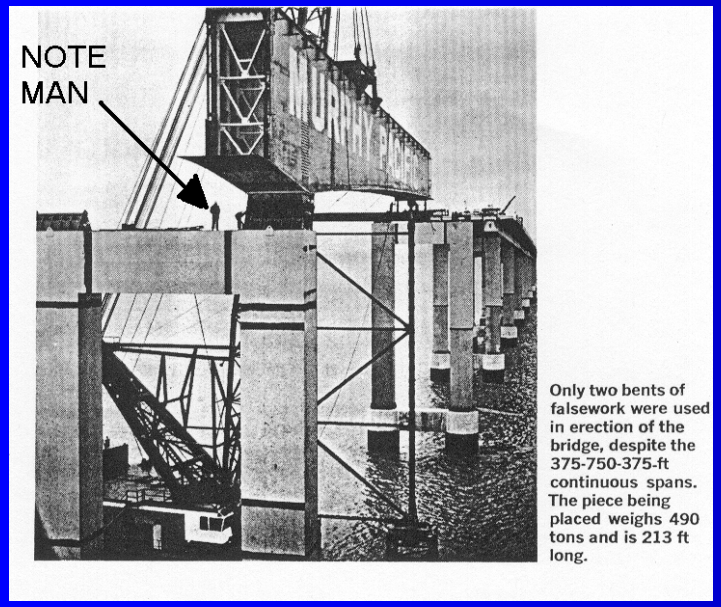


FIGURE 1

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
Division of San Francisco Bay Toll Crossings

SAN MATEO - HAYWARD BRIDGE





Only two bents of falsework were used in erection of the bridge, despite the 375-750-375-ft continuous spans. The piece being placed weighs 490 tons and is 213 ft long.

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Division of
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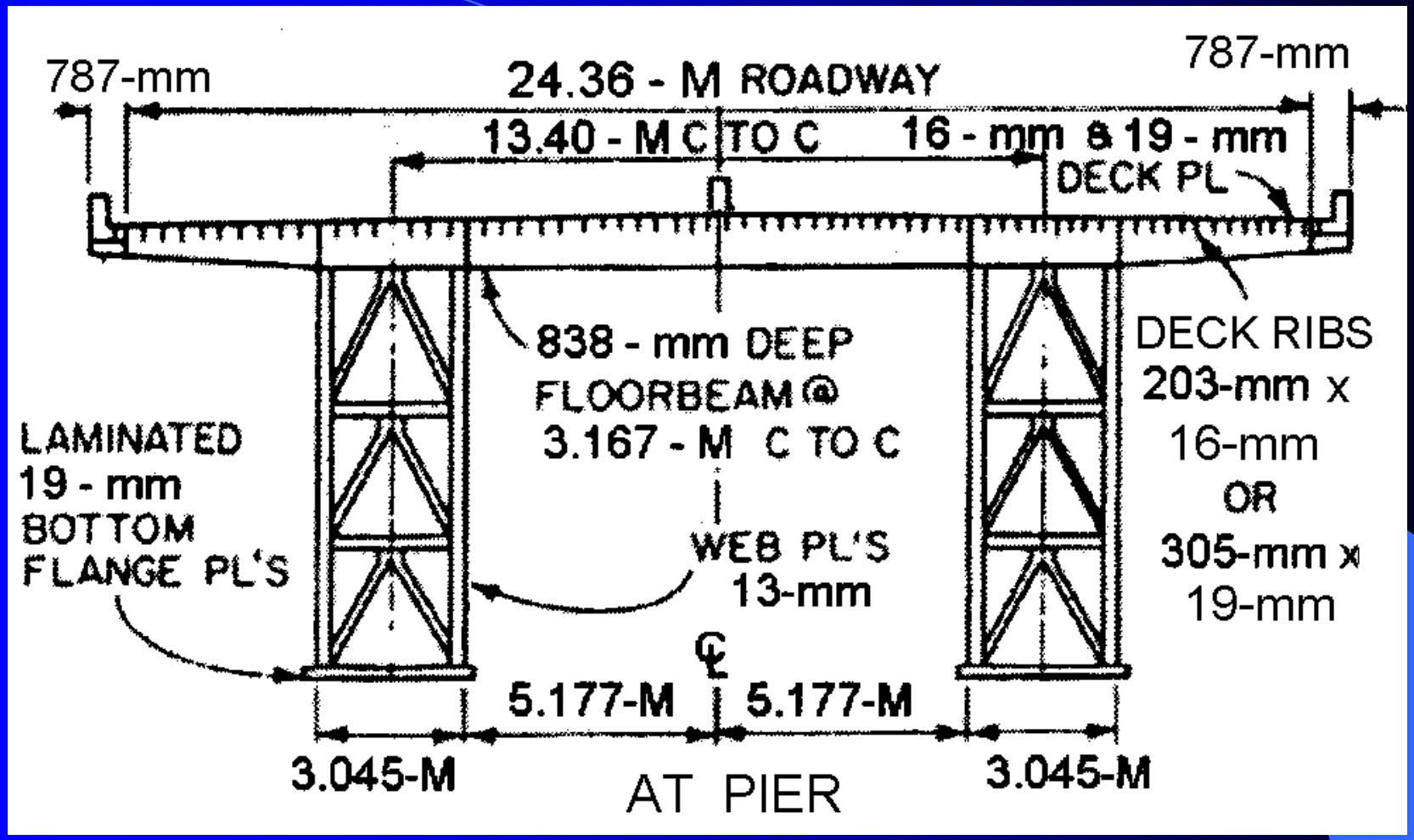
Toll Crossings

SAN MATEO - HAYWARD BRIDGE

500-ton Barge Crane Marine Boss



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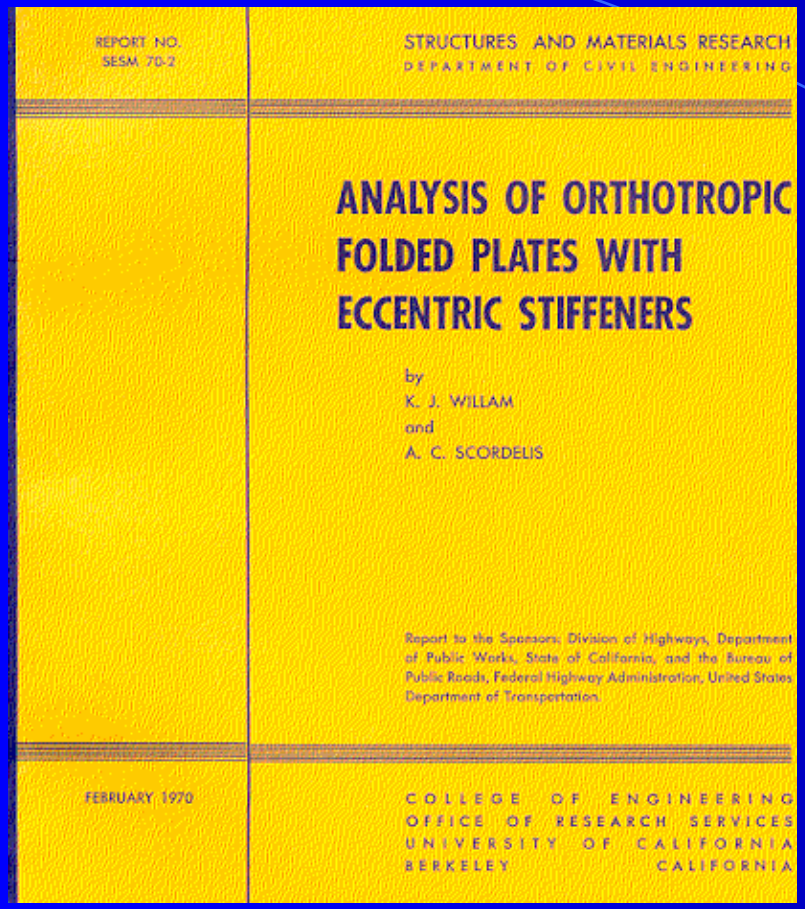
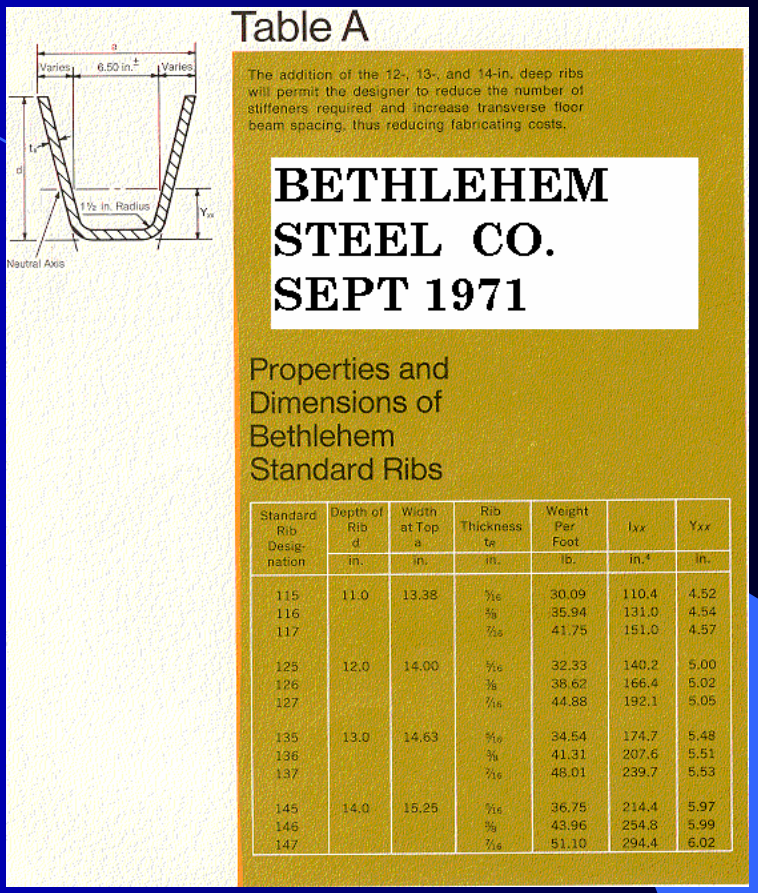
Toll Crossings

SAN MATEO - HAYWARD BRIDGE

35-0054, Opened OCTOBER 31, 1967

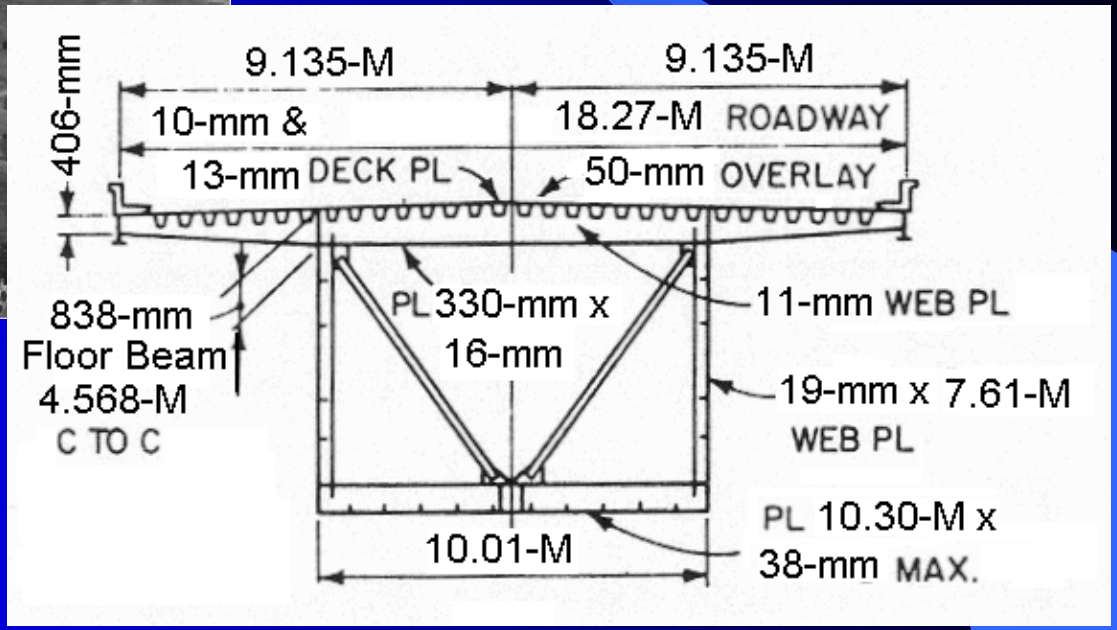




Standard Rib Designation	Depth of Rib d	Width at Top a	Rib Thickness te	Weight Per Foot	Ixx	Yxx
	in.	in.	in.	lb.	in.⁴	in.
115	11.0	13.38	5/16	30.09	110.4	4.52
116			3/8	35.94	131.0	4.54
117			7/16	41.75	151.0	4.57
125	12.0	14.00	5/16	32.33	140.2	5.00
126			3/8	38.62	166.4	5.02
127			7/16	44.88	192.1	5.05
135	13.0	14.63	5/16	34.54	174.7	5.48
136			3/8	41.31	207.6	5.51
137			7/16	48.01	239.7	5.53
145	14.0	15.25	5/16	36.75	214.4	5.97
146			3/8	43.96	254.8	5.99
147			7/16	51.10	294.4	6.02

OPEN OR CLOSED RIBS ????

ISSUES



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SAN DIEGO - CORONADO BRIDGE

57-0857 Opened 1969 – 40 Years

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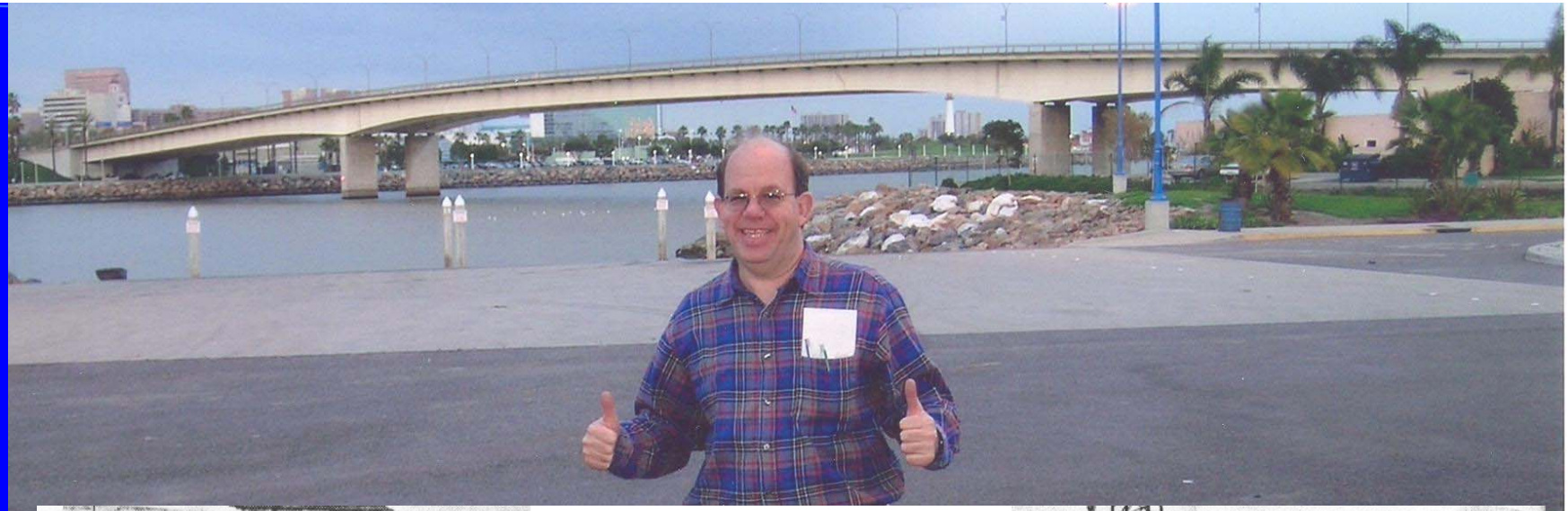
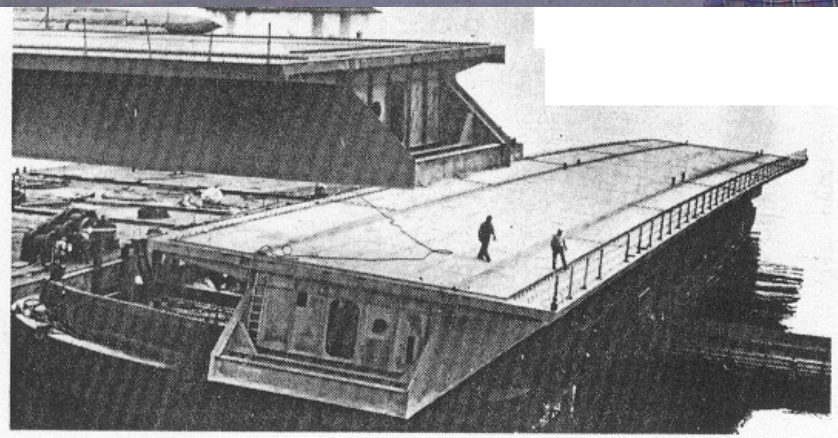
SAN DIEGO - CORONADO BRIDGE

57-0857 Opened 1969 – 40 Years





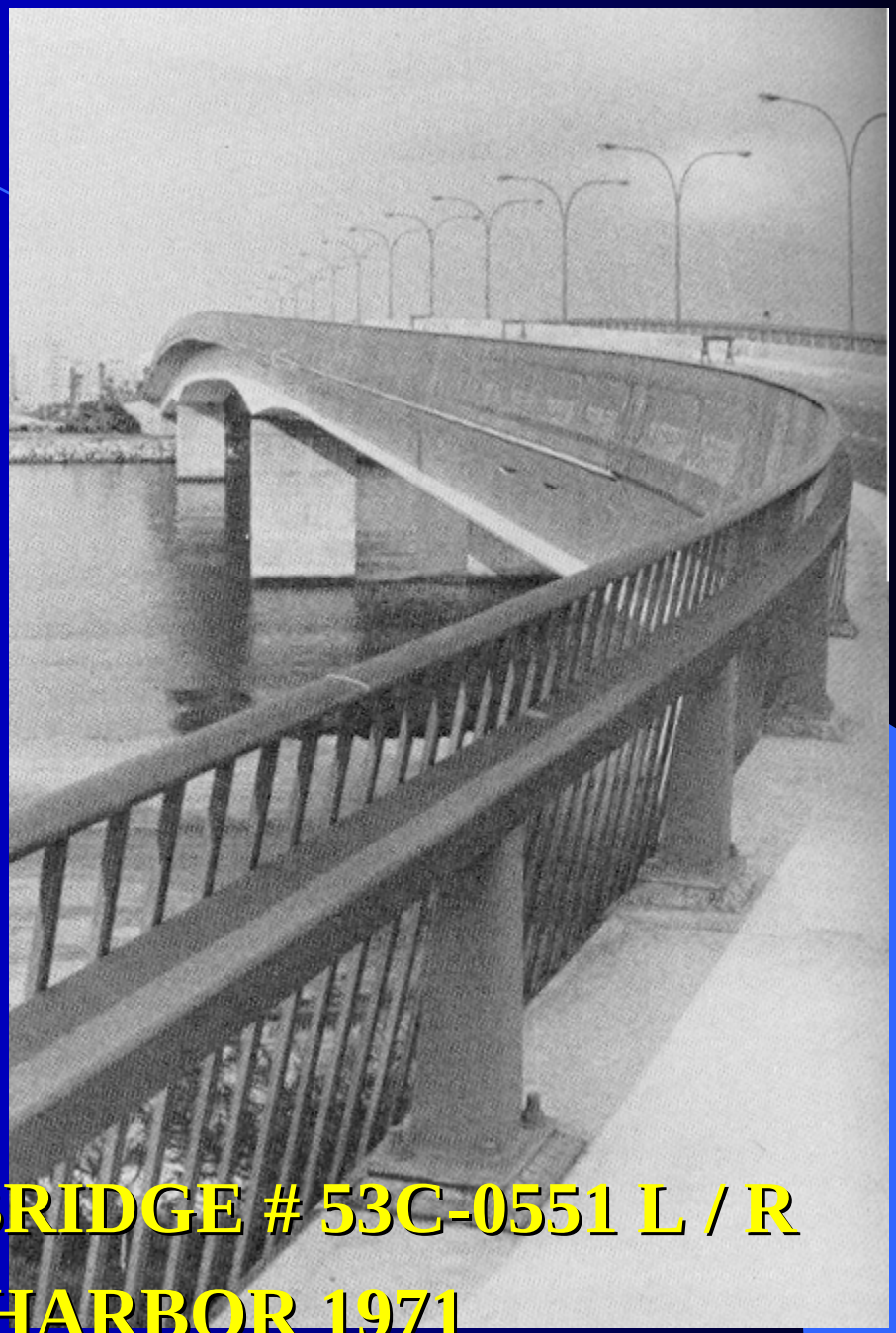
Bridge sections are barged 400 miles from prefabricating yard.

Crane positions girder for bolting to adjacent bridge section.

Prefab steel bridge girders are biggest ever lifted

CITY OF LONG BEACH

QUEENSWAY BRIDGE # 53C-0551 L / R
LONG BEACH HARBOR 1971



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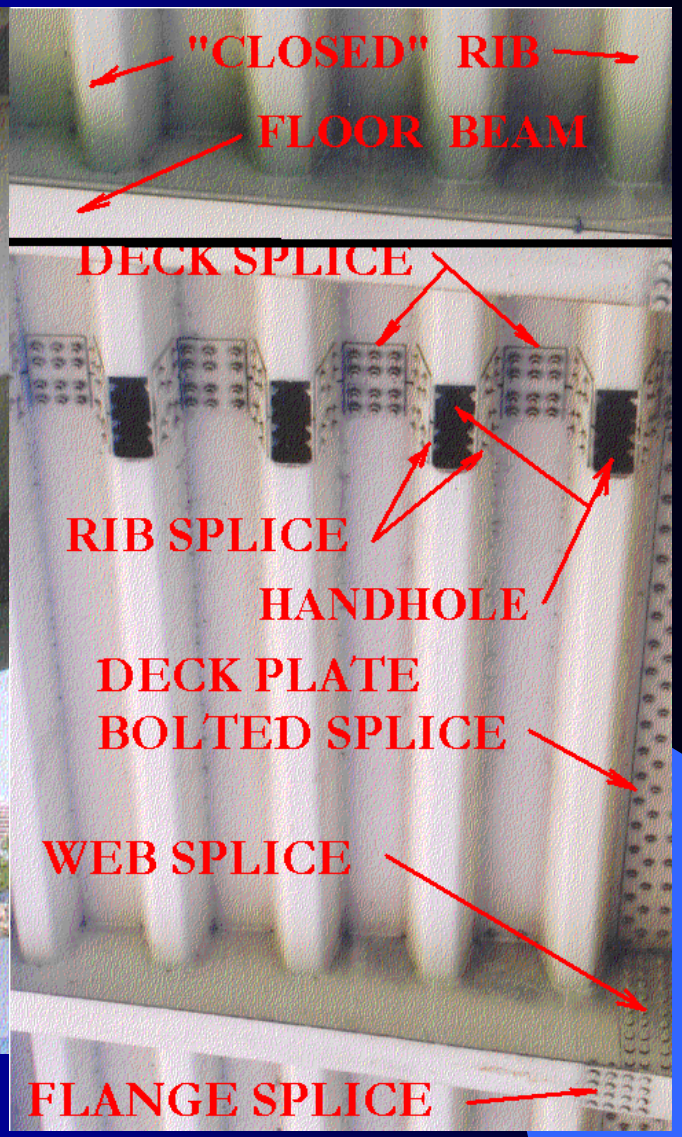
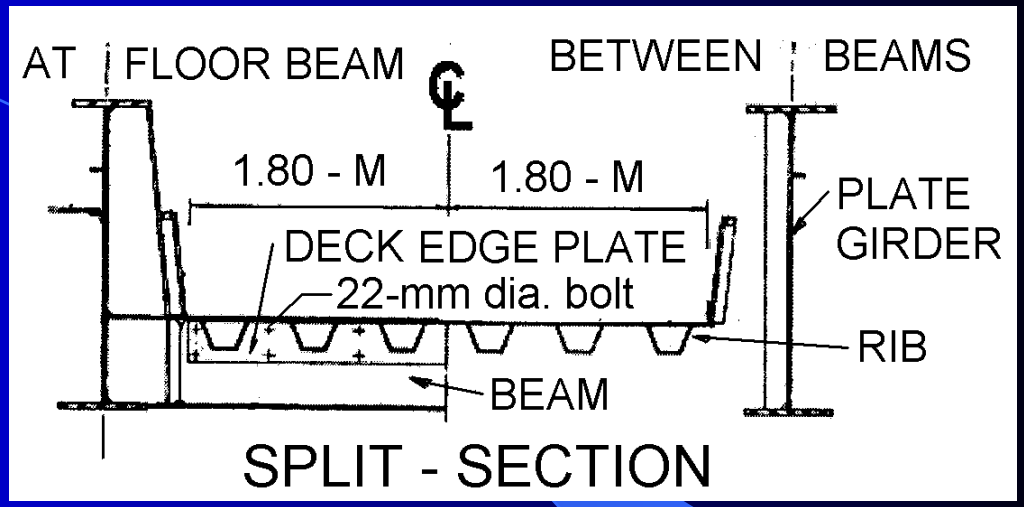


CITY OF LONG BEACH

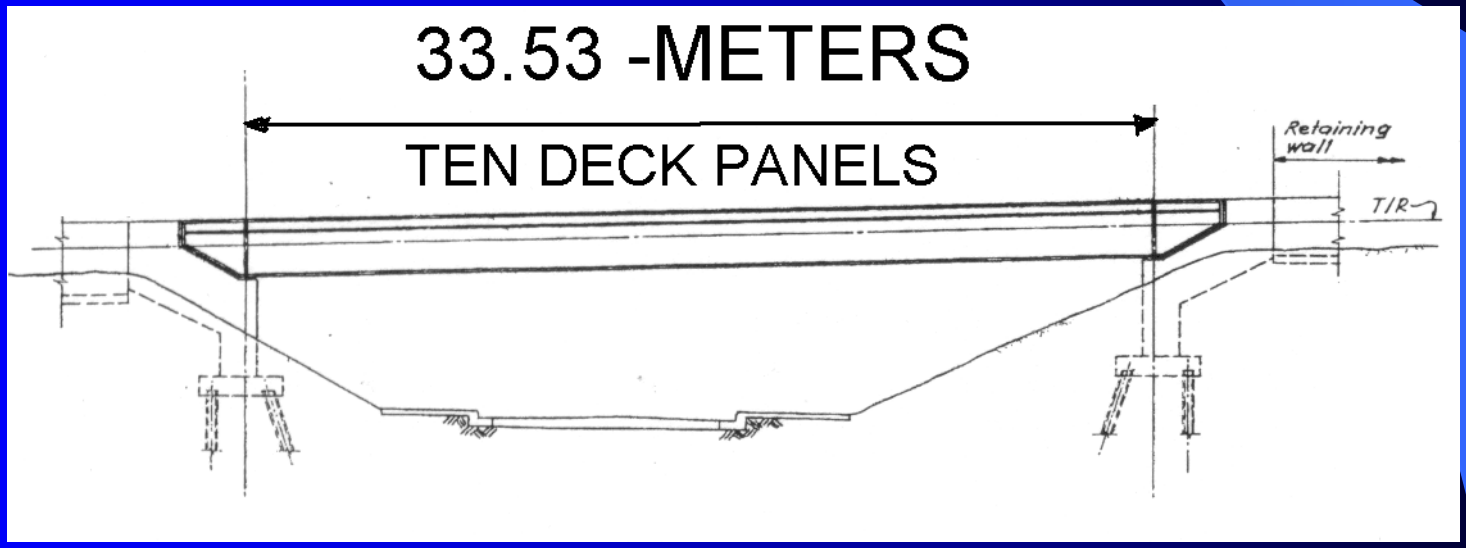
QUEENSWAY BRIDGE # 53C-0551 L / R

LONG BEACH HARBOR 1971

GOLDEN GATE AVENUE



CROSS SECTION OF BRIDGES

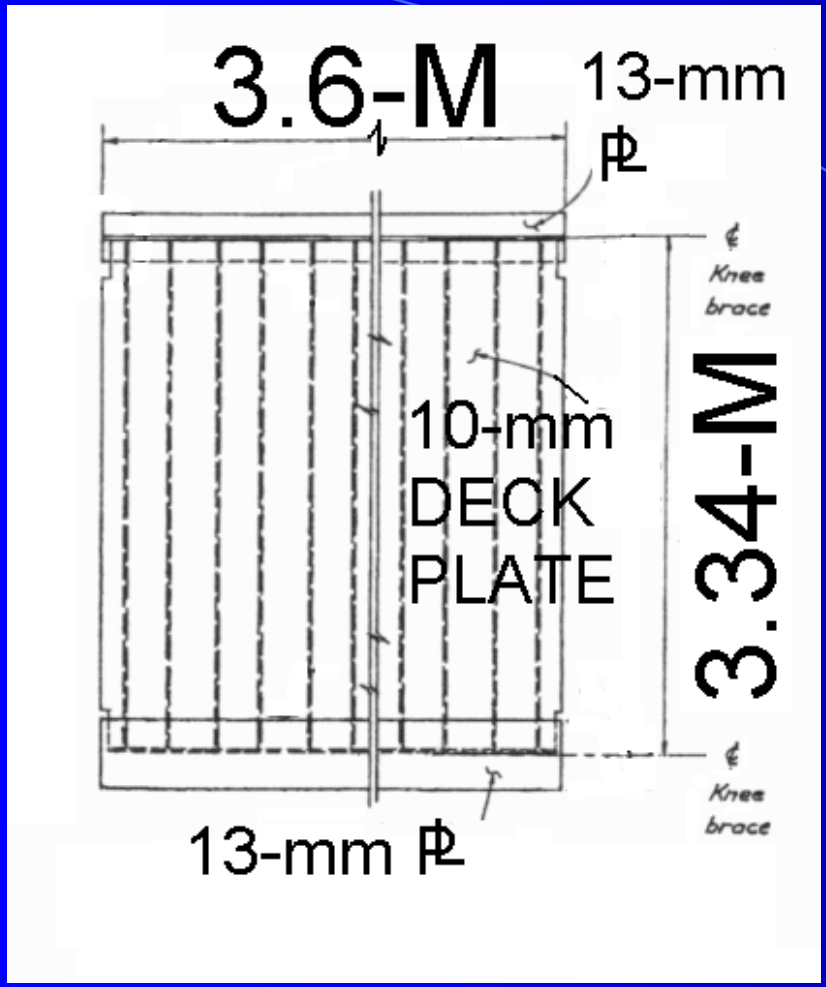


BART

Bay Area
Rapid Transit

BART--- WEATHERING STEEL BRIDGES

A-096 A & B == BERKELEY 1972



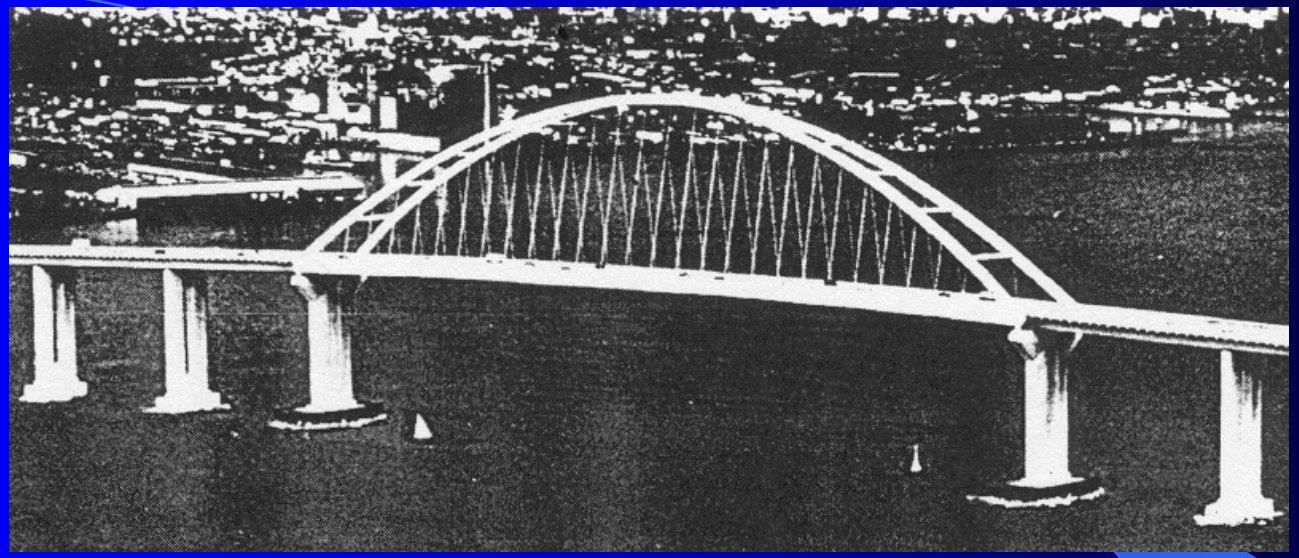
PANELIZED DECK BELOW DECK PHOTO

BART--- WEATHERING STEEL BRIDGES

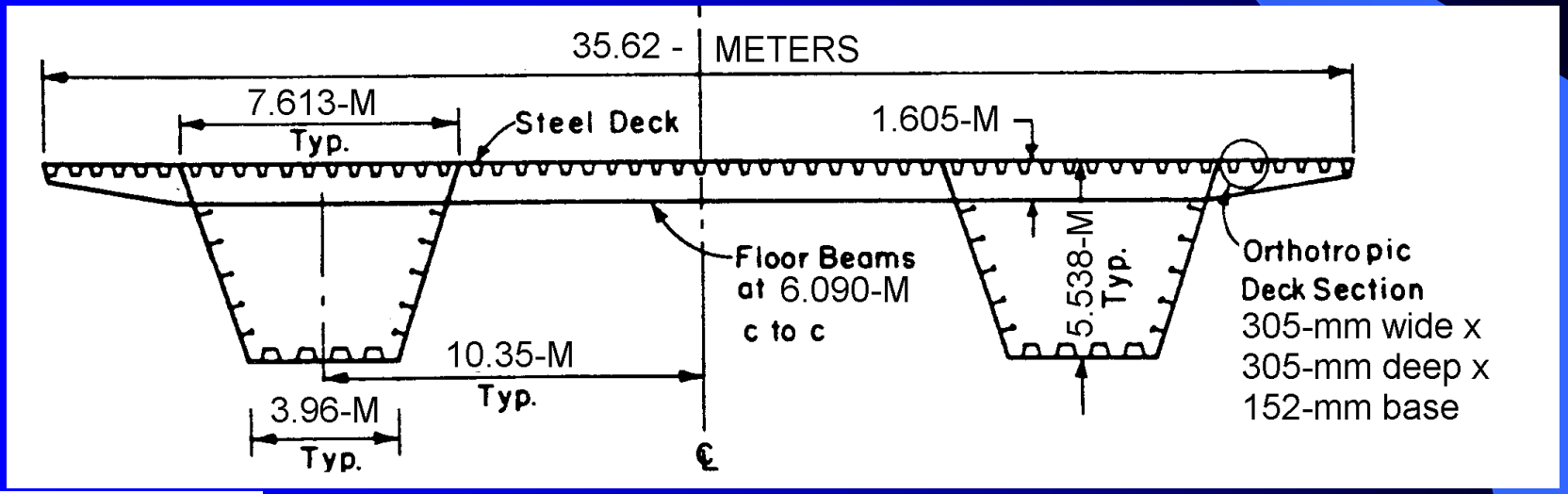
A-096 A & B == BERKELEY 1972

BART

Bay Area Rapid Transit



BASKET HANDLE TIED ARCH



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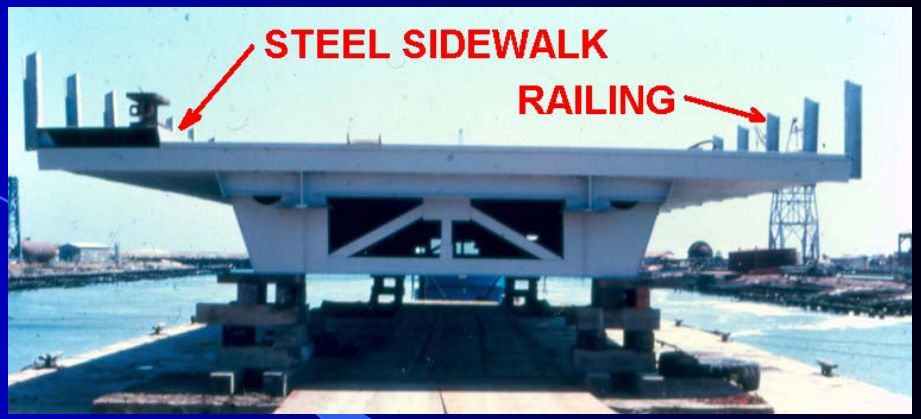
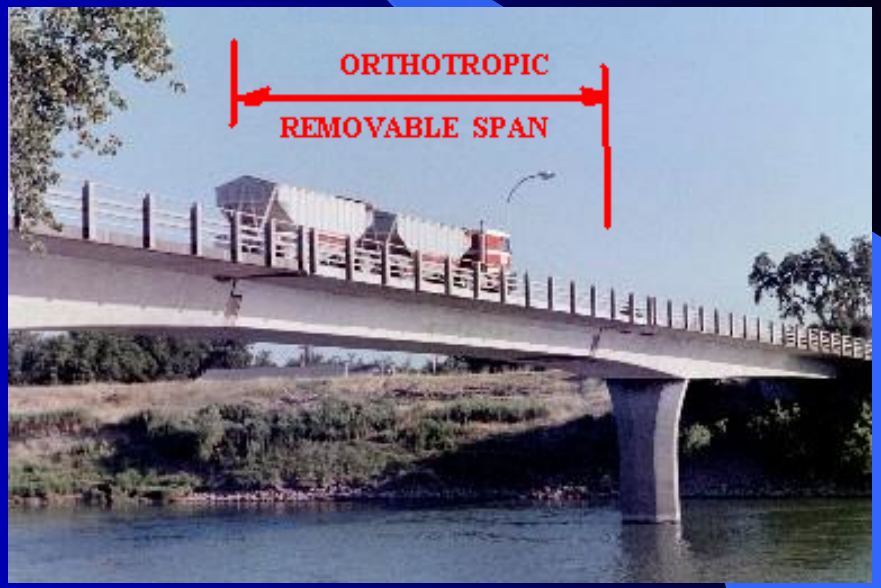
SOUTHERN CROSSING -- BAY TOLLS

14.5 MILES LONG 1972

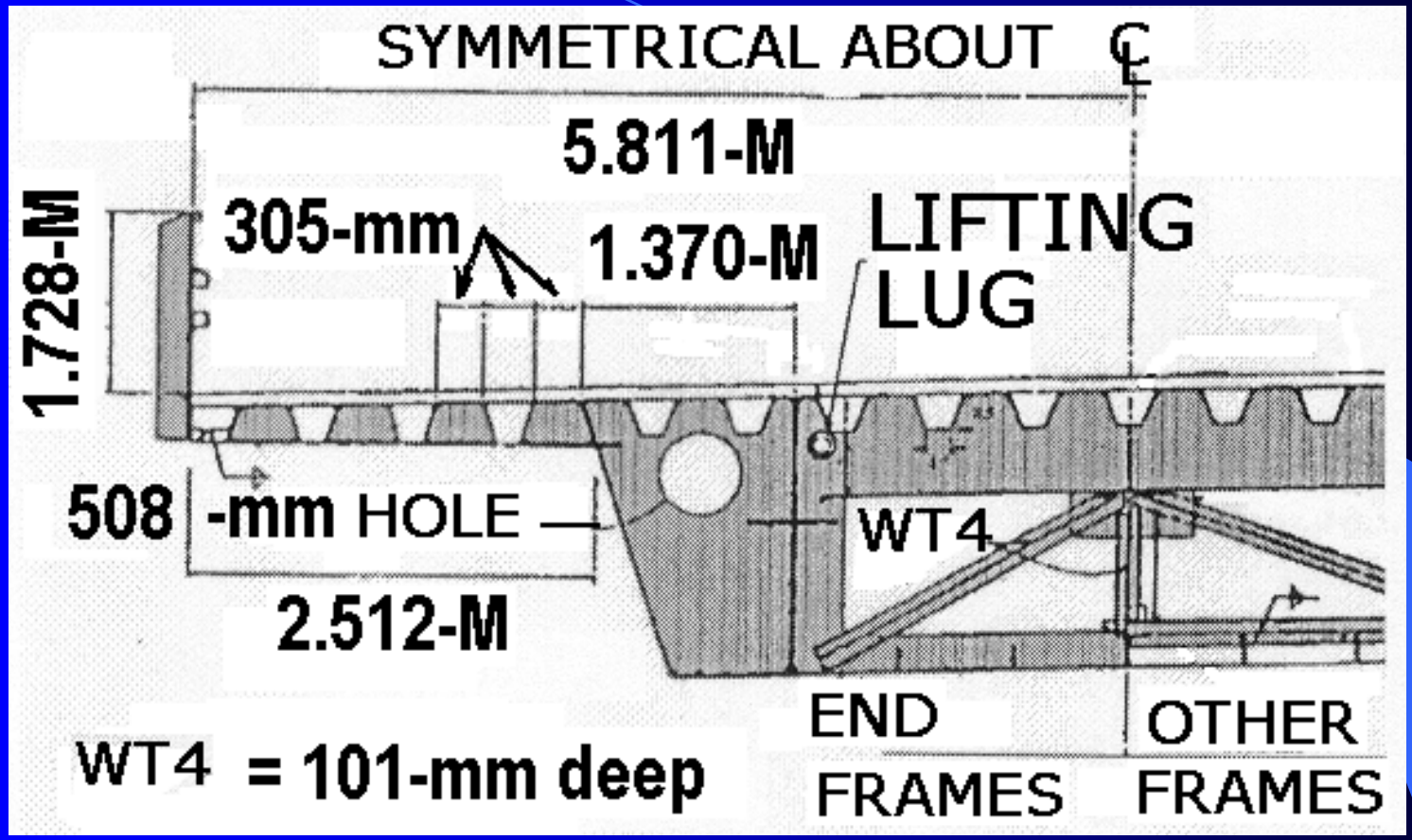




COLUSA

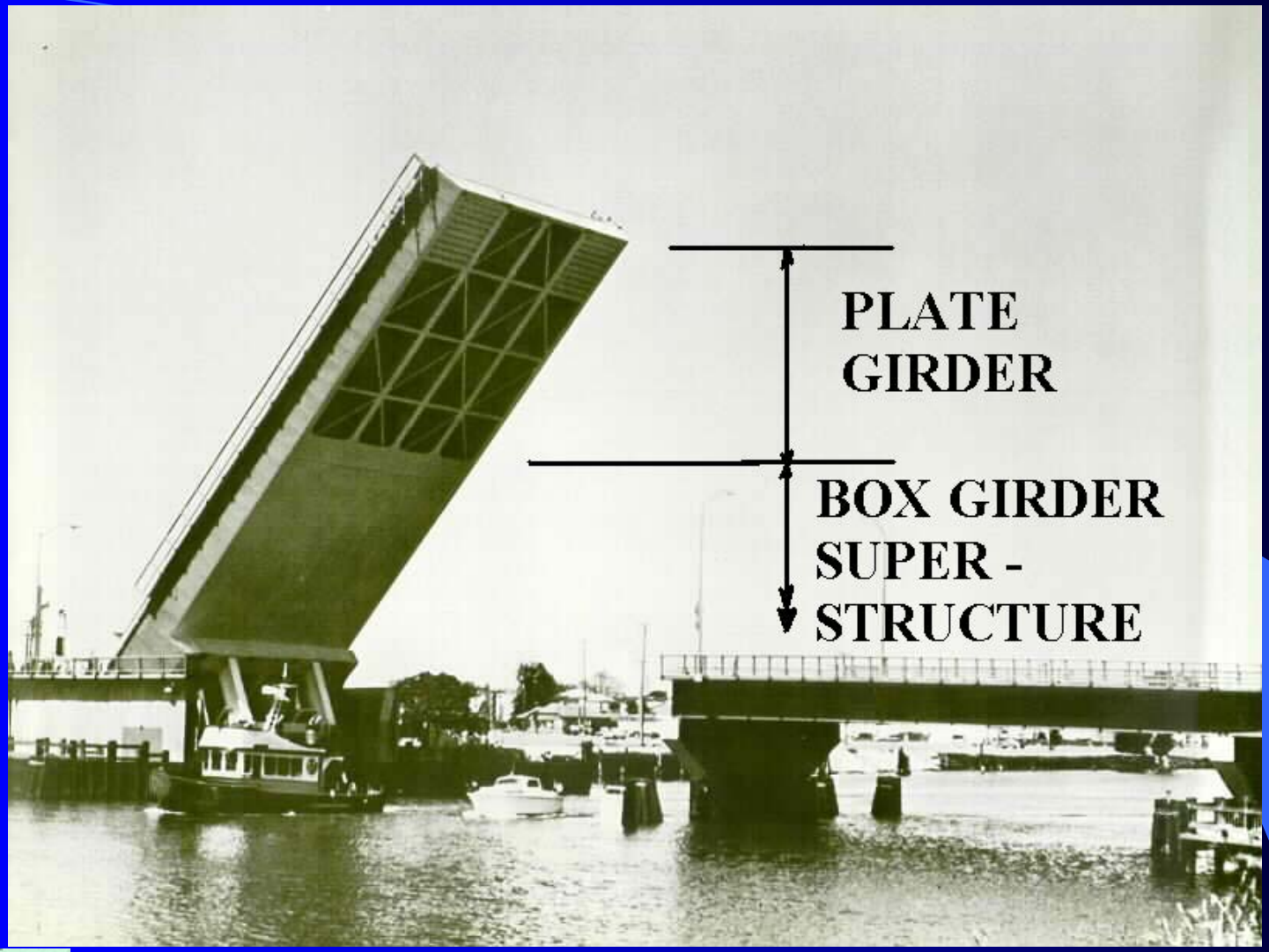
COUNTY

COLUSA BRIDGE OVER SACRAMENTO RIVER, # 15C-0001 COLUSA COUNTY 1972



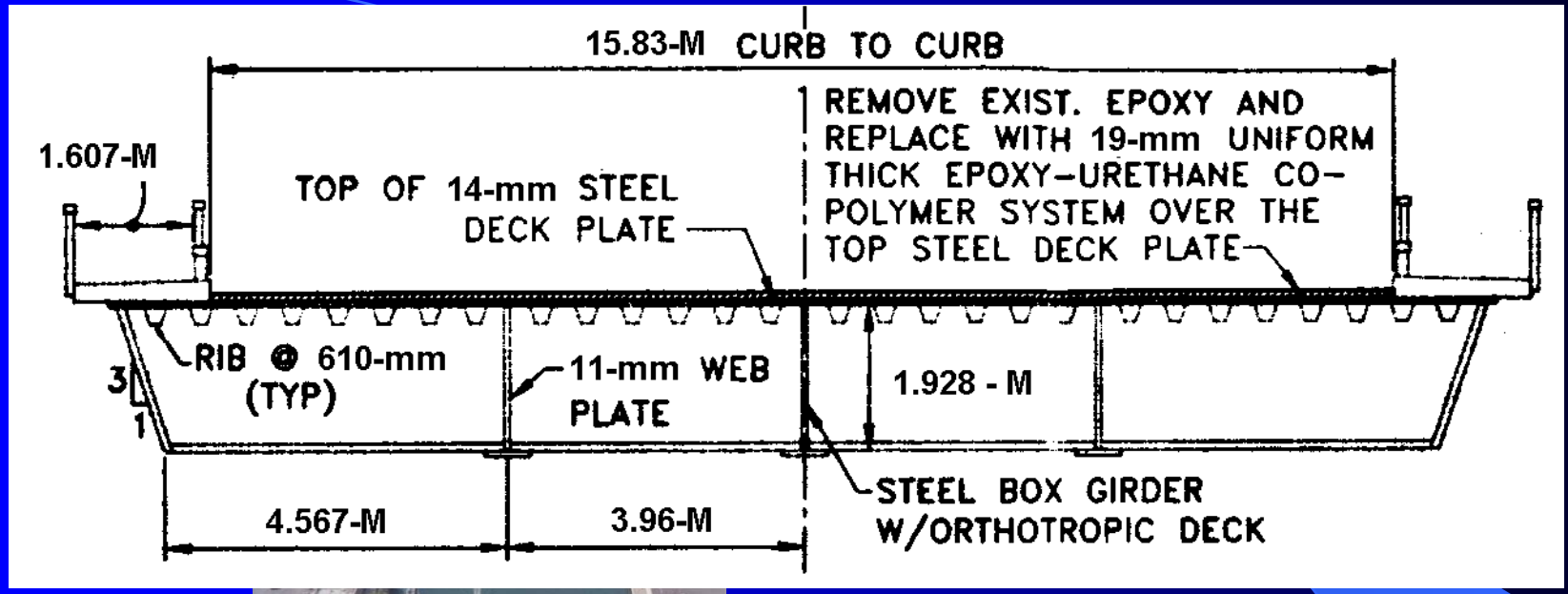
COLUSA BRIDGE OVER SACRAMENTO RIVER, 15C-0001 COLUSA COUNTY 1972

COLUSA COUNTY



MILLER SWEENY BASCULE BRIDGE
33C-0147, ALAMEDA COUNTY 1973

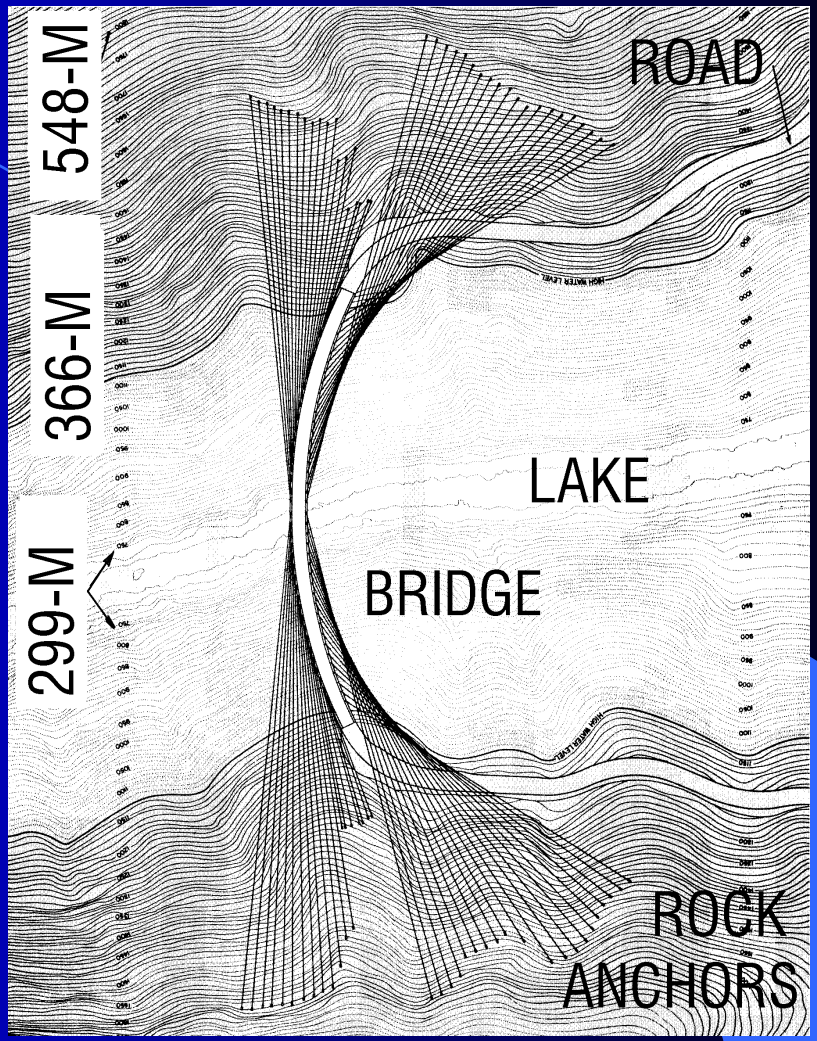
COUNTY OF ALAMEDA
PUBLIC WORKS AGENCY



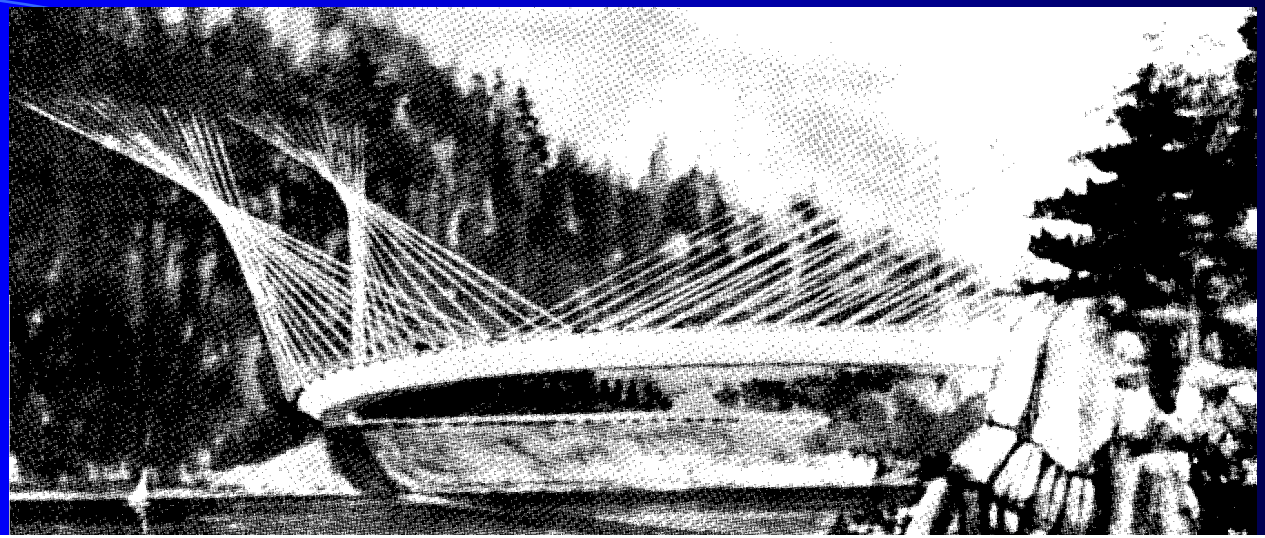
MILLER SWEENY BASCULE BRIDGE

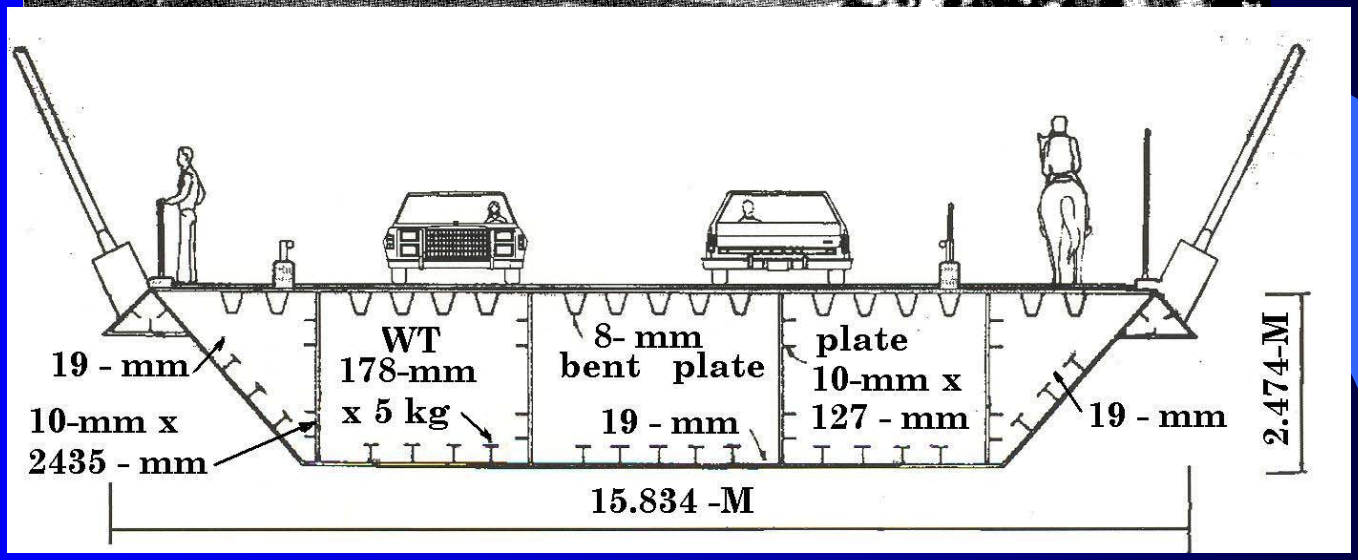
33C-0147, ALAMEDA COUNTY 1973

COUNTY OF ALAMEDA
PUBLIC WORKS AGENCY

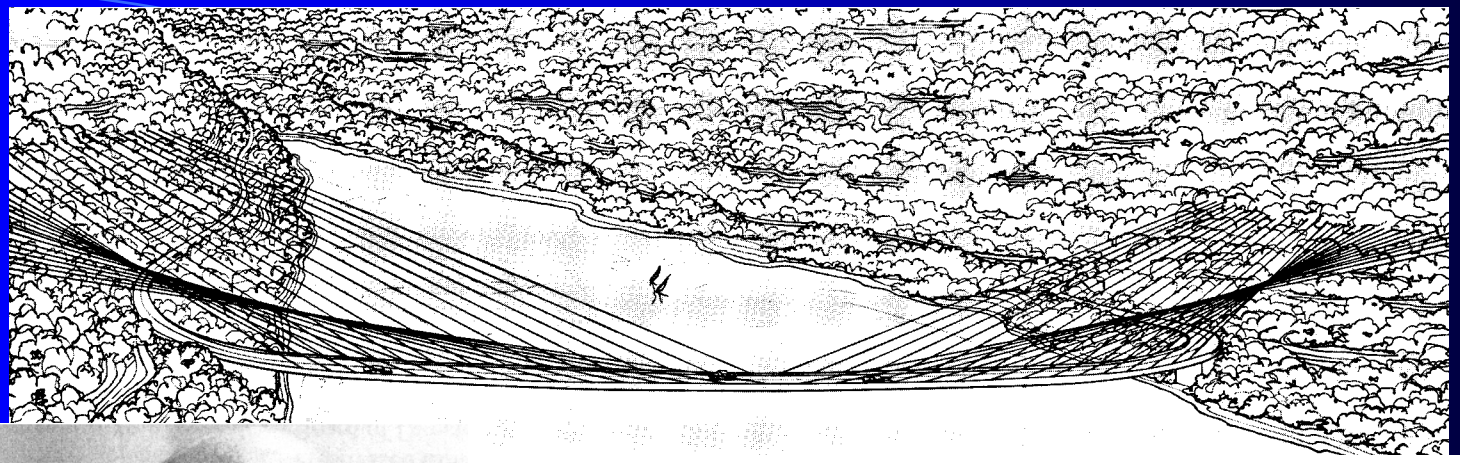


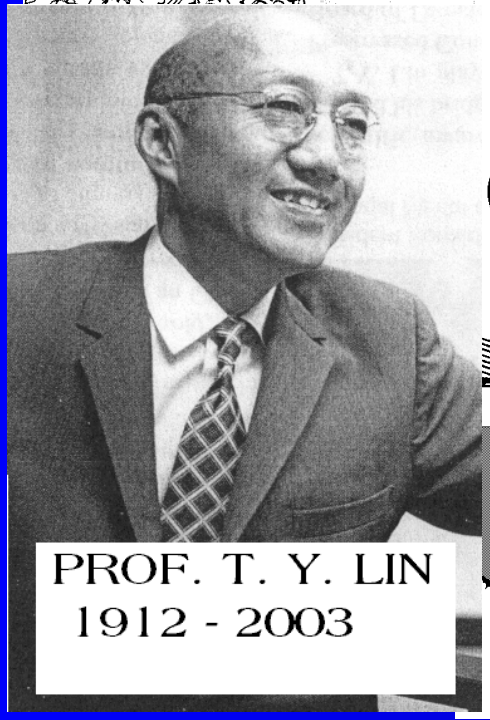
PROPOSED RUCK-A-CHUCKY BRIDGE OVER AUBURN DAM LAKE, 1976

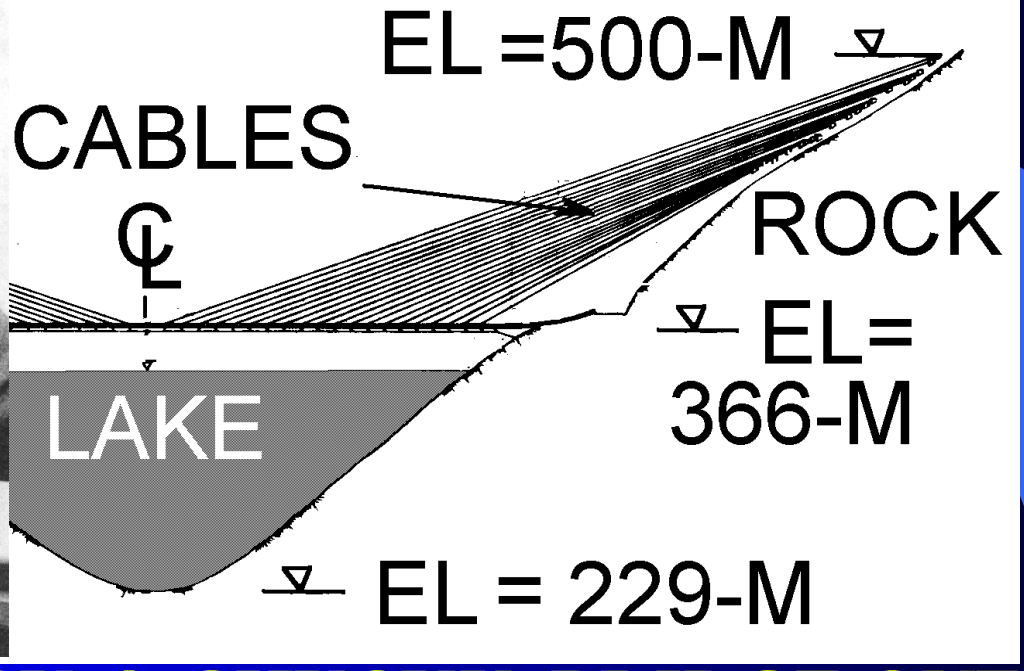




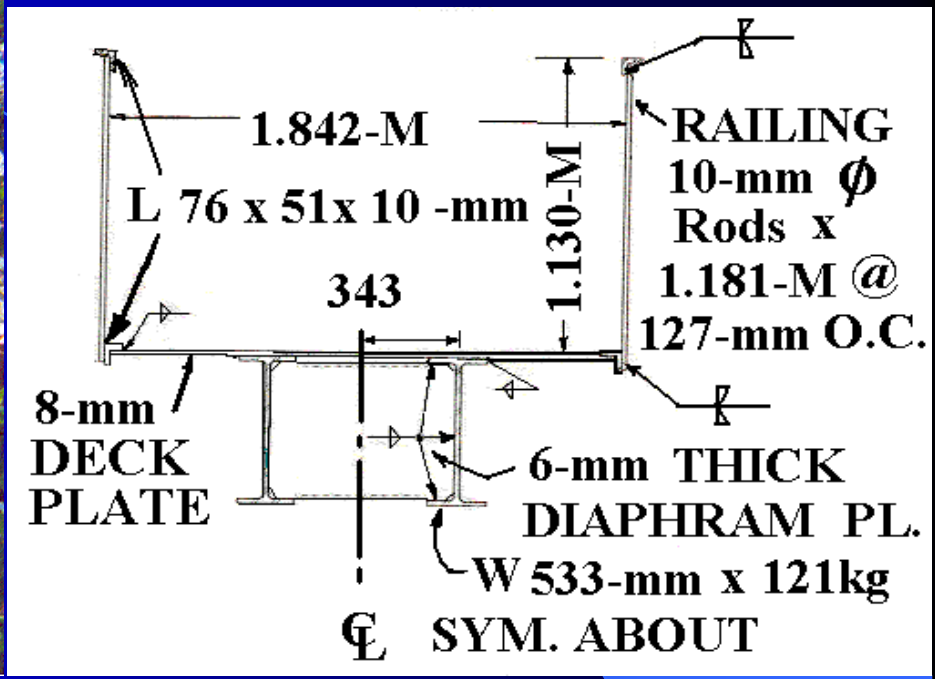
PROPOSED RUCK-A-CHUCKY BRIDGE OVER AUBURN DAM LAKE, 1976







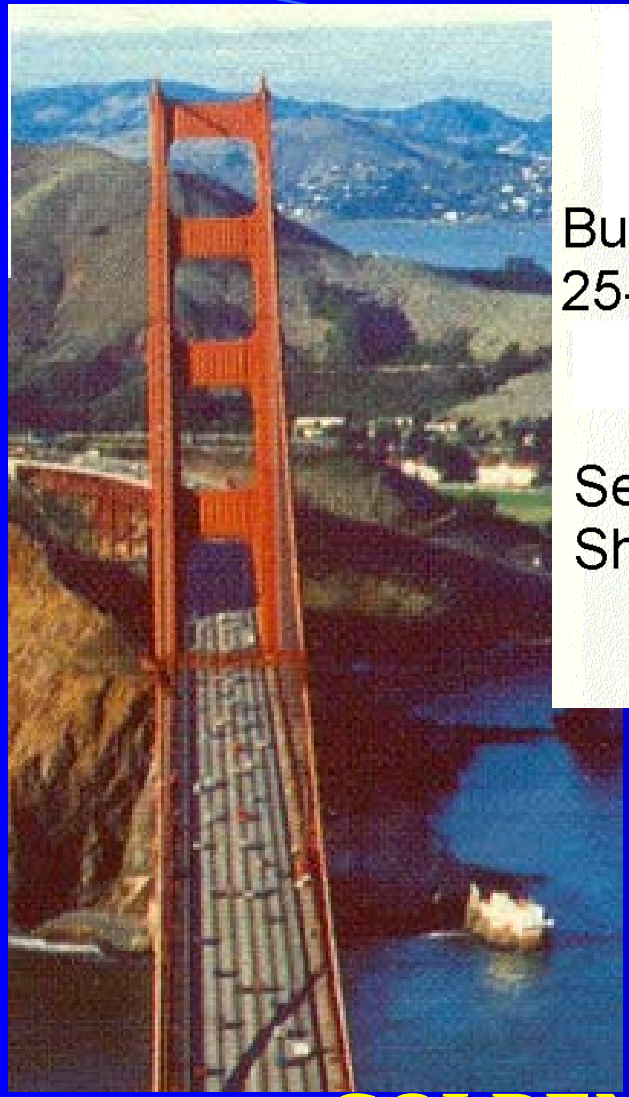
PROPOSED RUCK-A-CHUCKY BRIDGE OVER AUBURN DAM LAKE, 1976

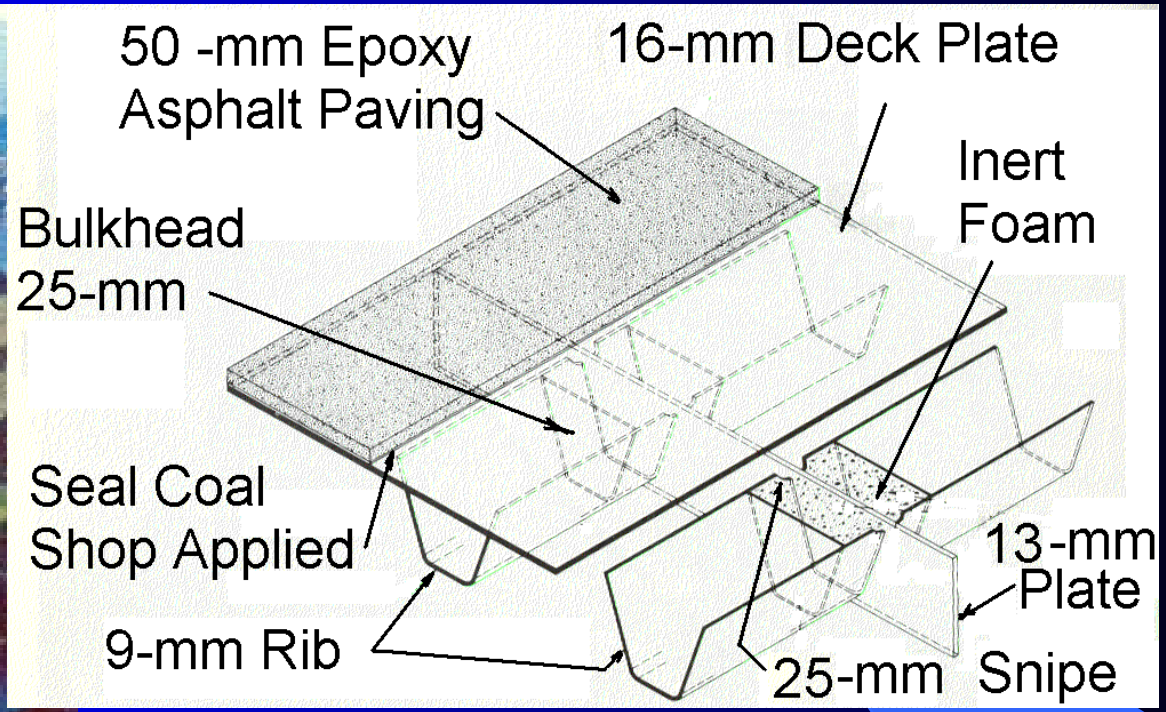


[Photos Summer 2001]

BRAILLE TRAIL PEDESTRIAN BRIDGE OVER CREEK , 1977

SONOMA COUNTY WATER AGENCY

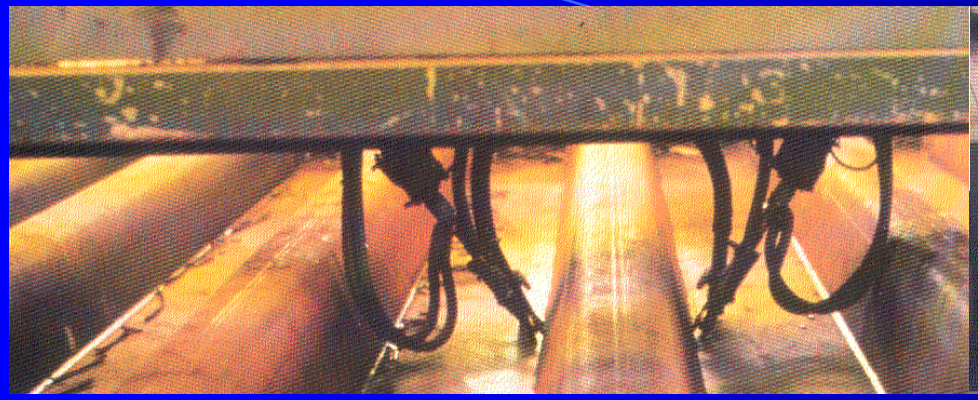


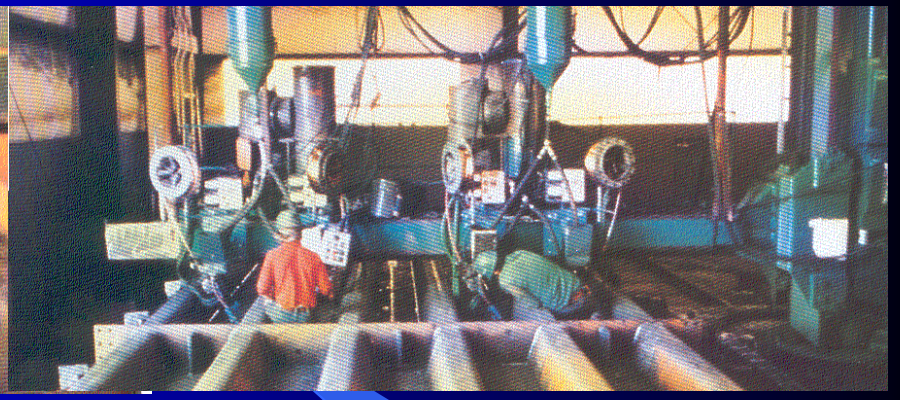


GOLDEN GATE BRIDGE

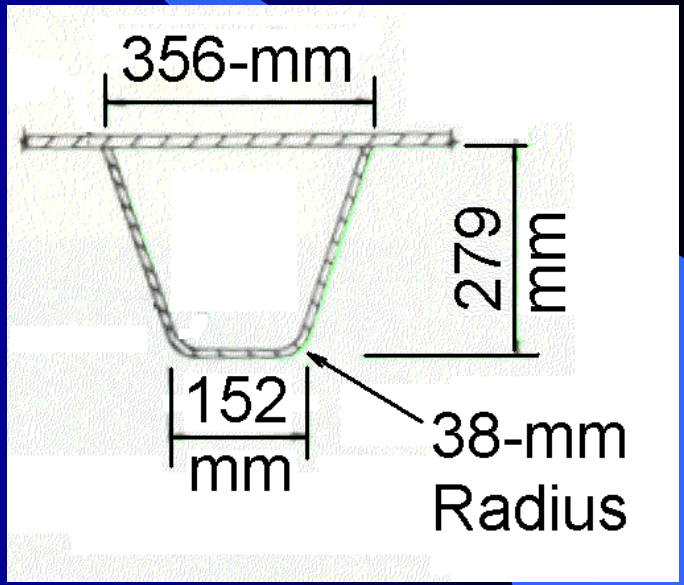
DECK REPLACEMENT , 1985

GOLDEN GATE BRIDGE, HIGHWAY & TRANSPORTATION DISTRICT





— Finished deck panel — shipment to site.

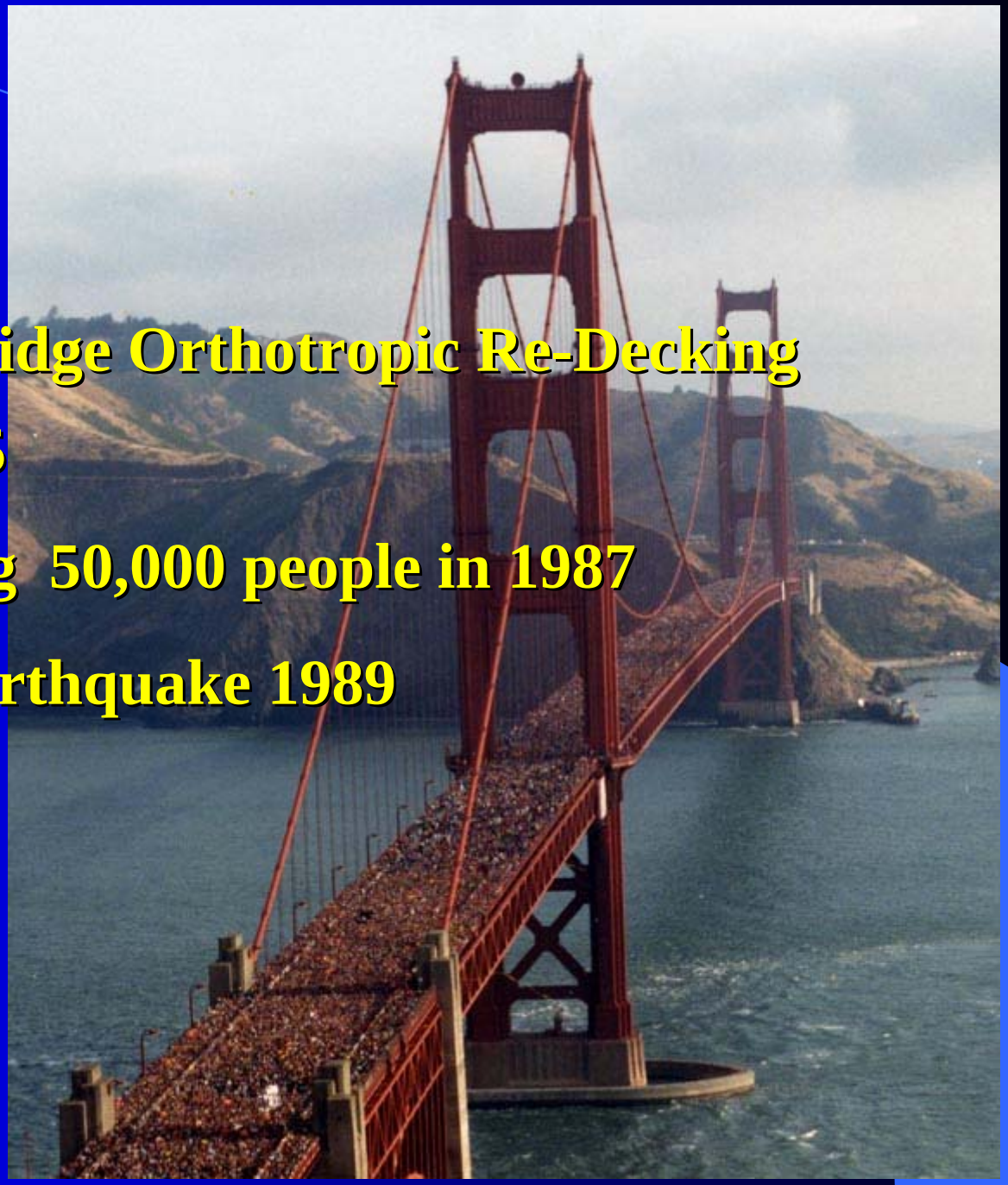


GOLDEN GATE BRIDGE

DECK REPLACEMENT , 1985

GOLDEN GATE BRIDGE, HIGHWAY & TRANSPORTATION DISTRICT

- **Golden Gate Bridge Orthotropic Re-Decking Completed 1985**
- **Largest Loading 50,000 people in 1987**
- **Loma Prieta Earthquake 1989**



GOLDEN GATE BRIDGE, HIGHWAY & TRANSPORTATION DISTRICT

MARITIME OFF-RAMP BRIDGE #33-0623S

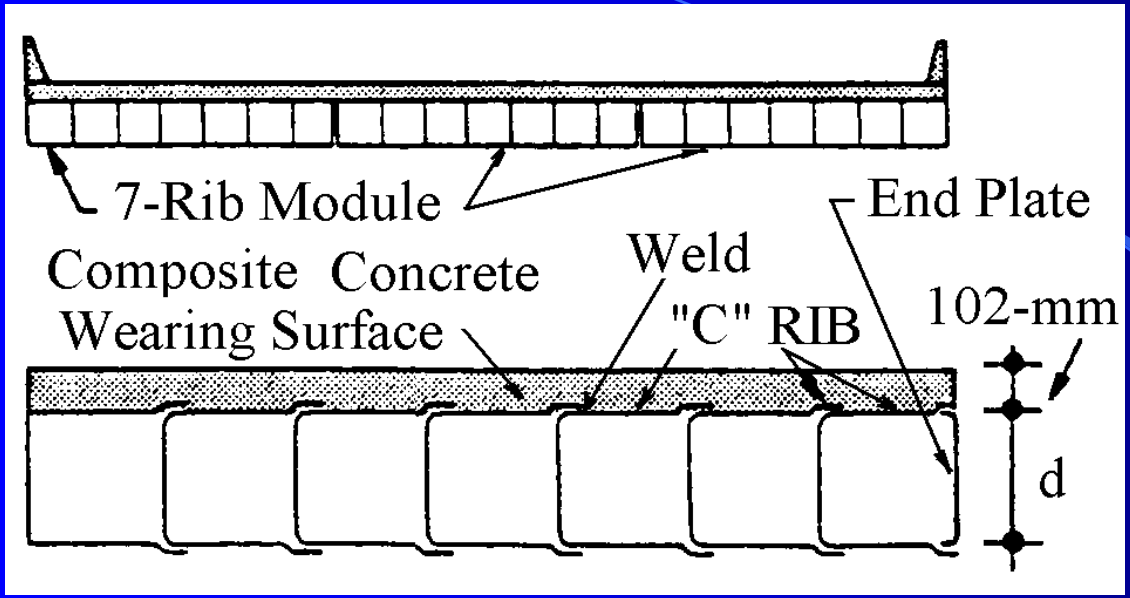
"HORSESHOE" , 1997

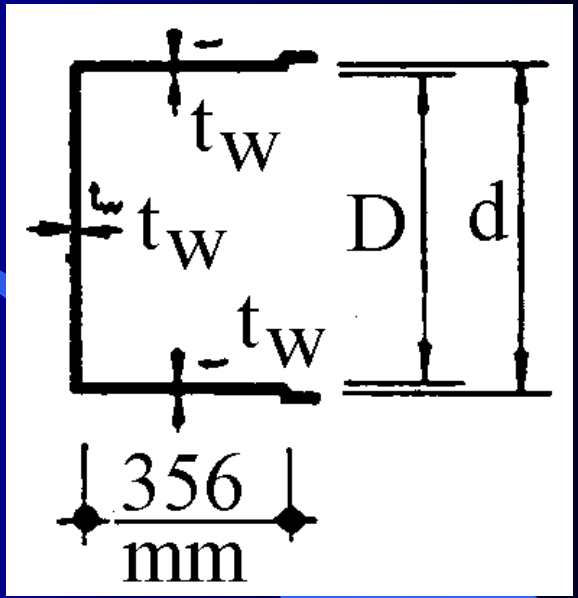
MARITIME OFF-RAMP BRIDGE #33-0623S

"HORSESHOE" , 1997

MARITIME OFF-RAMP BRIDGE #33-0623S

“HORSESHOE” , 1997





courtesy of Advanced Bridge Systems Inc.,
[Jiri Strasky, Consulting Engineers]

"PATENTED" SLAB BRIDGE, REDDING
APPROVED BY CALTRANS , 1998

Preassembly

Float –in >

US Navy Nicolas Island, CA floating dock

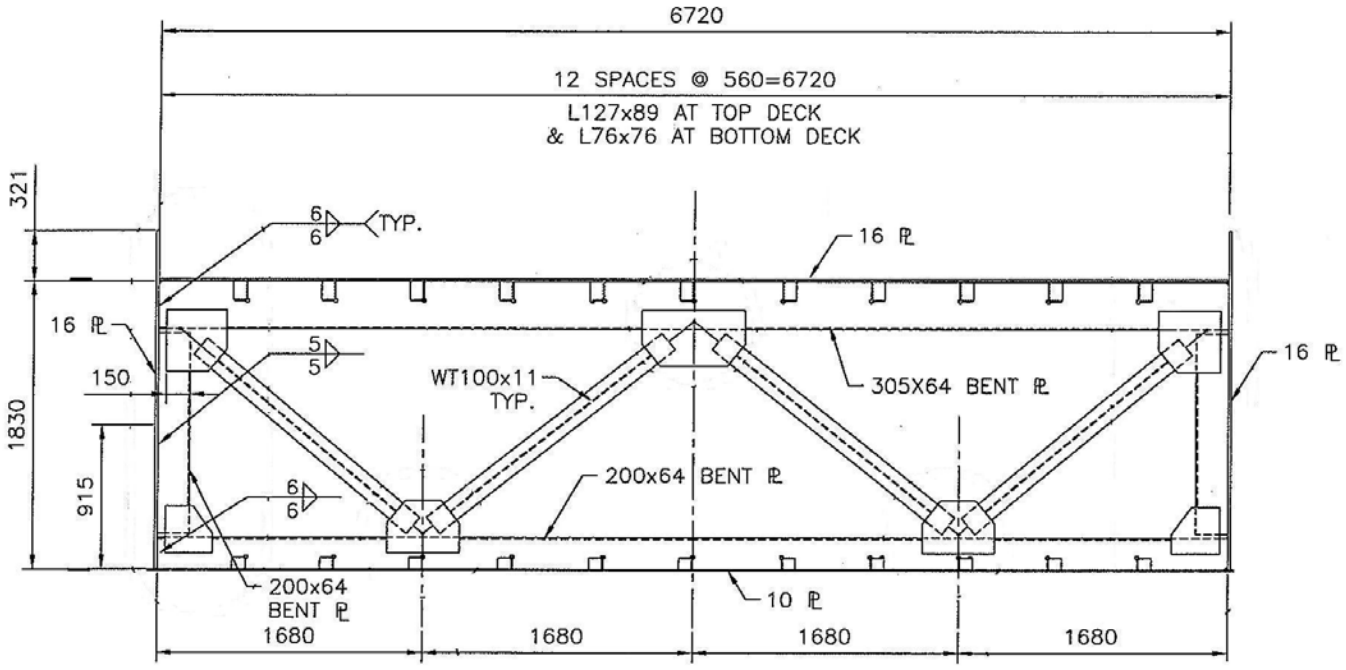
- **Design Build NOVA Group +**

Winzler and Kelly Engineers of San Francisco. Pontoons are 52.995-M x 6.7250-M.

US Navy Nicolas Island, CA floating dock Design Build NOVA Group +

Winzler and Kelly Engineers of San Francisco.

Pontoons are 52.995-M x 6.7250-M.



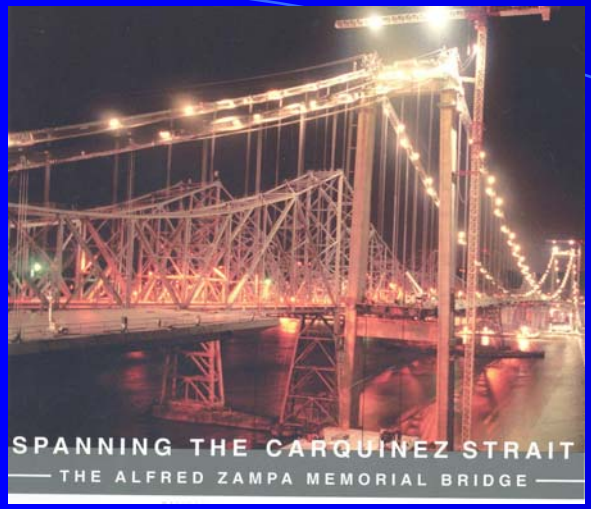
Dimensions in mm

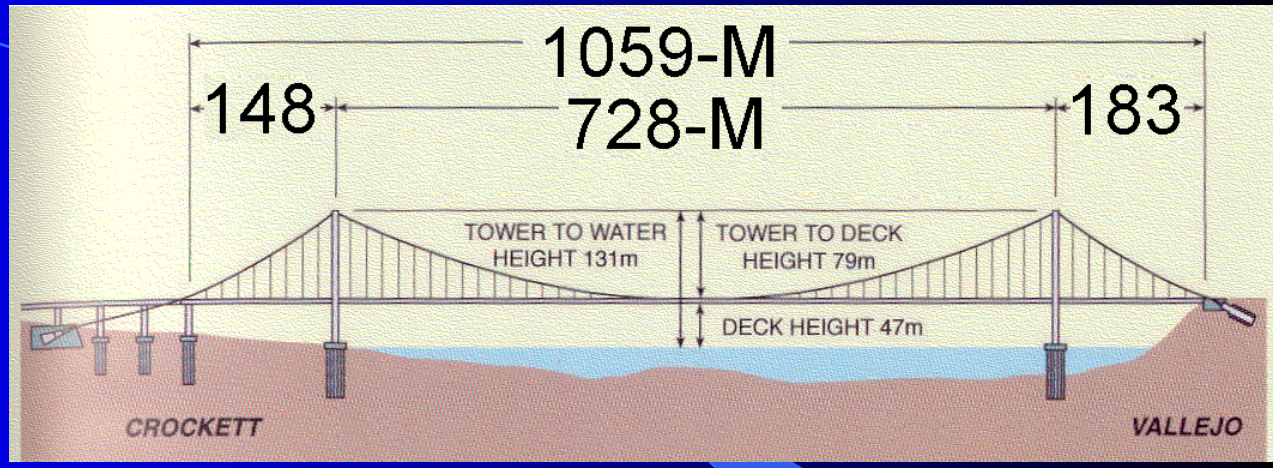
US Navy Nicolas Island, CA floating dock

Design Build NOVA Group +

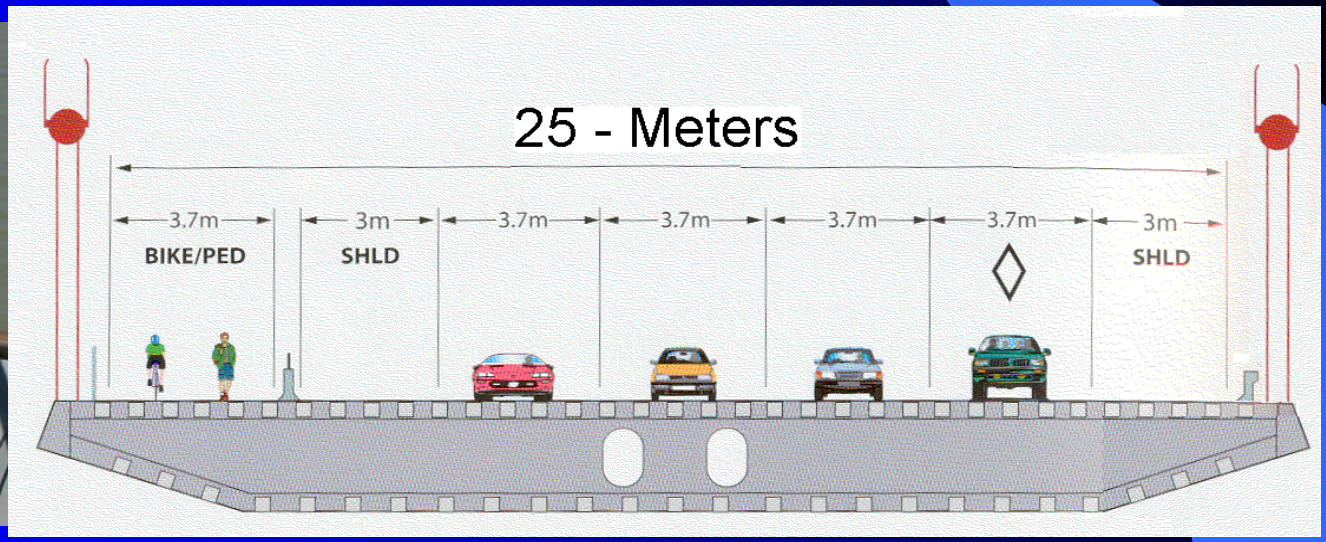
Winzler and Kelly Engineers of San Francisco.

Pontoons are 52.995-M x 6.7250-M.





California Department of Transportation, (Caltrans). (2003). *Spanning the Carquinez Strait – The Alfred Zampa Memorial Bridge*, Oakland, California, 93 pages.



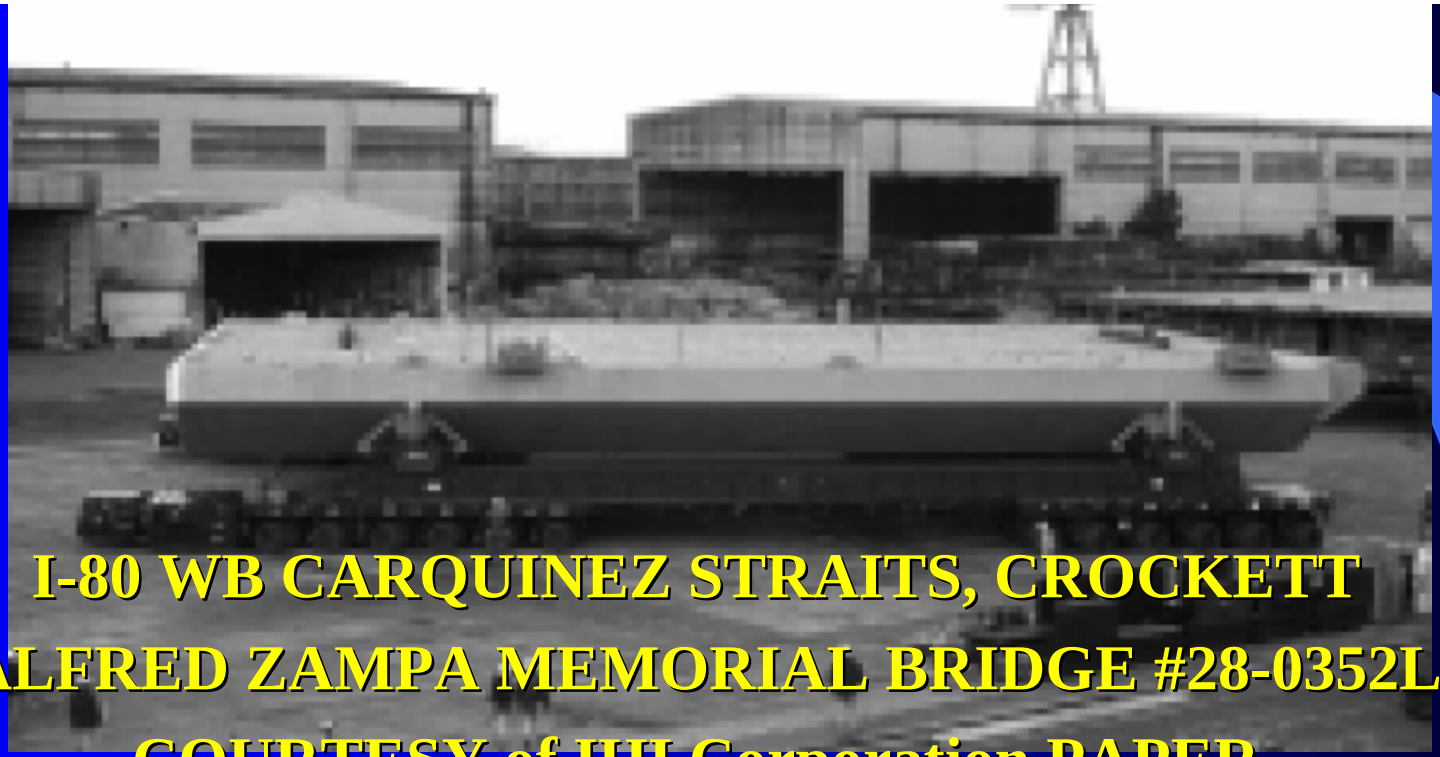
I-80 WB CARQUINEZ STRAITS, CROCKETT

ALFRED ZAMPA MEMORIAL BRIDGE #28-0352L

OBG = Orthotropic Bridge Girders

Construction schedule

Item \ Year / month	2000												2001												2002												2003												2004				
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
Foundation, tower																																																					
Cable erection																																																					
Fabrication of OBG																																																				
Erection of OBG																																																				
On-deck work Wearing Surface																																																			



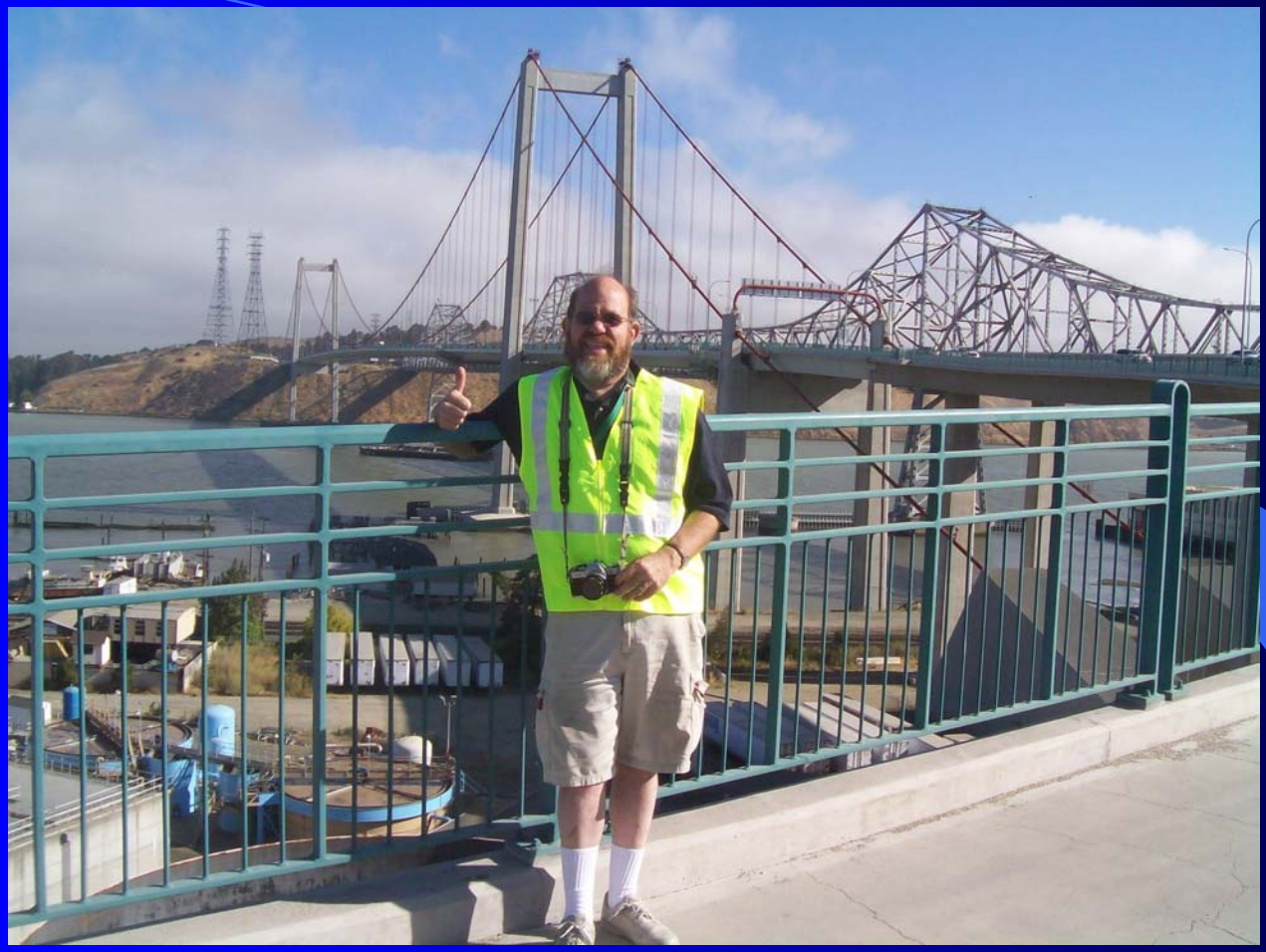
I-80 WB CARQUINEZ STRAITS, CROCKETT

ALFRED ZAMPA MEMORIAL BRIDGE #28-0352L

COURTESY of IHI Corporation PAPER

I-80 WB CARQUINEZ STRAITS, CROCKETT

ALFRED ZAMPA MEMORIAL BRIDGE #28-0352L

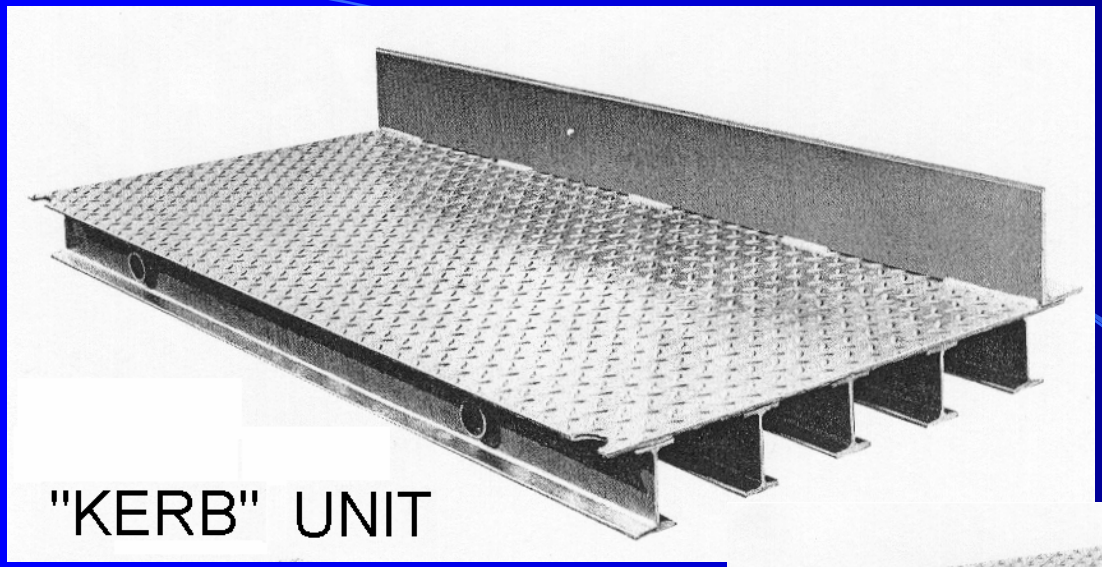


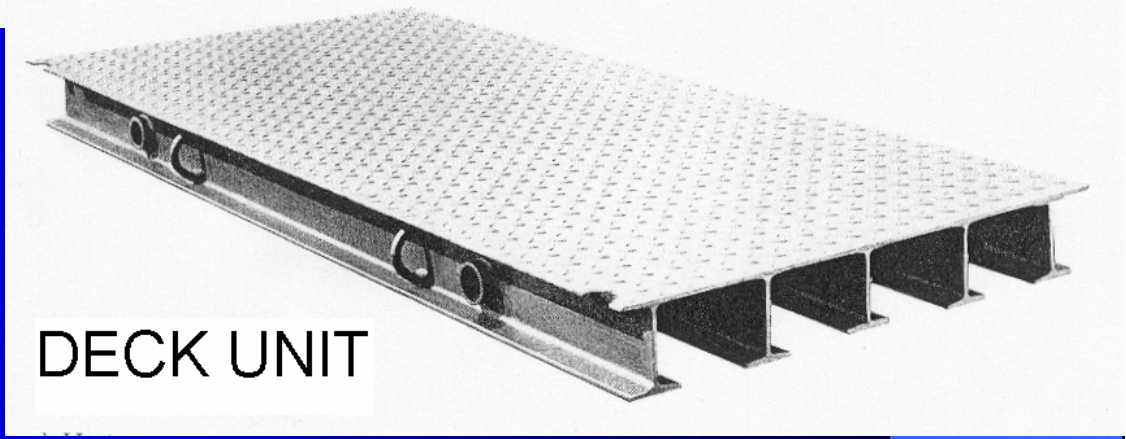
I-80 WB CARQUINEZ STRAITS, CROCKETT ALFRED ZAMPA MEMORIAL BRIDGE #28-0352L

About a 60-Minute drive from Sacramento

I-80 WB CARQUINEZ STRAITS, CROCKETT ALFRED ZAMPA MEMORIAL BRIDGE #28-0352L

View from "The Dead Fish" Restaurant

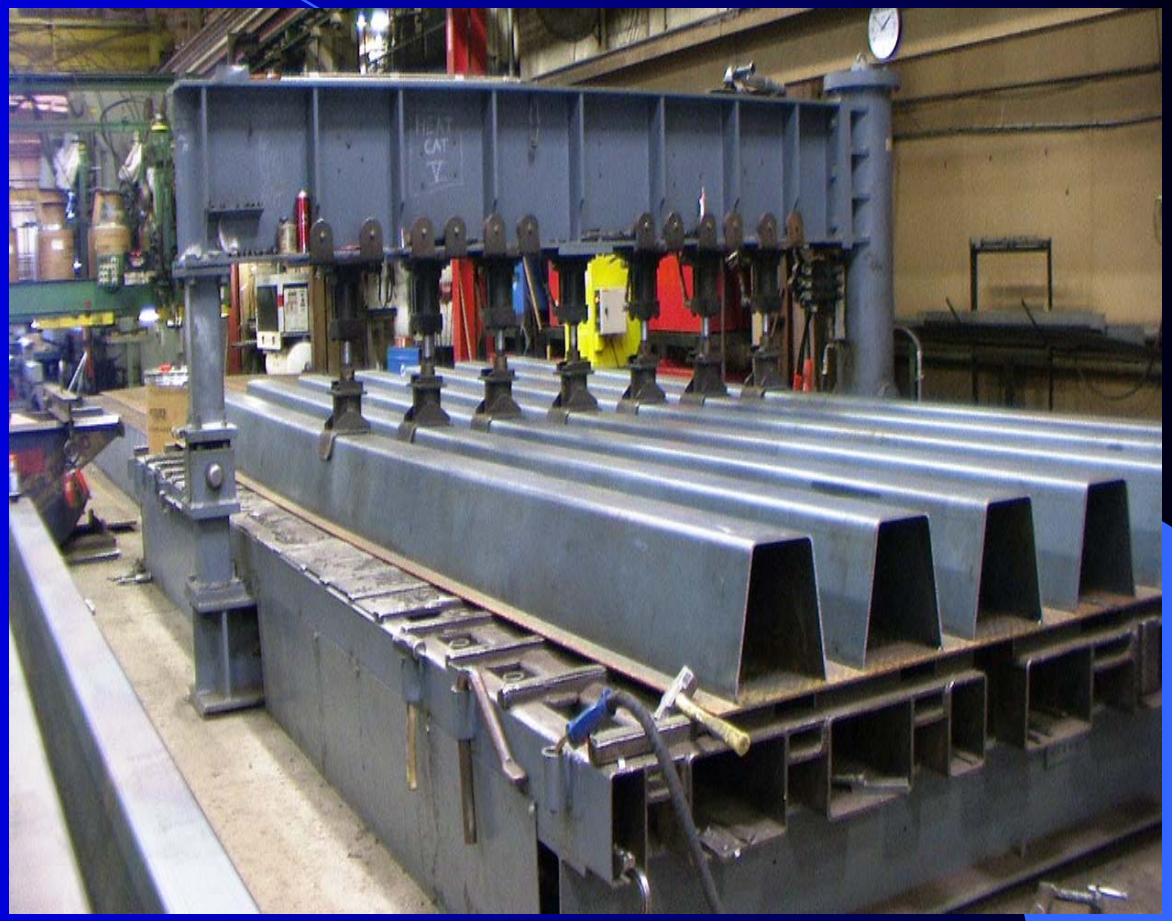




"Temporary" bridge for state of California or other government agency use. ACROW uses "chequered" steel deck welded to closely spaced "W-Beam" ribs

Truck Scale = Ribs Attached to Deck Plate

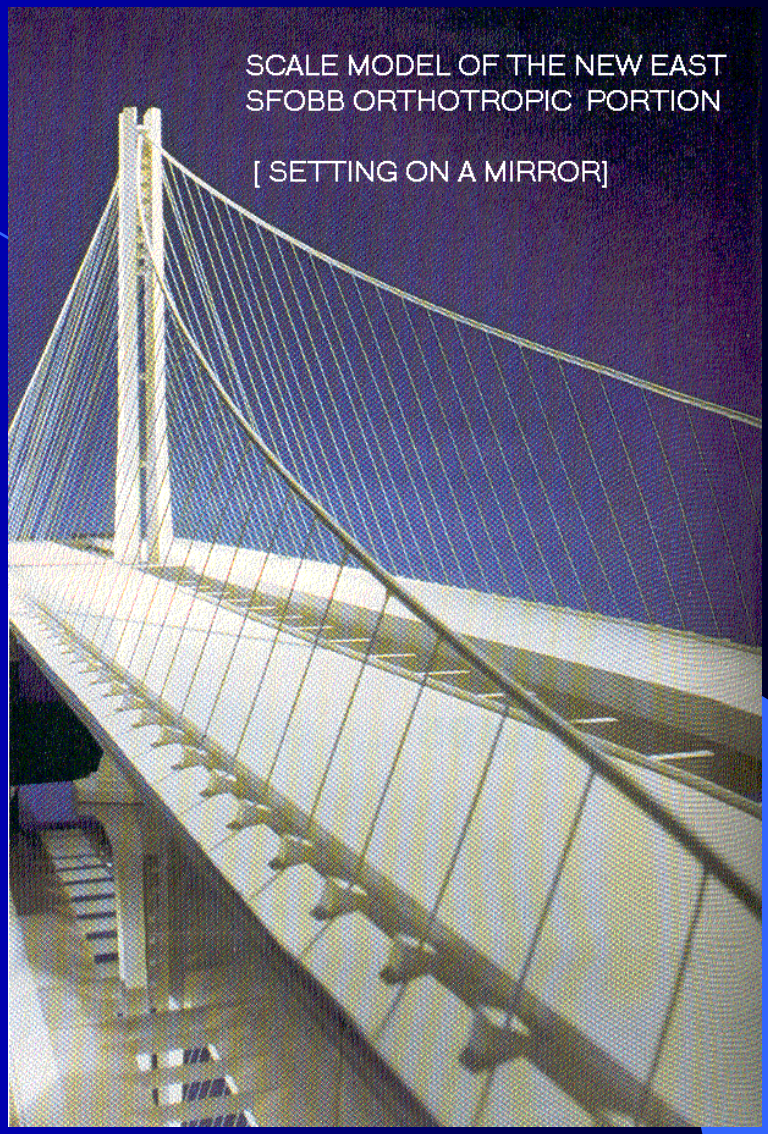
Mettler Toledo
Vehicle Scale
Production Facility
Columbus, Ohio



- **Camber press down for Ogden Welder**
- **on table two (2) for eliminating ponding**

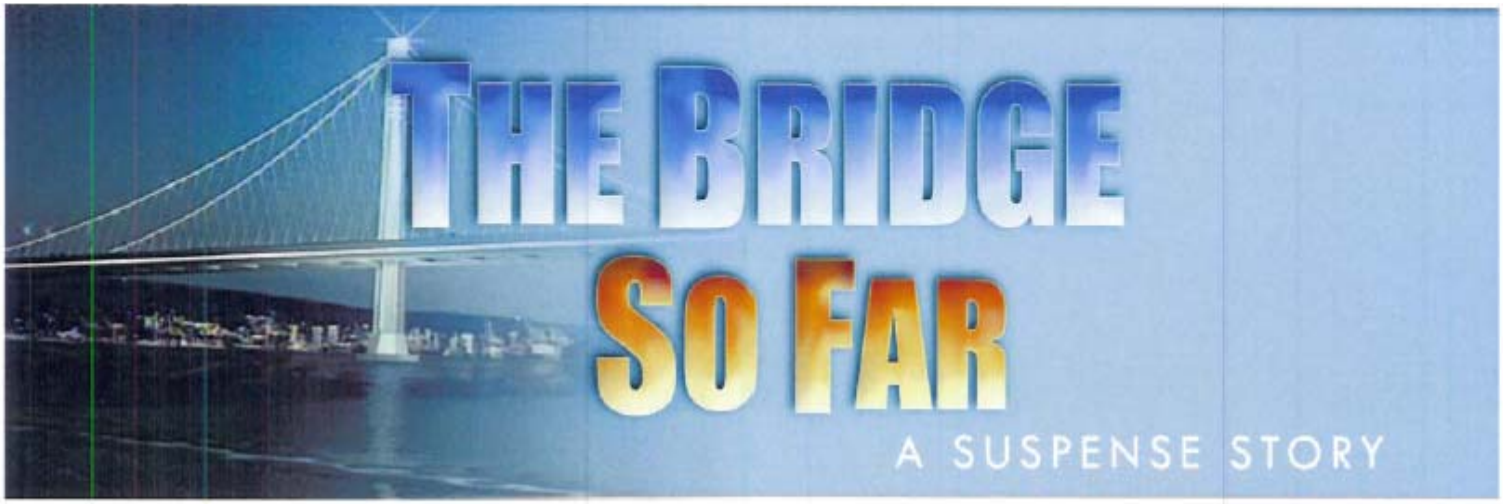
1989 Loma Prieta Earthquake Damage

- Most $$$$$ Damage of any California earthquake in the 20th Century
- Major improvement for ductility design



NEW EAST SPANS OF SFOBB

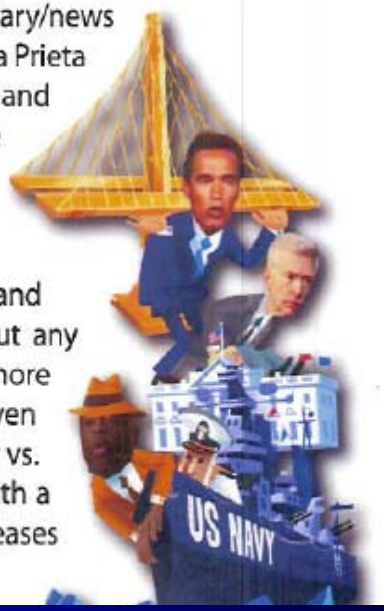
Caltrans



http://www.thebridgesofar.com/

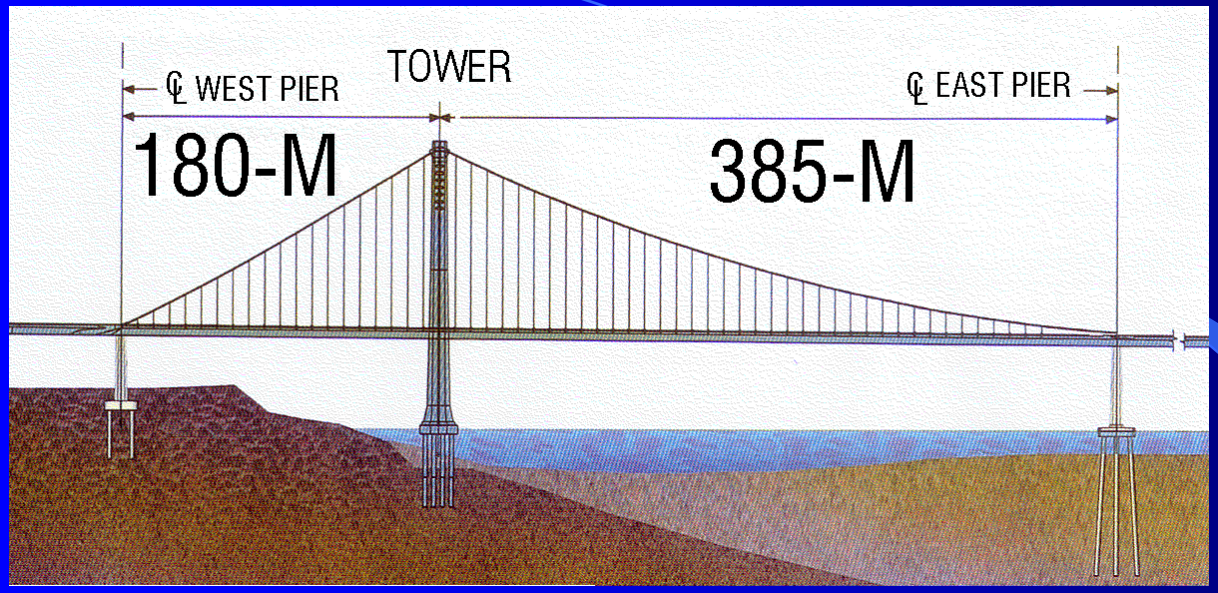
"The Bridge So Far -- A Suspense Story" is an entertaining one-hour documentary on the often outrageous and always controversial history and status of the San Francisco-Oakland Bay Bridge. Tragic, frustrating, comical, and historic, this entertaining documentary/news special follows the Bridge from its original construction through the 1989 Loma Prieta earthquake up to the present day. It recounts the progress, delays, setbacks, and politics during the design and construction of a new, safe bridge to re-complete the connection across the Bay between San Francisco and Oakland.

Sponsored by Professional Engineers in California Government (PECG), the documentary's genesis was a concern by PECG leaders that this major and historic infrastructure project would be constructed and completed without any photographic record. However, it quickly became clear that this was much more than a huge design and construction project. It was local, regional, state, and even federal politics; dollars and delays; finances and finger pointing; the U.S. Navy vs. Caltrans; northern vs. southern alignments; skyway vs. suspension bridge, with a bikeway; conceptual changes during construction; and monumental cost increases caused by such far-flung factors as the upcoming Olympics in China.

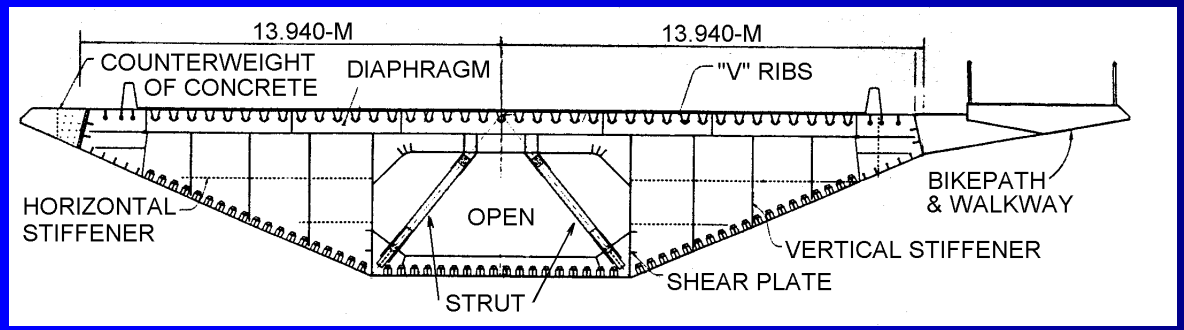


Caltrans

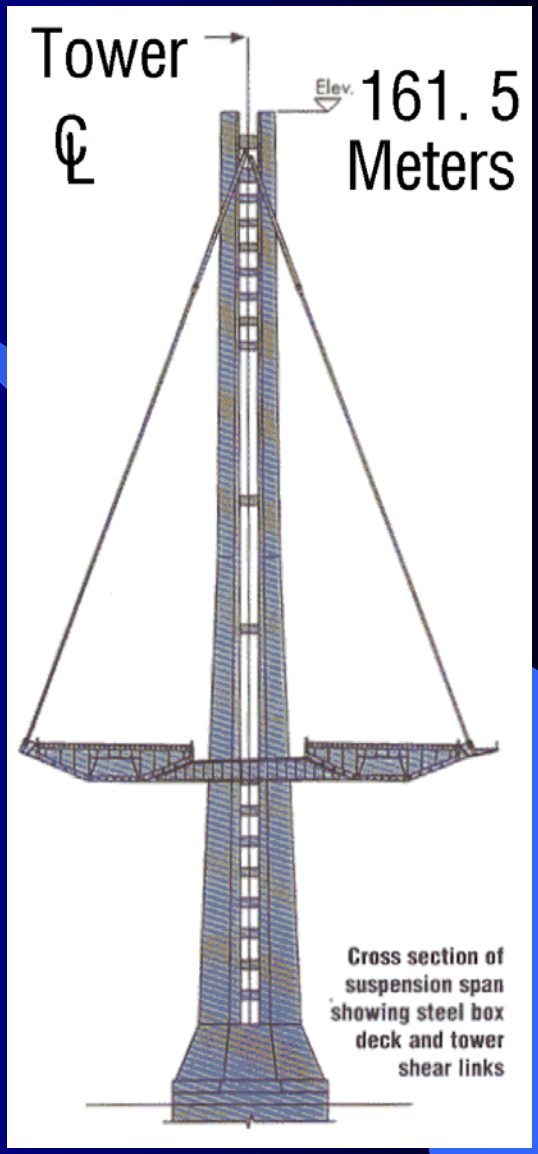
NEW EAST SPANS OF SFOBB



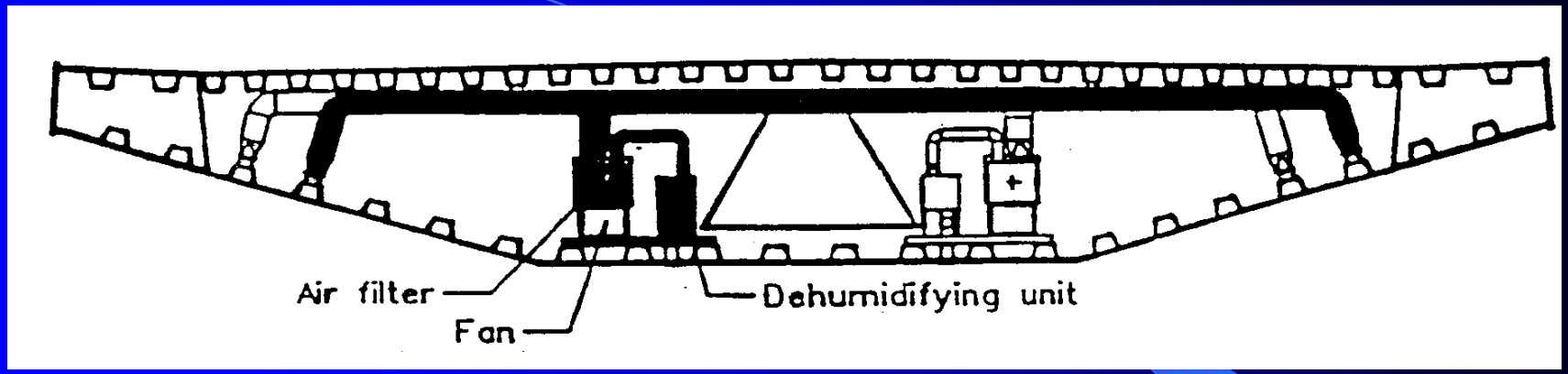
ELEVATION



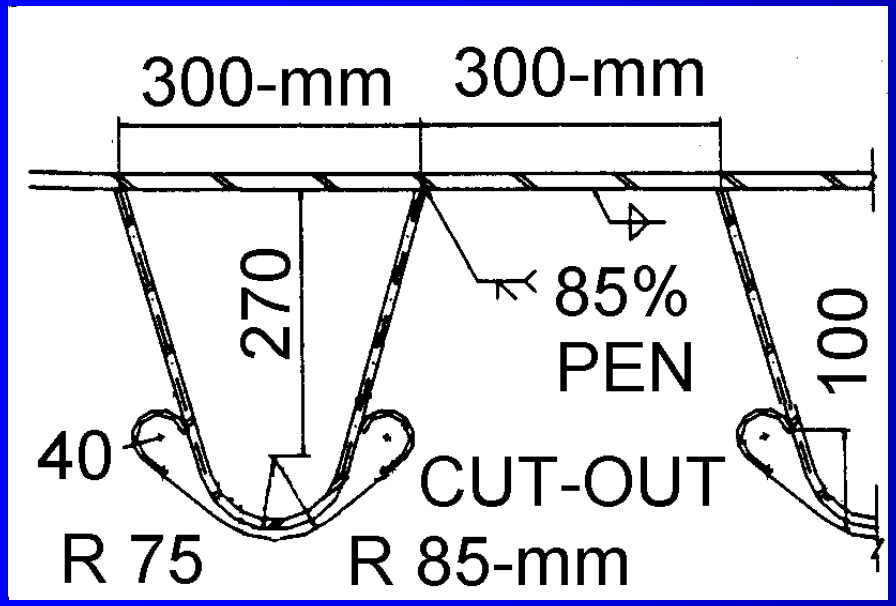
HALF - SECTION

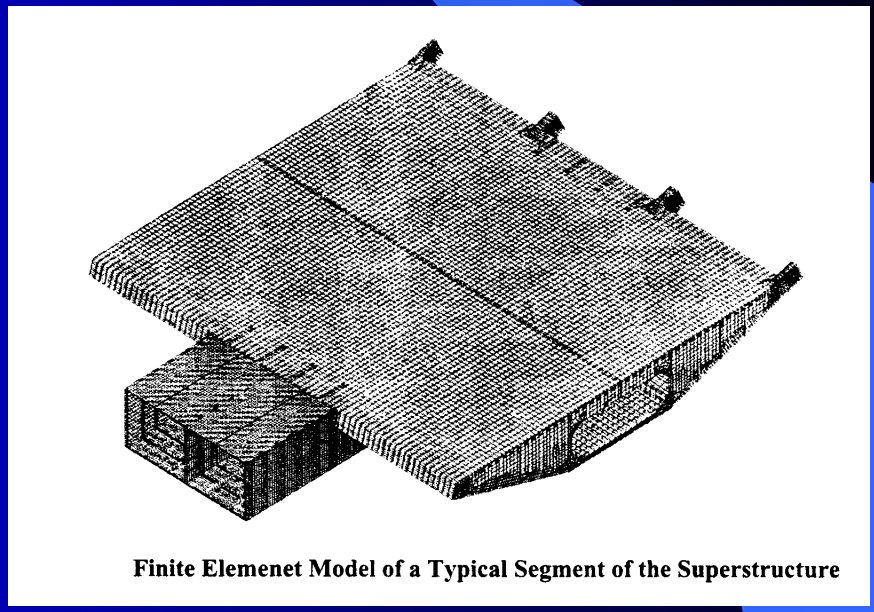


NEW EAST SPANS OF SFOBB



FEATURES DIFFERENT THAN OTHER CALIFORNIA BRIDGES



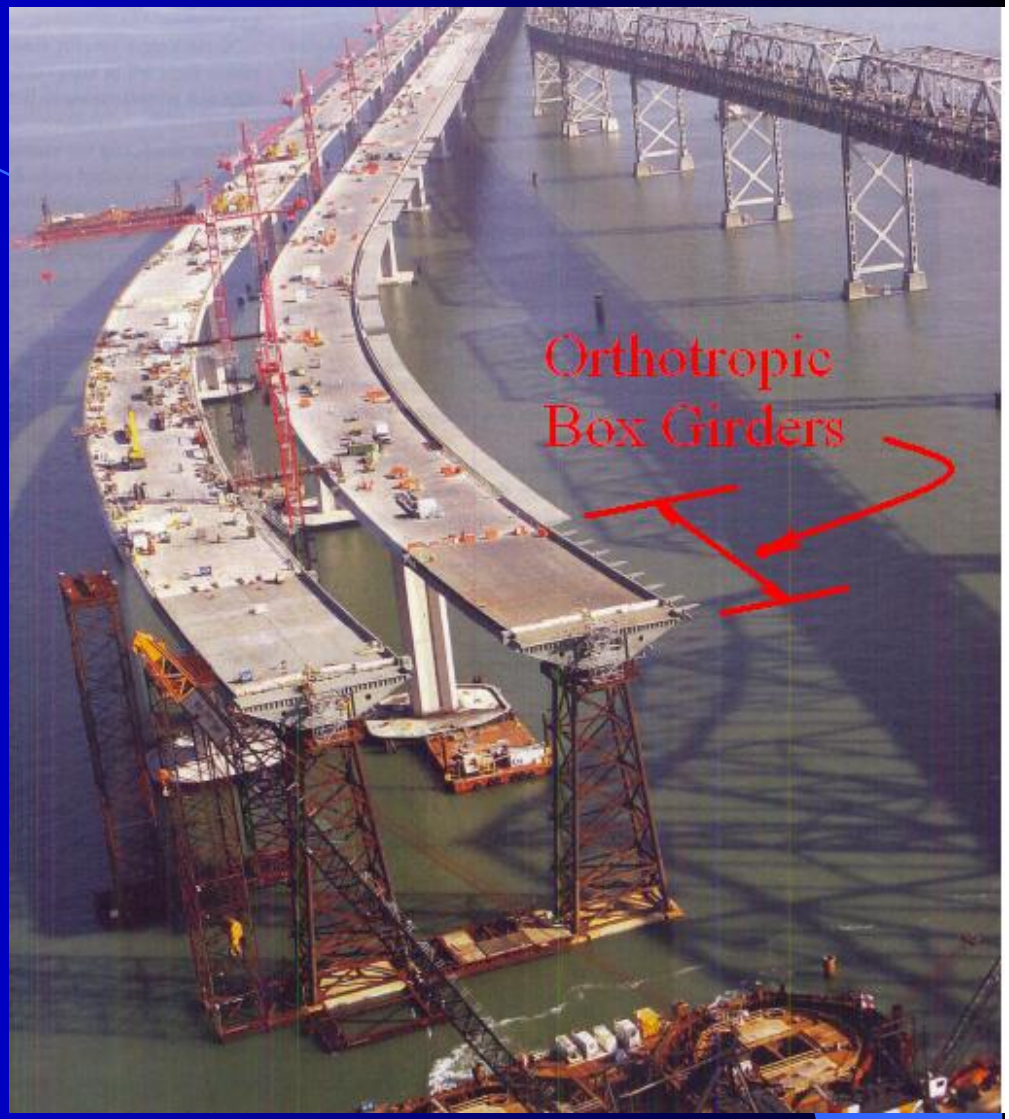


Finite Elemenet Model of a Typical Segment of the Superstructure

NEW EAST SPANS OF SFOBB

Lift of Skyway Orthotropic Spans – Fabricated by Universal Structures Inc and Oregon Steel

NEW EAST SPANS OF SFOBB



Lift of Skyway Orthotropic Spans – Fabricated by Universal Structures Inc and Oregon Steel

NEW EAST SPANS OF SFOBB

Fabrication in China

NEW EAST SPANS OF SFOBB

RIB DETAIL

1700 TON FLOATING CRANE

NEW EAST SPANS OF SFOBB

	Bridge NAME	Deck Area (Sq. meters)
3.	Dublin 580/680 Test [1965]	1011
4.	Ulatis Creek Test [1966]	441
5.	San Mateo – Hayward [1967]	43,533
6.	San Diego – Coronado [1969]	9467
7.	Queensway Twin [1971]	10,256
8.	Southern Crossing [1971]	Not Built
9.	Four ---- BART Rail [1972]	473
10.	Colusa [1972]	372
11.	Miller – Sweeney [1973]	722
12.	Ruck – A – Chucky [1976]	Not Built
13.	Braille Trail Pedestrian [1977]	33
14.	Golden Gate redecking [1985]	35,934
15.	Maritime Off-Ramp [1997]	7,921
16.	Slab [1997]	Unknown
17.	Alfred Zampa @ Carquinez [2003]	30,586
18.	SFOBB Self Anchoring [2007]	32,500
	TOTAL 17 California Bridges	**173,249**
	Millau Viaduct, France [2005]	**184,800**

Normandie Cable-Stayed

Millau Viaduct Cable-Stayed

2009 Deck Area

California's 17 Orthotropic Bridges = 173,249 square meters

[163,696 sq miles 36,756,666 people]

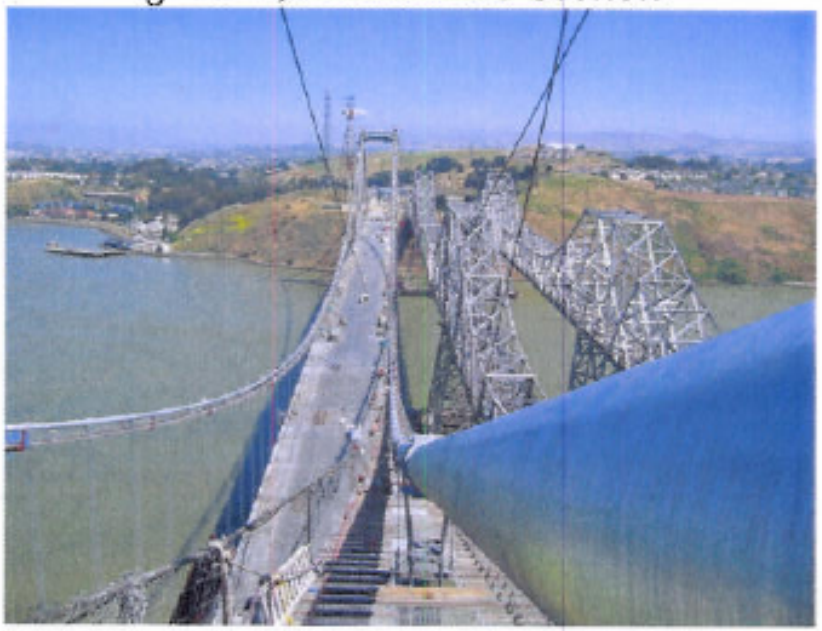
South Korea Orthotropic Bridges = 688,800 square meters

[38,622 sq miles 48,379,392 people]

Special thanks my Office Chief Mr. Vong Toan, PE Supervising Bridge Engineer for his support and Yeong-Jong [SAS] Bridge photo.

25 to 29 August 2008 INTERNATIONAL ORTHOTROPIC BRIDGE CONFERENCE SACRAMENTO, CALIFORNIA, USA

Hosted by the ASCE American Society of Civil Engineers, Sacramento Section



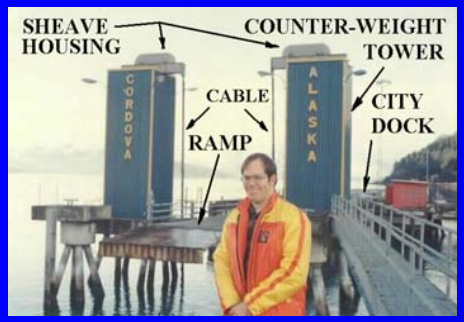
The new end spans of San Francisco Oakland Bay Bridge [SFOBB] , and Alfred Zampa Memorial Orthotropic Bridges at Carquinez Straits are part of conference bus tour [For updated information, see www.orthotropic-bridge.org

asce@asce-sacto.org

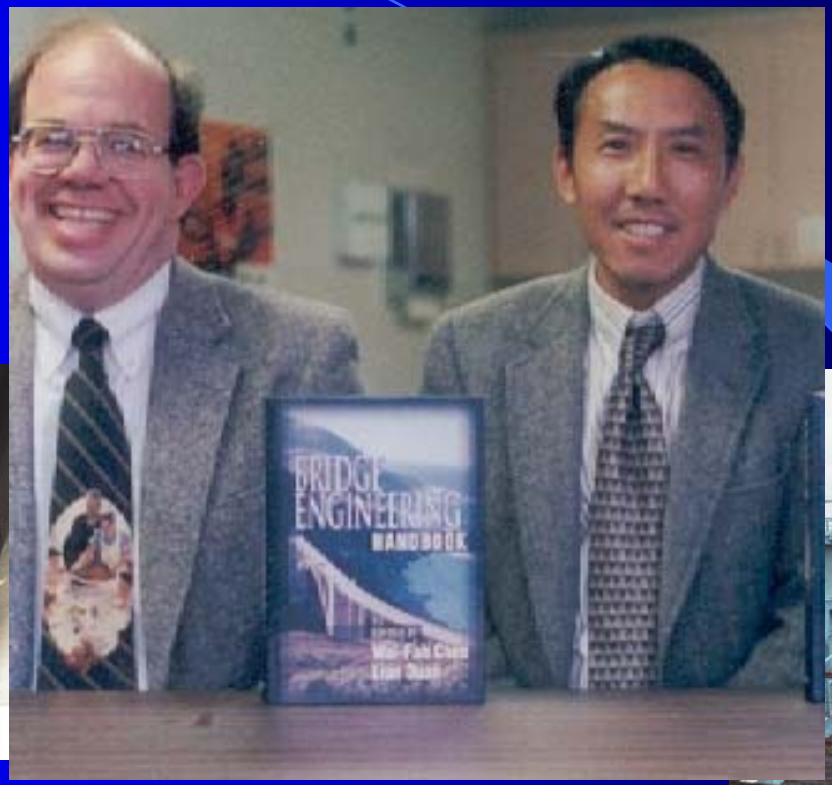
3RD OBC Conference 2012 Sacramento??

AUTHORS OF

***ORTHOTROPIC STEEL DECK BRIDGES* - CHAPTER 14**



Cordova Alaska Ferry Terminal



Battle Creek = Salem, OR

At Jesse Engineering, Tacoma WA

with Tim Moore, PE WASHDOT Tacoma Narrows 3

A few of the orthotropic bridges in Western States

AL MANGUS, PE DR LIAN DUAN, PE Chair Caltrans Steel Bridge Comm.

QUESTIONS ?