THE NEXT GENERATION ORTHOTROPIC STEEL DECK BRIDGES

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BIOGRAPHY

Mr. Alfred R. Mangus is currently a Transportation Engineer, Civil, with the Office of Structure Contract Management for the California Department of Transportation (CALTRANS). Mr. Mangus has been with the department for 13 + years. His previous employers include the Arizona Department of Transportation and consulting engineering firms located in Anchorage, Alaska & Washington. He earned the Bachelor of Architectural Engineering degree from Penn State University in 1976, and the MSCE from the University of California, Berkeley in 1977. He is actively licensed in five western states. Mr. Mangus is co-author of "Orthotropic Deck Bridges" Chapter 14 of *Bridge Engineer Handbook* published by CRC Press. He is a licensed engineer in five western states. In 1987 and again in 2000, he received Professional Awards from the James F. Lincoln Arc-Welding. Foundation. He joined as an individual AISC professional member in 1981 and is on the board of directors of the HMS Heavy Movable Structures Inc.

SUMMARY

This paper describes current key issues or topics for Orthotropic steel deck bridges including; the need for new AASHTO and AWS 1.5 code details; rib to diaphragm detail that will result in 100-year bridge life; standardize details; "Mega" and Signature Bridges from Europe; Africa and Asia; successful durable bridges such as the San Mateo Hayward and Fremont Bridge; thicker decks that will allow wearing surfaces to be installed 2 to 3 times for 100-year life bridges.

DISCLAIMER

This paper is solely the opinion of Mr. Mangus and does not necessarily reflect the California Department of Transportation's opinion or position on topics discussed.

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by
Alfred R. Mangus

INTRODUCTION:

What is meant by the term "the next generation"? For example, at Caltrans an engineer with a BSCE graduates normally about age 22 and retires about age 62. A doctorate of engineering employee would work at Caltrans from age 26 to age 66 to achieve a full pension. Thus the typical impact of a person or a generation is about 40 years. About 40 years ago the first generation of orthotropic bridges began to be built in the USA [Reference #1]. Bridges with Orthotropic steel decks in North America are very rare. There are less than one hundred bridges in three countries, while there are 650,000 bridge structures of all types just in the U.S.A. In Europe there are over 1,000 orthotropic steel deck bridges of all types. However, since the 1950's, there has been a continuing evolution of orthotropic steel deck bridges. The goal after World War Two was to use the minimal amount of steel. Currently the Federal Highway Administration (FHWA) is advocating longer life of 100 years for bridges in the USA. In 2005, the FHWA held regional workshops and, or conferences plus published papers on "ABC = Accelerated Bridge Construction" techniques with the goal of: "Get In; Get Out; and Stay Out". Thus the second or next generation of bridges must last 100 to 150 years. Overseas large Mega Bridges such as the Millau Viaduct are engineered to produce at least 75-years toll bridge revenues to its investors. This viaduct's deck are of 1,989,168 sq. ft. exceeds sum total of all California Orthotropic Bridges of 1,545,198 sq. feet. The accurate recording of design, research, fabrication, construction and maintenance are necessary to transfer knowledge between the generations. The primary goal of this paper will describe the second or next generation of orthotropic steel deck bridges, plus "new topics" [see table #1]. These are global topics that have value to bridge owners, educators, designers, fabricators, suppliers and contractors. Ideas or details from the first generation cannot just be copied because the goals of the generations are different. Also there is a sufficient amount of completed bridges to give appropriate "field test" data on "aging" of these bridges. The first generation had no database of in service bridges. A few items such as wearing surface need to be replaced every 25 to 40 years.

Table 1

	TOPIC	**NORTH AMERICA**	**EUROPE**	**ASIA Japan, China, Korea**
1	Orthotropic Code	Behind Eurocode	Euro-code Underway	unknown
2	Fatigue	Ahead Dr. Fisher	Behind	Unknown
3	Standard Details	Behind Eurocode	Ahead	Unknown
4	Building "Mega" Bridges	Behind all others	Many	Many
5	Durability Study /Survey	ASCE & Mangus	Unknown	Unknown
6	"Fat" Deck" Proposal	Mangus	Not applicable	Not applicable
7	Conferences	ASCE -NSBA	Behind USA	Behind USA

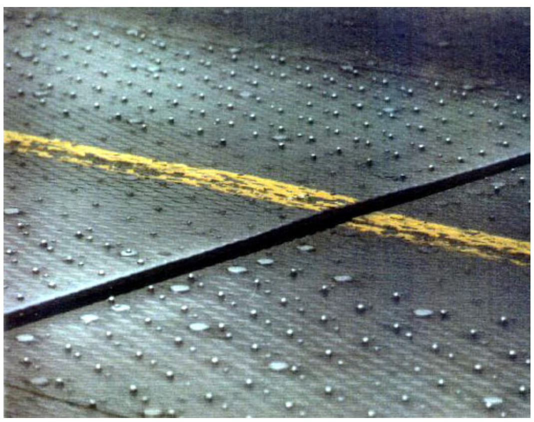
Topic 1: Enhanced AASHTO code details are needed and the Eurocode leads currently. Topic 2: Dr. Fisher's rib to diaphragm detail will result in 100-year life bridge. Topic 3: Only Russian with open ribs and Germany's wearing surface have tried to standardize details. Topic 4: "Mega" or "Signature Bridges from Europe; Africa and Asia were selected demonstrate the complete range of all types such as the world's largest Cable-Stayed, Suspension double swing bridge; the floating movable bridge. Topic 5: Durability Study was completed by ASCE in 1991, but not well publicized. Continuing to emphasize that successful bridges such as the San Mateo Hayward and Fremont Bridge have been durable for more than 25 to 38 years is an important

task that must continue. Topic 6: A thicker deck will allow wearing surfaces to be installed 2 to 3 times for 100-year life bridges. Topic 7: ASCE –NSBA will hold the next www.orthotropic-bridge.org in August 2008.

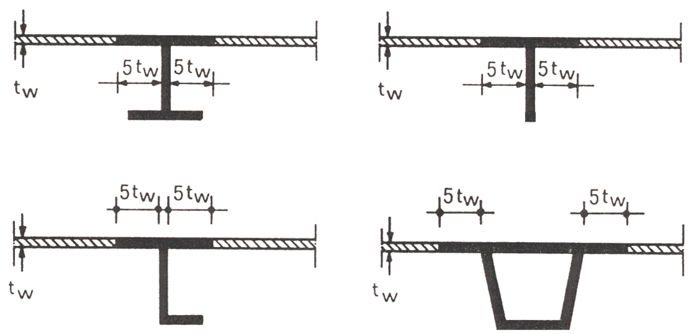
Need for Enhanced AASHTO Orthotropic Code Details

A brief Summary of AASHTO code-Issues

In the 1920's, American engineers began using steel plates riveted to steel beams for large movable bridges. The purpose was to minimize the dead load of the lift span. The predecessor of HNTB (Ash-Howard-Needles & Tammen) designed this lift span for the Burlington-Bristol Bridge Company, a private toll company. The designer wrote, ***"Since the plates are heavy enough to distribute some load to the adjoining beams, the individual stringers are designed to carry only 80% of the maximum wheel loading."*** Thus began the publishing the idea of using the steel deck plate in harmony with rolled steel sections. At the time of erection it was the longest lift span in existence (see References #2 & #3). Ash-Howard-Needles & Tammen designed another similar steel plate deck lift span bridge for the Port Authority of New York, New York in the 1930's. So this bare steel plate riveted to steel beams lasted 64 years without a wearing surface used on Orthotropic bridges [see figure # 1]. The average life for either concrete decks or open steel grating is about 30 years.



BURLINGTON - BRISTOL BRIDGE, NJ -PA (1931)
Riveted Steel Deck after 64 years of use prior to removal
In 1995 Photo courtesy and by Sasha J Harding PE of
Burlington County Bridge Commission
[Figure 1]



EFFECTIVE AREA FOR VARIOUS TYPES OF ORTHOTROPIC RIBS

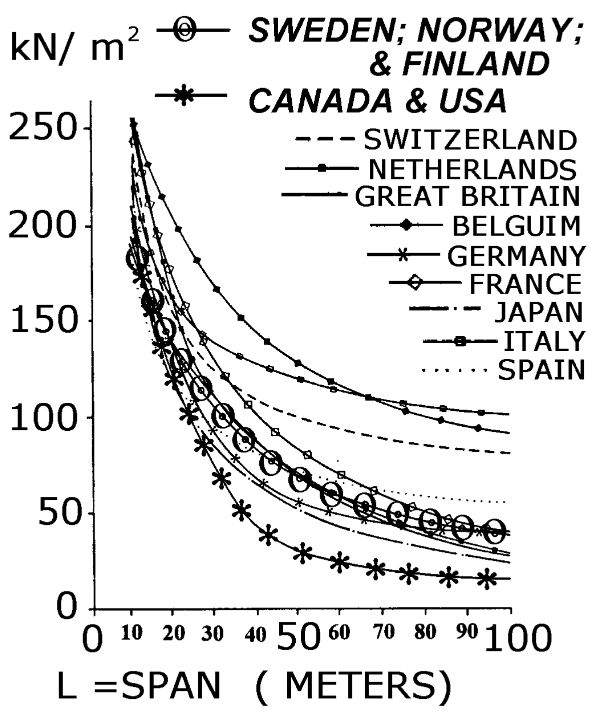
Adapted from Ballio, G.; Mazzolani, F. M. 1983. "*Theory and Design of Steel Design Structures*" Chapman & Hall Ltd. , New York 632 pp. [Figure # 2]

In 1938, the AISC began publishing research findings of this system, which is called the "battledeck floor," because it had the strength of a battleship. Many of the ideas of stiffening steel plates had been in use by the ship building industry for decades. The James F Lincoln Arc Welding Foundation published the idea of an all welded together system steel bridge system (see Reference 8). Germany began to use steel deck bridges as grade separation bridges for their "Autobahn" in 1934. After the war, the German Company "MAN" developed better analytical methods to analyze this "orthotropic" system in the 1950's. The AISC funded and published In 1963, the pioneering work "Design Manual for Orthotropic Steel Plate Deck Bridges," authored by Roman Wolchuk of the USA (see Reference 9). Mr. Wolchuk traveled to Germany to meet with Prof. W. Pelikan to discuss publishing these equations by AISC. The AASHO code was different than the German code, so engineering calculations were needed for the AISC Manual.

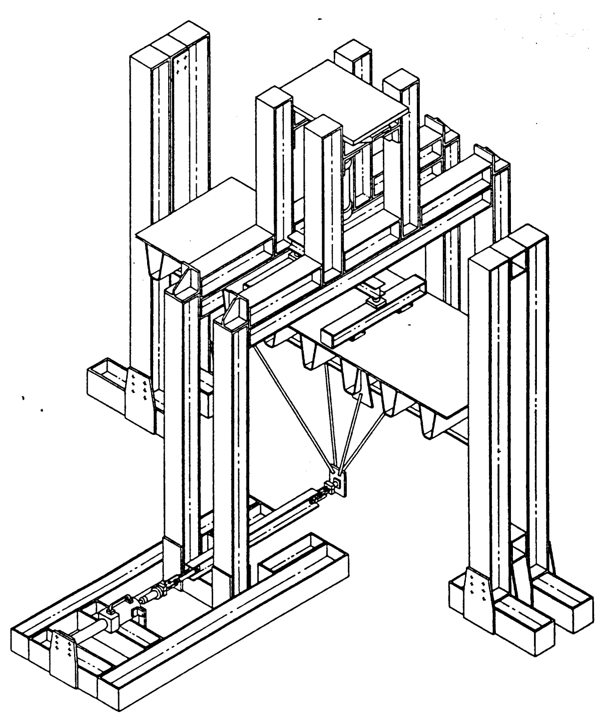
The James F Lincoln Arc Welding Foundation has promoted the use of welded orthotropic bridges with their numerous publications and design contests. Canadian Engineer, M. S. Troitsky authored "Orthotropic Bridges" in 1967, with minor revisions in 1985(see Reference 10). AISC granted permission to reprint copyrighted design aids from the 1963 manual by R. Wolchuk to encourage the construction of all-steel orthotropic bridges. In 1967, Bethlehem Steel Company of the USA published a design aid of tables based on using ten trapezoidal rib shapes, which is the most material efficient of all stiffeners. The tables [based on

English units] were developed using an IBM-360 computer and distributed free of charge. The typical engineer using a slide rule could use these complete plans for a bridge. Most North American Orthotropic bridges designed after used steel deck rib geometry described in these tables. The design engineer was able to use a slide rule or computer to complete the design. These manuals and design tables were successful because they were essential tools needed by the bridge engineers. These documents were distributed worldwide and it is difficult to measure their impact. English is currently the primary technical language used throughout the world today. Since 1967 then there has been an evolution of the AASHTO code, but some excerpts of this aid that still comply with current AASHTO code minimum plate thickness requirements are reproduced in Reference 1. A few of the early Orthotropic test bridges were not too durable because of thinner steel components. There has been over publicizing of repairs as part of marketing either repair services or manufactured products used in repairs. Thus more recent AASHTO code versions have minimum thickness of various components to achieve more durable.

Today Bridges with Orthotropic steel decks in North America are very rare, primarily due lack of interest. There are less than one hundred bridges in three countries, because realistic code with related design aids are not available from AASHTO or AWS [reference # 11]. Roadblocks have occurred mainly due being assigned a low priority due Orthotropic bridge technology to lack of interest. In Europe there are over 1,000 Orthotropic steel deck bridges of all types. Europe has connected many countries separated by water either with long span bridges and or tunnels or tubes. An integrated freeway system throughout Europe is needed for economic competitiveness. A similar freeway building program is occurring in Asia. USA based consulting engineers, educators and suppliers have been involved and earning income from other countries. A few code enhanced AASHTO details been added because the Federal Highway Administration (FHWA) is advocating longer life for bridges in the USA. Since the 1950's, there has been a continuing evolution of Orthotropic steel deck bridge AASHTO provisions for minimum deck plate thickness and rib geometry. Most [more than 90%] of Orthotropic bridges are functioning in a successful and normal life span compared to other bridge systems [reference # 12]. So there are and new issues or solutions for Orthotropic bridges.



VARIOUS NATIONAL BRIDGE LOADINGS for 4-Lane Bridges (courtesy OECD), Chatterjee, S. , "The Design of Modern Steel Bridges", BSP Professional Books, Oxford UK 1991 pp. 185 reference # 12 [FIGURE # 3]



DELFT, NETHERLANDS Kolstein, M. H., and J. Warendier, www.orthotropic-bridge.org
See reference # 13 [FIGURE # 4]

Another purpose of this of paper is draw to attention of the under utilization of the most efficient in terms of achieving the "lowest total gross weight of the structure". Around the world Orthotropic bridges have been used for long span suspension; cable stayed, arch and box girder bridges and floating bridges. For a movable bridge spans, a lower mass moving means less energy to move it. The lower mass movable span results in smaller lifting cables, smaller trunnions, smaller motors, smaller towers etc. In Europe all new movable spans are almost 100% Orthotropic steel decks. Lower mass also means lower seismic forces on the structure during an earthquake. The Japanese have the largest amount in a high seismic region. Countries with fewer resources to spend on infrastructure are building Orthotropic steel decks, because they are economically logical in all disadvantaged communities.

However due to the fact that there are less than about 100 Orthotropic bridges in North America the bridge engineering community has not made code research a high priority. In Europe more than 1000 Orthotropic bridges have been built. Many major crossing have been erected. Politically Europe has been trying minimize trading barriers on their continent with the "Euro". A very detailed "Eurocode" is underway with a very large portion discussing in much more codified details for Orthotropic fabrication. Comparing designs between countries is more complicated than just translating the languages (also more difficult because engineering slang or jargon varies with each country) (see Figure 3). Complicating the issue is that every country has a different vehicle live loading. An interesting graphic comparison between code minimum design vehicle loads of Germany, Belgium, Sweden, Norway, Finland, Netherlands, Italy, Spain, USA (HS 20), Switzerland, United Kingdom, France and Japan is shown on pages 62 & 63 (see Reference 12). The author goes into more detail comparing the United Kingdom BS = British Standard code vs. USA (HS 20). These complexities make it more difficult to compare design and maintenance issues. So the Eurocode will take decades because of these issues. However they take this issue seriously and there are extensive details on fabrication tolerances for all components including rib fabrication. Bridges in Europe may fabricated in several countries so market place unification is occurring..

Japanese code is called *Specific*ation for Highway Bridges. However some Japanese code-books are available in English versions. Several American Orthotropic bridges have been fabricated in Japan, which allows them to study American designs in detail, plus discuss concepts during the shop drawing process.

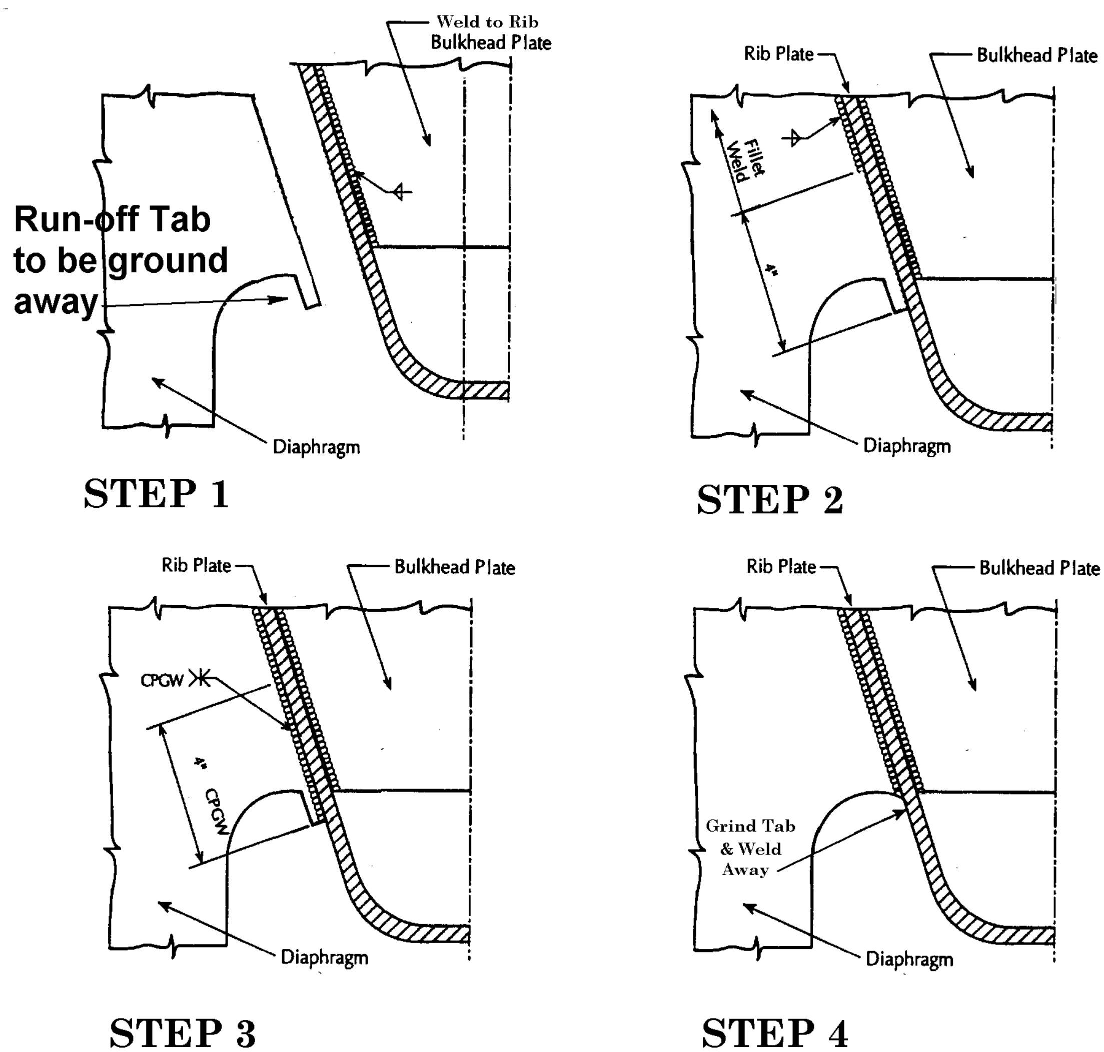
Thus code-writing changes for Orthotropic issues in AASHTO & AWS are "somewhat" behind in North America primarily due to lack of interest. The Euro-code has extensive sections on fabrication process and tolerances. Some US Orthotropic designers are keeping up with these draft documents, to use a references for their projects. It was hoped that a meeting held in August 2004, as part of www.orthotropic-bridge.org would help synergist a team of champions from designers, fabricators, contractors, wearing surface manufacturers and other parties. The March April 2005 Issue of Public Roads www.tfhrc.gov has request from top FHWA management and others who believe in this technology and need to properly codify it.

Status of Orthotropic Fatigue Details for AASHTO & AWS 1.5

Dr. John Fisher's fatigue research for Orthotropic steel deck has shown that changes in welding of components will make them last much longer. At recent conference speeches including www.orthotropic-bridge.org he has stated that a 100-year life Orthotropic steel deck are possible with appropriate details [Ref #13].

Japanese research has also been extensive since they have the world's longest span suspension bridge; cable-stayed bridge and floating bridge. All three bridges use Orthotropic steel decks with wearing surfaces. Also in "Bridges and Roads" October 1998 and November 1999 of Orthotropic Steel Decks written by Prof. Shigeyuki Matsui of Osaka University; K. Ohta and Kazuhiro Nishikawa Head of the Bridge Division of PWRI, 1-Asahi, Tsukuba-shi, 305 Japan discuss research issues for their bridges. One topic is a summary of fatigue crack locations in their bridges. Japanese engineers presented at www.orthotropic-bridge.org, a summary of the actual amount of cracks occurring in the steel deck Orthotropic bridges, and it's a very small portion of their bridges.

In the USA, Dr Fisher's studies on Orthotropic steel decks have created a next generation system adopted by AASHTO code(see References 14, to 17). An internal baffle plate positioned inside the trapezoidal rib makes the deck have a longer fatigue cycle life. This detail has been used on decks for the newest suspension bridges in the USA: Williamsburg Bridge [1999], of New York City; Alfred Zampa Memorial Bridge [2003], across Carquinez Straits, CA; Triborough Bridge [1999], of New York City; Bronx-Whitestone Bridge [2007], of New York City; Tacoma Narrows "3" Bridge, Washington [2006], of and Skyway Span of the SFOBB [under fabrication by USI Vancouver Washington] San Francisco Bay California. [at the time of writing the Governor + Legislature has directed Caltrans to advertise again for bidding the SAS Portion of SFOBB]. Practicing design engineers have combined research findings and testing into new code design formulas and repair techniques. The durability of their designs is also very important to bridge design engineers Researchers plus the owners of Orthotropic steel deck bridges have been monitoring their performance. Research equipment for testing of the entire steel Orthotropic deck system with wearing surface is available in all major universities and is described in the proceedings of www.orthotropic-bridge.org (see Figure # 5).



[FIGURE # 5] Dr. Fisher's welding of Rib Detail and "Cut-out"

Standardize Six Orthotropic Rib Details

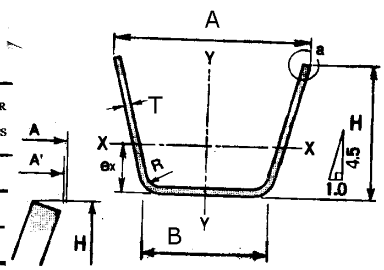
The Japanese have over 250 Orthotropic bridges The four Japanese trapezoidal ribs with section properties (see table #2) at the are essentially identical metric equivalents to Bethlehem Steel Company ribs and shown in tables in Reference 14. This is the best table showing how "total freedom" of 44 rib shapes intimidates the first time designer of Orthotropic bridge. This table #2, also shows [as of 1999] with a bar chart the most popular rib spacings and floor beam spacing. Most bridges built around the world have totally unique rib shapes. Then adding the spacing plus spans quickly adds a lot of variables. Next every researcher has a cornucopia of cutouts competing with Dr. Fisher's code approved detail. All these variables really intimidates the first time user. Many belittle the "cook-book" approach however it reduces the "fear-factor" in using a system. Japan also uses open ribs in their bridges, primarily in the sidewalk portion.

RIBS A × H × T	DIMENSIONS (mm) t	A	A'	B	H	R	AREA (cm²)	MASS (kg/m)	CENTROID e_y (cm)	INERTIA I_x (cm⁴)
320 × 240 × 6.0	6	320	319.4	213.3	240	40	40.26	31.6	8.86	2460
320 × 260 × 6.0	6	320	319.4	204.4	260	40	42.19	33.1	9.91	3011
324.1 × 242 × 8.0	8	324.1	323.3	216.5	242	40	53.90	42.3	8.99	3315
324.1 × 262 × 8.0	8	324.1	323.3	207.7	262	40	56.47	44.3	10.03	4055

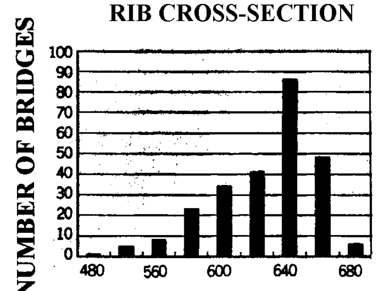
TRAPEZOIDAL RIBS USED AS OF 1990

RIB TYPE	DIMENSION (mm) WIDTH x DEPTH x THICK.	NUMBER OF BRIDGES	RIB TYPE	DIMENSION (mm) WIDTH x DEPTH x THICK.	NUMBER OF BRIDGES
1	280 × 220 × 8	1	23	320 × 260 × 8	5
2	300 × 200 × 6	2	24	320 × 270 × 6	1
3	300 × 220 × 6	32	25	320 × 300 × 8	1
4	300 × 220 × 8	7	26	324.1 × 242 × 8	7
5	300 × 224.6 × 7.9	1	27	324.1 × 242 × 15	1
6	300 × 240 × 6	1	28	324.1 × 262 × 8	1
7	300 × 250 × 8	2	29	325 × 250 × 8	1
8	300 × 270 × 6	1	30	327.2 × 274 × 8	1
9	300 × 280 × 8	1	31	330 × 250 × 8	2
10	300 × 280 × 12	1	32	330 × 250 × 14	1
11	304.1 × 222 × 8	1	33	330 × 263 × 6	1
12	310 × 250 × 6	1	34	330 × 280 × 8	1
13	310 × 250 × 8	1	35	330 × 288 × 8	1
14	318 × 258 × 8	1	36	330 × 288 × 10	1
15	320 × 200 × 6	7	37	340 × 200 × 9	1
16	320 × 200 × 8	1	38	340 × 250 × 8	1
17	320 × 230 × 8	1	39	340 × 280 × 8	1
18	320 × 240 × 6	96	40	370 × 250 × 8	1
19	320 × 240 × 8	15	41*	320 × 240 × 6	8
20	320 × 250 × 6	3	42*	320 × 240 × 8	1
21	320 × 250 × 8	3	43*	320 × 240 × 6	2
22	320 × 260 × 6	37	44*	320 × 260 × 8	1

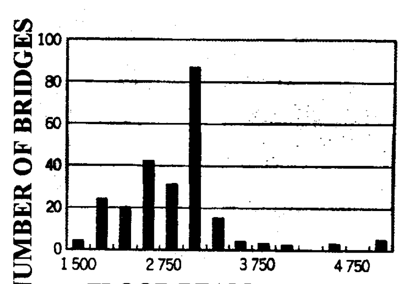
RIB CORNER RADIUS $R = 40$mm



RIB CROSS-SECTION



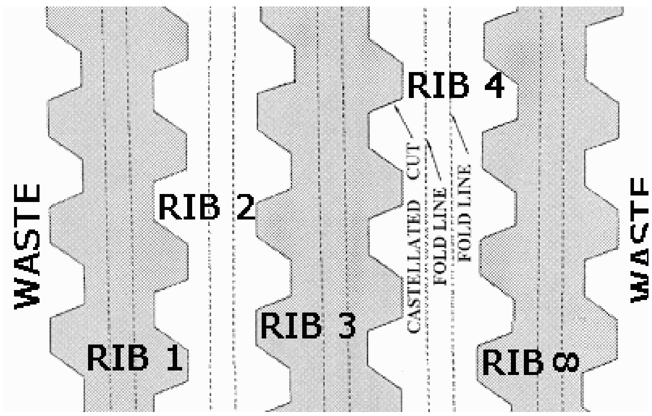
TRANSVERSE SPACING OF RIBS (mm)



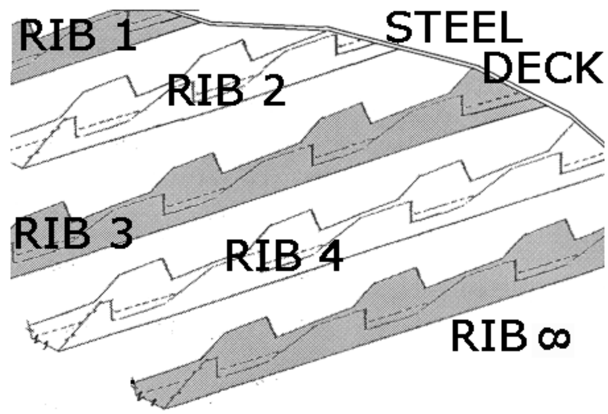
FLOOR BEAM SPACING
in millameters

JAPANESE RIBS – 44 TYPES - SURVEY REPRINTED AND TRANSLATED FROM *ORTHOTROPIC STEEL DECKS* APPE. IN "BRIDGES AND ROADS" OCT 1998 AND NOV 1999. BY MATSUI S.; OHTA K. AND NISHIKAWA K. OF PWRI PUBLIC WORKS RESEARCH INSTITUTE [table # 2]

However Russian engineers have exclusively only used the open flat plate rib. British Steel mills roll a bulb flat, that has extra steel lip. The US Navy created a special rib for floating steel bridges fabricated for Vietnam [References # 19, 20, 21 & 22]. The question is whether these bi-serrated ribs really practical. The main draw back is that they are not suitable for automatic welding machines. But every surface can be inspected for weld quality, unlike a normal trapezoidal rib. When AASHTO started the standard girders, they selected six types. My initial proposal is five ribs, based on well-known Orthotropic bridges that have been performing well. I have included, as rib #6, the SFOBB's new rib shape due to its extensive research and team of experts developing it. The key organizations and or industries need to meet to create industry standard systems for Orthotropic bridge decks. AASHTO has standard precast prestressed concrete bridge girders that designers may utilize for basic smaller bridges. This encourages the first type use of this system.



US NAVY PONTOON PROTOTYPE - CASTELLATED CUTTING PATERN FOR THE BISERRATED RIBS - DASHED LINES INDICATE FOLDING PATTERN [plan view] - Drawing by Author [Figure # 6]

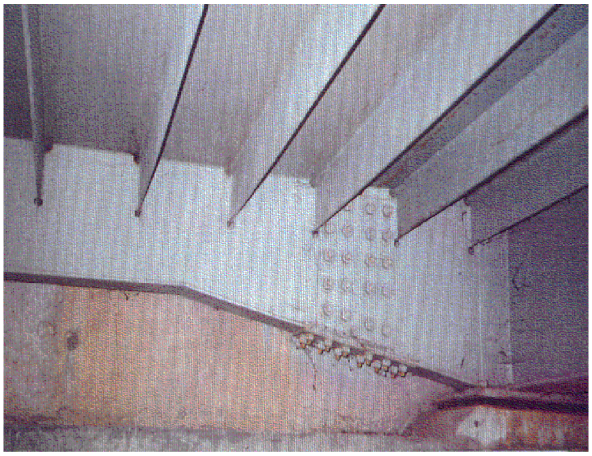


US NAVY PONTOON PROTOTYPE - BISERRATED RIBS -- [isometric view] Shaded to coordinate with previous figure Drawing by Author [Figure # 7]

Several states have their own unique standard precast prestressed concrete bridge girders. This is basis for my choices and background is as follows. The State of Oregon designed a "test bridge", the "Battle Creek", that is still in service [50% open & 50% closed ribs] without any maintenance problems. Arguably the most success Orthotropic bridge in North America, the San Mateo Hayward has its original wearing surface in use for 38-years. It has open plate ribs and a thick ¾-inch. This bridge's deck system is a great starting point because it is very successful. Orthotropic decks will not be used for small and intermediate sized bridges if job specific research and other testing studies are required. The BART = Bay Area Rapid Transit system is a simple span weathering bridge for single track subway train that utilized ten shop built deck panels that field connect to two beams. The owner, BART is happy with it and system was used on four of their bridges. Other successful bridges are the Queensway & Concordia still in service. The "U" shape rib is different solution than flat or trapezoidal. When a span reaches around 500-ft it is when Orthotropic becomes cost competitive, even in non-seismic areas.

	Type	**Bridge Name**	**Main Span**	**City, State**	**Ref.**
1	Open	Oregon Battle Creek Test [1967]	30-FT	Salem Oregon, USA	18
2	Open	San Mateo Hayward [1967]	750-FT	San Francisco, CA, USA	13
3	Trapezoidal	BART Grade Separations[1978]	110-FT	Berkeley, CA, USA	1
4	Trapezoidal	Queensway Bridge [1971]	500-FT	Long Beach, CA, USA	23
5	U Shaped	Concordia [1967]	525-FT	Montreal, Quebec, Canada	10
6	U Shaped	SFOBB[2005 & 2012]	1400-FT	San Francisco, CA, USA	24

table # 3 Proposal of six rib systems to be industry standards in North America.



PROTOTYPE BRIDGE --THE BATTLE CREEK BRIDGE ON COMMERCIAL STREET IN SALEM, OR The City of Salem owns and maintains the structure now, but it was designed by ODOT. This is a three span bridge with a main span of only 30ft. It is 77ft. long and 46.4 ft. wide. Half of the deck is an open rib design and the other half is a closed rib design. Photo courtesy of Casey Faucett City of Salem. [Figure # 8]

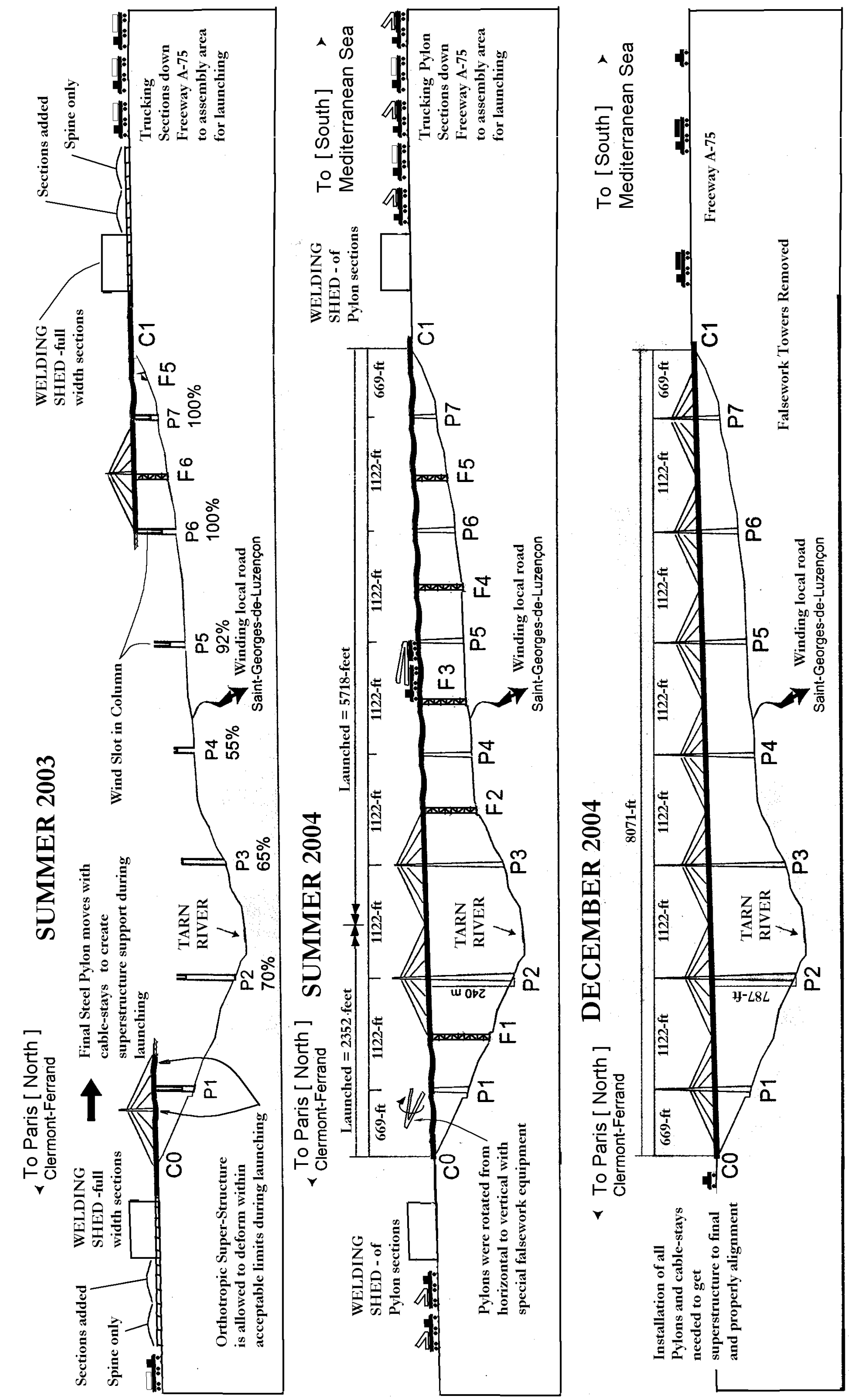
CONCORDIA, ORTHOTROPIC, BRIDGE Montreal Canada. Features "U" Shaped ribs preferred by Canada Engineers, Bridge was completed in 1964. Photo by author (June 2005) Reference # 10 [FIGURE # 9]

Building Mega & Signature Bridges

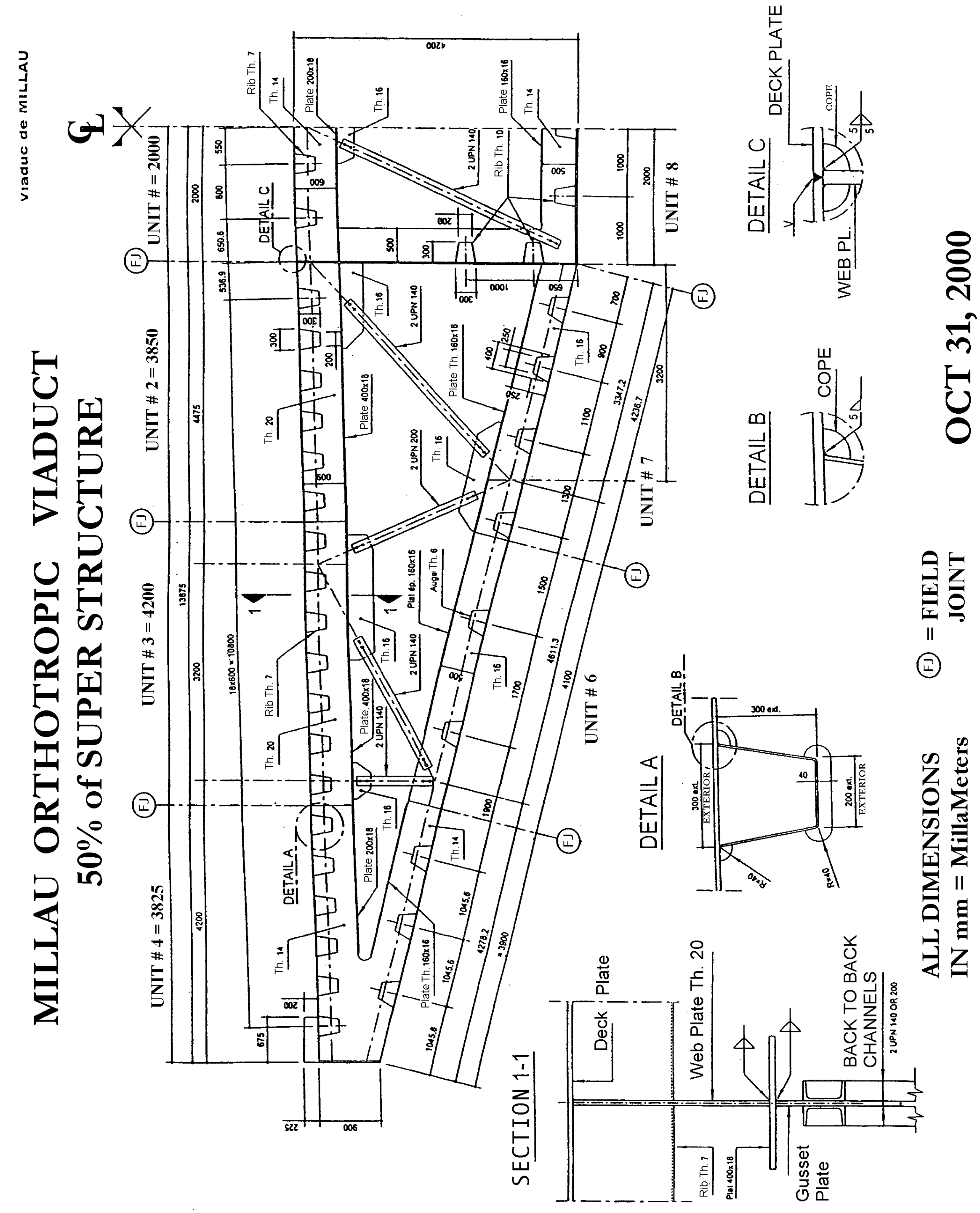
The next generation of Orthotropic steel deck bridges are world record class bridges in every category of bridge. [based on Jackson Durkee table by NSBA & case history papers by Mangus]

Year	Type	Name	Main Span	Country, City	Reference
2015	Suspension	Messina	10,000-ft	Italy – Sicily, Messina	Ref # 14, 43
1998	Suspension	Akashi-Kaikyo	6,538-ft	Japan	Ref # 14, 43
2007	Cable-Stayed	Stone Cutters	3,343-ft	China, Hong Kong	Ref # 14, 43
1999	Cable-Stayed	Tatara	2,883-ft	Japan	Ref # 14, 43
2004	Cable-Stayed	Millau Viaduct	1,122-ft	France, Millau	Ref # 25,26
2004	Steel Arch	Orleans Bridge	500–ft	France, Orleans	Santiago Calatrava
2004	Steel Arch	Dagu Bridge	349–ft	Tianjin, China	WSBS 2005
1976	Steel Arch	Fremont	1,000-ft	USA, Portland, OR	Ref # 37
1961	Slant-leg	Luxembourg	815-ft	Luxembourg	Ref # 10
1956	Plate girder	Save River	856-ft	Yugoslavia	Ref # 9, 10
1974	Box Girder	Cost e Silva	980–ft	Brazil, Rio de Janeiro	Ref # 10, 43
1997	Curved Box	Maritime Off-Ramp	195-ft	Oakland, CA	Ref # 1, 14, 28
1994	Floating	Nordhordland	370-ft	Norway,	Ref # 30, 31
2002	Floating Swing	Yumeshima-Maishima	1,000-ft	Japan, Osaka	Ref # 2, 38, 39, 40
2002	Double Swing	El Ferdan	550-ft	Egypt	Ref # 2, 36
1999	Double Bascule	Gateway to Europe	318-ft	Spain, Cadiz	Ref # 32
1999	Single Bascule	Erasmus	172-ft	Holland, Rotterdam	Ref # 33- 35, 41

Table # 4 Mega & Signature Orthotropic Steel Deck Bridges



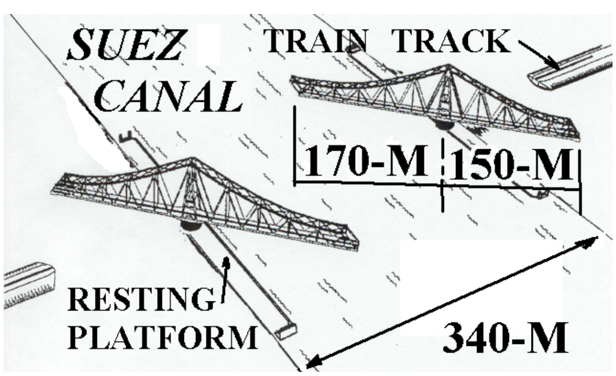
Millau Viaduct, France Worlds Largest Orthotropic Steel Deck Area [Figure # 10]



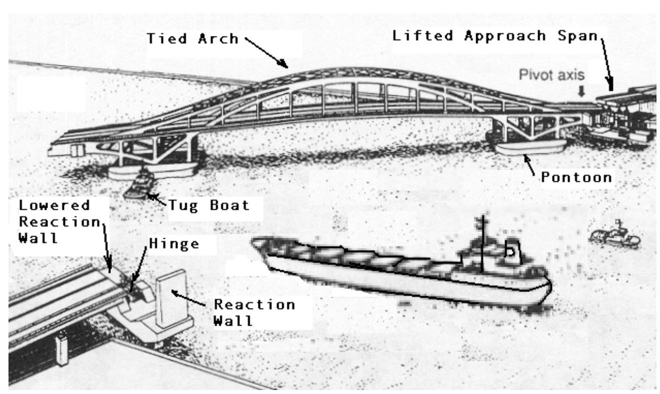
Millau Viaduct, France Worlds Largest Orthotropic Steel Deck Area [Figure # 11]

RANK	BRIDGE	SPAN - M	SITE	COUNTRY	YEAR	DECK
1.	Akashi-Kaikyo	1991	Kobe-Naruto	Japan	1998	Orthotropic
2.	Great Belt East	1624	Korsor	Denmark	1998	Orthotropic
3.	Runyang South	1490	Zhenjiang	China	2005	Orthotropic
4.	Humber	1410	Kingston-upon-Hull	United Kingdom	1981	Orthotropic
5.	Jiangyin	1385	Jiangsu	China	1999	Orthotropic
6.	Tsing Ma	1377	Hong Kong	China	1997	Orthotropic
7.	Verrazano-Narrows	1298	New York, NY	USA	1964	Concrete
8.	Golden Gate	1280	San Francisco, CA	USA	1937	Orthotropic
9.	Hoga Kusten	1210	Kamfors	Sweden	1997	Orthotropic
10.	Mackinac	1158	Mackinaw City, MI	USA	1957	Concrete
11.	Minami Bisan-seto	1100	Kojima-Sakaide	Japan	1988	Orthotropic
12.	Fatih Sultan Mehmet	1090	Istanbul	Turkey	1988	Orthotropic
13.	Bosporus	1074	Istanbul	Turkey	1973	Orthotropic
14.	George Washington	1067	New York, NY	USA	1931	Orthotropic
15.	Kurushima-3	1030	Onomichi-Imabari	Japan	1999	Orthotropic
16.	Kurushima-2	1020	Onomichi-Imabari	Japan	1999	Orthotropic
17.	Ponte 25 deAbril	1013	Lisbon	Portugal	1966	Concrete
18.	Forth Road	1006	Edinburgh	United Kingdom	1964	Orthotropic
19.	Kita Bisan-seto	990	Kojima-Sakaide	Japan	1988	Orthotropic
20.	Severn	998	Bristol	United Kingdom	1966	Orthotropic
	Tacoma Narrows-3	853	Tacoma, WA	USA	2007	Orthotropic
	Alfred Zampa	728	Crockett, CA	USA	2003	Orthotropic

Table # 5 List of suspension bridges with longest main span and deck type



EL FERDAN double swing bridge Schematic courtesy of Tomlinson, G K ; Weyer, U.; Maertens, L.;Binder B. "El Ferdan Bridge – design" Bridge Engineering Conference, March 2000 - Sharm El Sheikh, Sinai, Egypt [Figure # 12]



Yumeshima-Maishima Floating Swing Bridge, Osaka , Japan 1000-ft span [Figure # 13]

Need for Current and complete Durability Study

ASCE published a durability study in 1991 in a fairly obscure journal where the Professors asked ten questions to their bridge owners about only 15 bridges in USA & Canada (see Reference # 42). This paper has questions and tables. The vast majority of Orthotropic bridges built in the 1960's are still in service and performing in an acceptable manner, even without Dr. Fishers' Orthotropic steel rib fatigue detail (see References # 13-17). Some experts are concerned about the excessive use of closed trapezoidal ribs.

Birds and other creatures have nested in the handholes for bolt splice for trapezoidal ribs used bridges built in the 1960's. Expanding inert foam has been placed inside the cells or trapezoidal ribs in California. This material is believed to prevent internal corrosion; nesting of creatures; and possibly help in delaying "cool-down" of slippery decks. Everything constructed is really a test structure. Engineers biannually monitor the real world performance of bridges and create "bridge maintenance reports". The FHWA is proposing the design of a bridge now be 100 years.

2. Fat Deck Proposal

During the ASCE –NSBA event www.orthotropic-bridge.org held in August 2004, there was an advanced seminar by Wolchuk & Baker held on Aug 23 & 24. Figure #7 is from their Seminar notes and shows relative fabrication costs [Ref # 43]. The deck steel is the least expensive piece to fabricate. Also an introductory course was taught on Aug 23 & 24, by Mangus, Williams, Seim, Constantino and Angeloff. During these discussions, plus a meeting held to discuss new code needs, and Saturday field tour of Orthotropic bridges of San Francisco Bay, minimum deck thickness was debated and compared between bridges. I feel that a fat deck is needed for the "100-year" life bridge based on what has happened in California and other locations. Two small USA Orthotropic "Test bridges" have not been durable because the primary goal was to reduce steel weight.

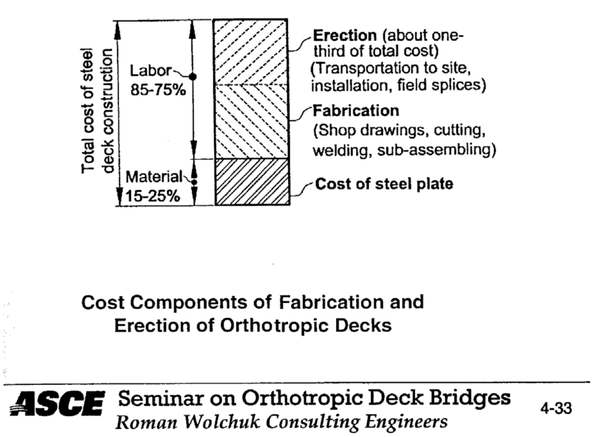
Caltrans Project EA 11-108254 San Diego-Coronado Bay Bridge New Deck Overlay Advertised on 9/28/92 Bid opening date 12/17/92 Approved 12/17/92 Accepted 4/12/93 Contract amount $1,993,815 Structures amount $1,148,460Work area from Pier 18 - Pier 21 approximately 1880 ft., Quantities were as follows:

Remove epoxy asphalt concrete surfacing	12,952	Square yards
Epoxy Asphalt Concrete Aggregate	1,330	ton
Epoxy Asphalt Concrete Surfacing	25,900	Square yards
Epoxy Asphalt bond coat and binder	187,280	lbs.
Apply epoxy bond coat	25,900	Square yards
Blast clean and paint undercoat	lump sum	

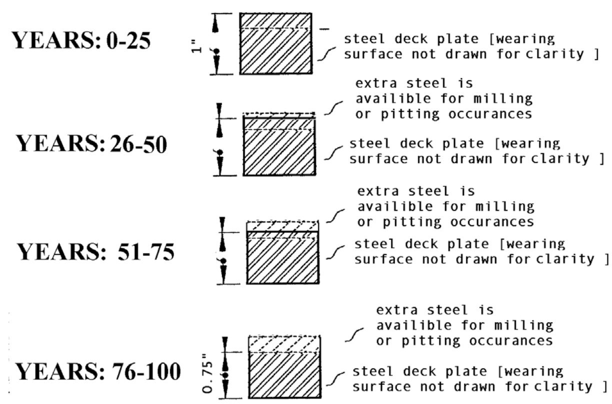
Reference # 44 Bavirisetty, R., San Diego Coronado Bay Bridge Overlay Project (Orthotropic Deck), Structure Notes, California Department of Transportation, Sacramento, CA, 1993. "*The decision to replace the existing aged and failing deck for the San Diego Coronado Bridge overlay was made in 1991 [bridge opened to traffic in 1969]. EAC = Epoxy Asphalt Concrete was the best candidate for the new overlay and seal because of its flexibility, durability, and past performance. Overlay replacement work began in January 1993. Damage due to corrosion was detected in portions of the deck plate when the existing overlay material was removed. It was difficult to determine the amount of section loss during the initial inspection, but it was estimated that the maximum pit depths were 1/8 inch (design plate thickness = 3/8 inch). Deck plate samples were removed from the bridge deck and submitted to an independent laboratory for determination of section losses, which turned out to be 10%, by weight. The Orthotropic deck was analyzed for local effects from wheel loads with two and three dimensional finite element modeling using SAP90 to determine adequacy. The* *stress levels in all structural elements were within the allowable limits when analyzed by the finite element method. The placement of the overlay was completed in March 1993*".

Real world lessons learned from actual bridges are put forth to initiate a more detailed parametric study and or research test. Thus we start we ¾ deck plate same as San Mateo Hayward bridge, since it is still working with original wearing surface after 38 years. We add ¼ inch extra steel to accommodate accidental milling cuts while removing wearing surface of the steel deck and or corrosion pitting due cracks in wearing surface. Real world delays from realizing need for resurfacing to actually starting construction may allow pitting to occur. Basis for proposal and figure # 15 are three re-surfacings occur at year 25; re-surfacing occurs at year 50; and thus another re-surfacing occurs at year 75. Based on California Bridges at 5/8 deck plate will result in 25 years EAC wearing surface life San Diego Coronado 1969-1993. Proposal based on California Bridges at ¾ deck plate will result in 38+ years EAC wearing surface life San Mateo Hayward Bridge Oct 1967 to Oct 2005. See wearing surface references # 45 – 50.

One wearing surface issue unique to bascule or drawbridges is the ability to take vertical shear loadings while the movable span is the raised position. Two reports are listed (see References # 2 & 46). Mechanical tabs to assist in this vertical loading to the wearing surface are used to keep wearing surfaced attached. This solution on the Canadian bridge has performed satisfactorily (see Reference # 18).



RELATIVE COST CHART FOR FABRICATING ORTHOTROPIC
August 2004 Seminar Sacramento
[Figure # 14]



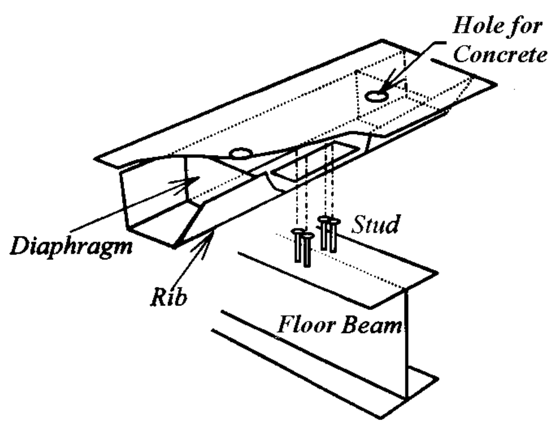
FAT ORTHOTROPIC DECK vs. TIME
. [Figure # 15]

Conferences [WWW.ORTHOTROPIC-BRIDGE.ORG](http://www.orthotropic-bridge.org)

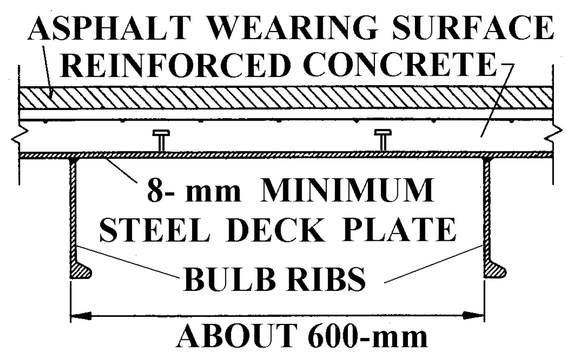
ASCE –NSBA will hold the next www.orthotropic-bridge.org in August 2008 in Sacramento**.** The first conference was held in August 2004 in Sacramento and 800+ pages of proceedings are available on CD-ROM for purchase from the ASCE Capital Branch of Sacramento, CA**.** ASCE goal was education Advanced Seminar for experienced bridge engineers; Introductory Course for college students & younger engineers; the 3-day conference; Tour of Orthotropic bridges hosted by their owners Golden Gate Bridge District; Alameda County; BART and others. All of these owners are satisfied with their Orthotropic bridges, and BART distributed the complete set of bridge plans. The National Student Champions for the ASCE-NSBA student steel bridge participated in the 2004 Class plus displayed the University of California, Davis Steel Bridge in the vendor. www.orthotropic-bridge.org funds were used to assist this team and the CSUS team located near Sacramento. The goal is to transfer this technology to the next generation and interest in Orthotropic decks.

Conclusions

It took almost 80 years from the idea of the "Battle-Deck" bridge system to Dr. Fisher's details. Although the evolution is not as dramatic as the evolution of flight from Wright Brothers to Jet Airplanes, dramatic changes have occurred. "Fabrication A float" Orthotropic steel Design Build project for the US Navy is California's most recent Orthotropic Structure Built for the US Navy. [Modern Steel Construction Scott melnick@modernsteel.com]. New ideas for welding bridges and naval ships together are still occurring. Researchers in Europe and Asia have been testing and inventing systems based on Orthotropic steel decks. Italian researchers are proposing a hybrid system that is shown in Figure 17. The trade-off of an increased dead weight is justified with the long-term knowledge of the actual useful life of composite reinforced concrete deck on steel superstructure. The Orthotropic deck allows rapid erection of the superstructure and the need for an additional deck forming system. Thicker wearing surfaces dissipate wheel loadings to a larger number of ribs. Therefore, bridges with thicker wearing surfaces have a longer fatigue life, but they weight more. The Italian studies are available in Reference ??. Also in "Bridges and Roads" Oct 1998 and Nov 1999 of Orthotropic Steel Decks written by Prof. Shigeyuki Matsui of Osaka University; K. Ohta and Kazuhiro Nishikawa Head of the Bridge Division of PWRI, 1-Asahi, Tsukuba-shi, 305 Japan discuss wearing surface issues for their bridges. One related topic discussed is a study of rapid cool down of steel deck bridges. A nice graph compares, the around the clock, rapid "cool-down" of a bridge deck above a river. The slippery surface on two California's smaller Orthotropic bridges has required the posting of yellow warning signs. Currently English is the primary technical language. New codes such as the Eurocode are being written in English, it makes much easier to keep current with changes in other countries. To maintain a current technology key representatives are needed to meet to generate appropriate guidelines to be incorporated and implemented by the various industries, agencies and organizations. One or two individuals can be the "cheerleader" to encourage these changes, but group consensus is needed for it to occur.



NIPPON STEEL SYSTEM, JAPAN
Reference # 52 [Figure # 16]



RIO VERDE BRIDGE, ITALY - courtesy of IABSE Caramelli, S.; Croce, P.; Salvatore W. "The Composite Steel-Concrete Orthotropic Plate Bridge" Bridge Engineering Conference, March2000 - Sharm El Sheikh, Sinai, Egypt
Reference # 54 [FIGURE # 17]

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