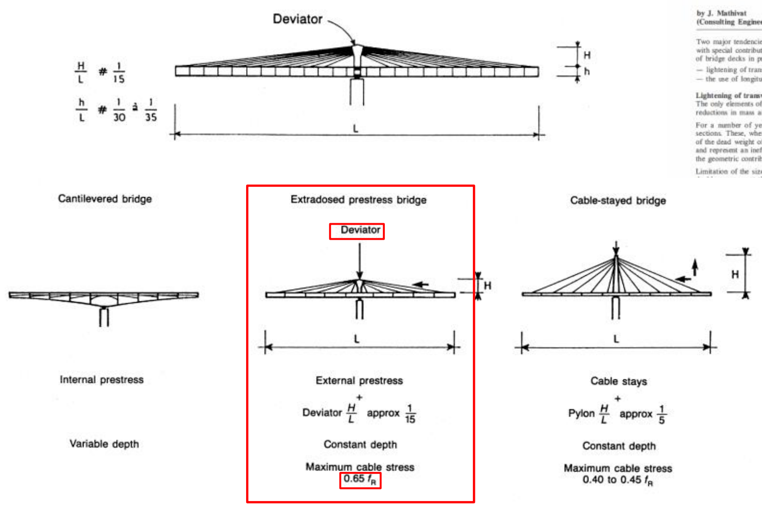
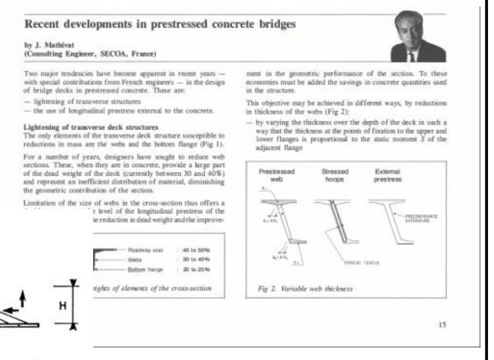

BIRTH, DEVELOPMENT AND FUTURE
OF
EXTRADOSED BRIDGES
AKIO KASUGA
SUMITOMO MITSUI CONSTRUCTION
JAPAN

Birth

Mathivat’s Paper (FIP Note,1988)





Recent developments in prestressed concrete bridges

by J. Mathivat
(Consulting Engineer, SECOA, France)

Two major tendencies have become apparent in recent years — with special contributions from French engineers — in the design of bridge decks in prestressed concrete. These are:
— lightening of transverse structures
— the use of longitudinal prestress external to the concrete.

Lightening of transverse deck structures
The only elements of the transverse deck structure susceptible to reductions in mass are the webs and the bottom flange (Fig 1).

For a number of years, designers have sought to reduce web sections. These, when they are in concrete, provide a large part of the dead weight of the deck (currently between 30 and 40%) and represent an inefficient distribution of material, diminishing the geometric contribution of the section.

Limitation of the size of webs in the cross-section thus offers a ... level of the longitudinal prestress of the ... reduction in dead weight and the improvement in the geometric performance of the section. To these economies must be added the savings in concrete quantities used in the structure.

This objective may be achieved in different ways, by reductions in thickness of the webs (Fig 2):
— by varying the thickness over the depth of the deck in such a way that the thickness at the points of fixation to the upper and lower flanges is proportional to the static moment S of the adjacent flange

Roadway slab	40 to 50%
Webs	30 to 40%
Bottom flange	20 to 25%

...eights of elements of the cross-section

Prestressed web — Stressed hoops — External prestress

Fig 2. Variable web thickness

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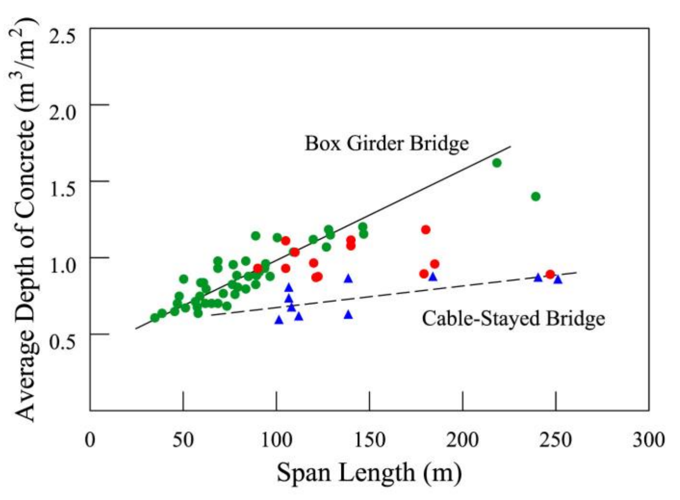
Span Length VS Average Depth of Concrete



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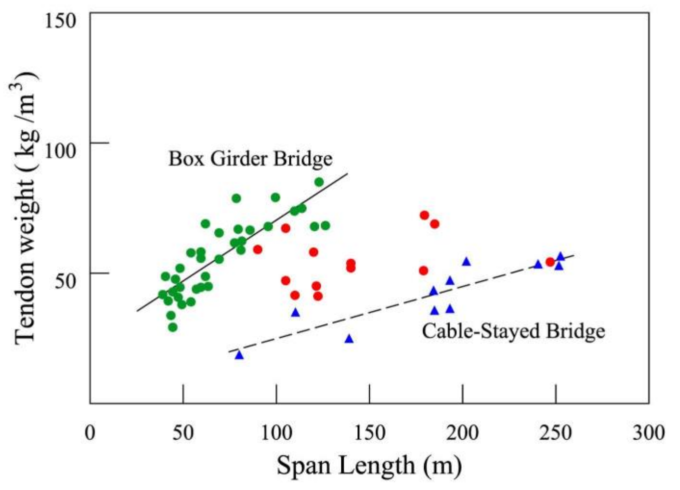
Span Length VS Tendon Weight



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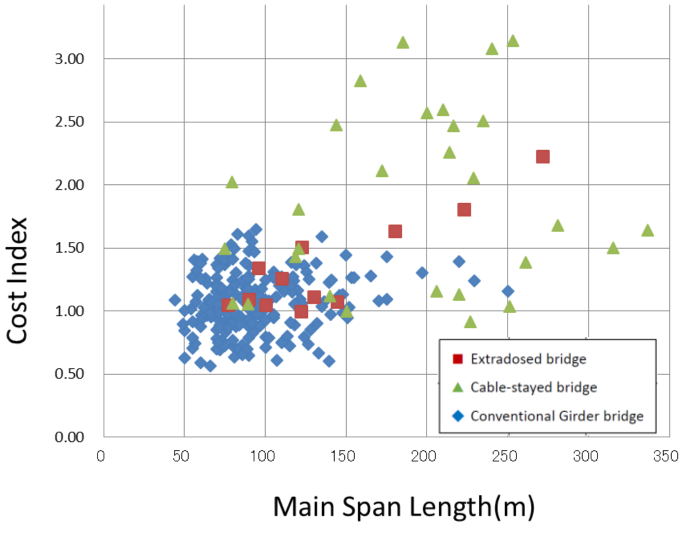
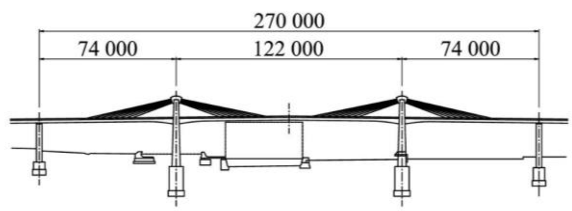
Cost Comparison

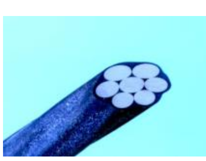


Odawara Blueway Bridge (1994)

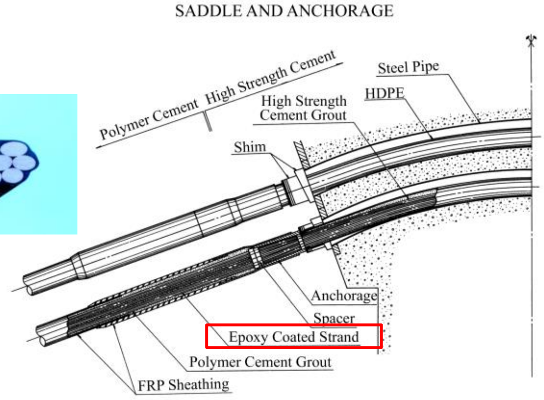


Development of Saddle & Extradosed Cable System

- ✓ No saddle system was available.
- ✓ New saddle system fixed at both ends was developed.
- ✓ Epoxy coated strand was used as extradosed cables.

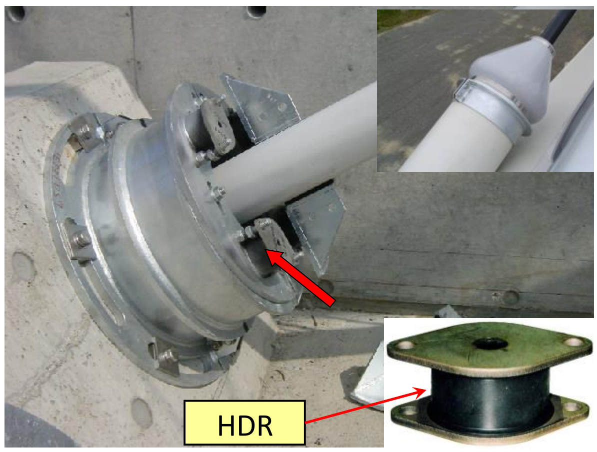


SADDLE AND ANCHORAGE

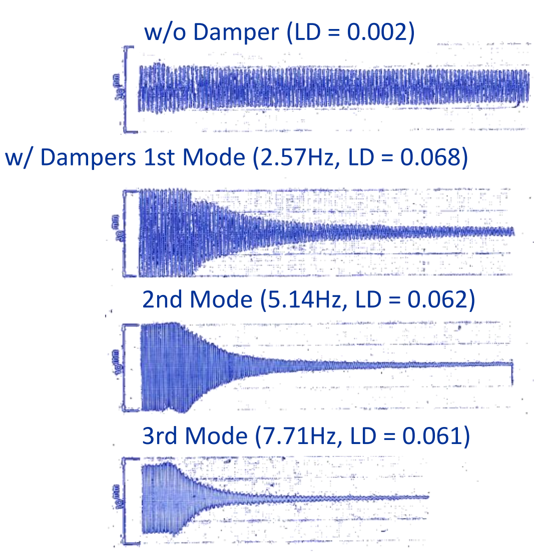


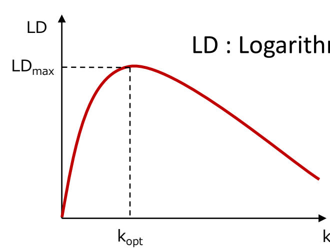
Development of High Damping Rubber Damper

- ✓ After Odawara, HDR damper was widely used all over the world.



Development of High Damping Rubber Damper

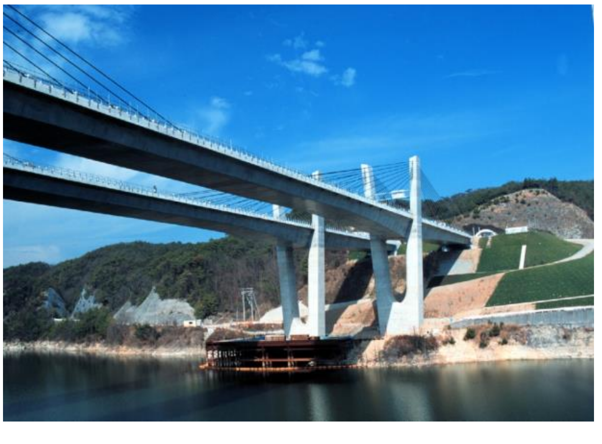


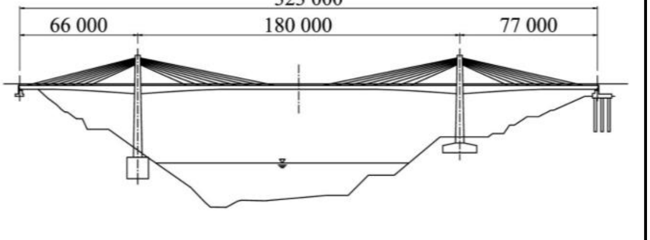


LD : Logarithmic Decrement

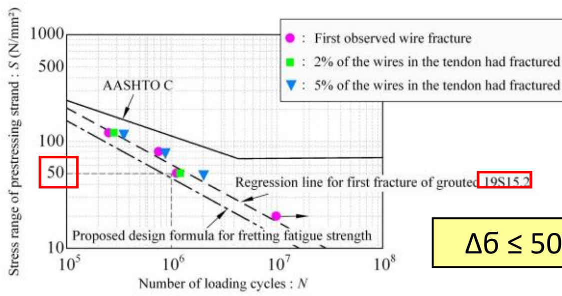
Development

Tsukuhara Bridge (1997)

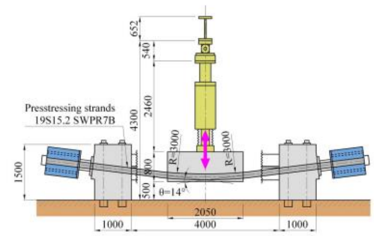




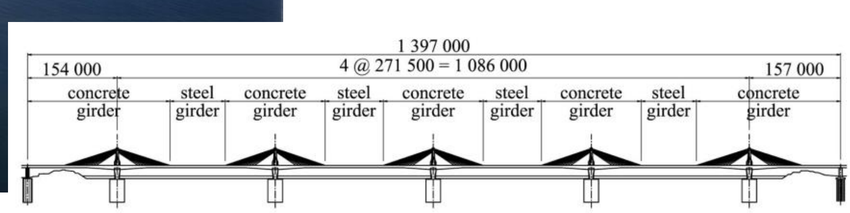
Fretting Fatigue Test of Saddle



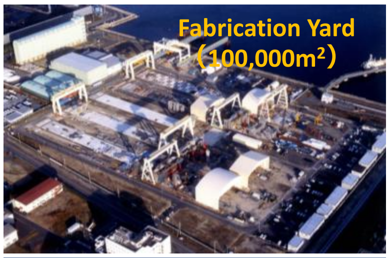
Δ6 ≤ 50N/mm^2



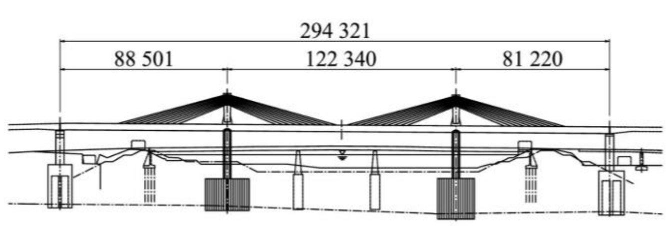
Ibigawa Bridge (2001)



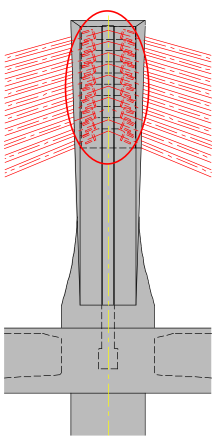
Construction of Ibigawa Bridge



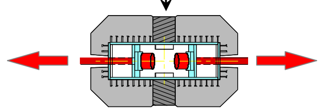
Shin-Meisei Bridge (2004)

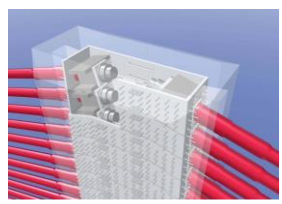


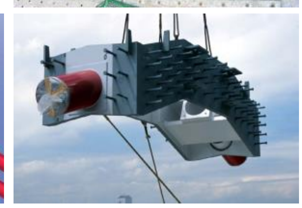
Development of Steel Box Anchorage for Pylon



Concrete after Completion

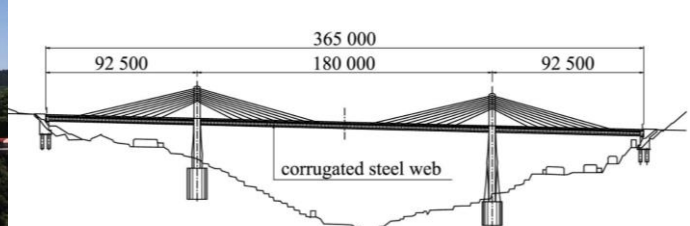






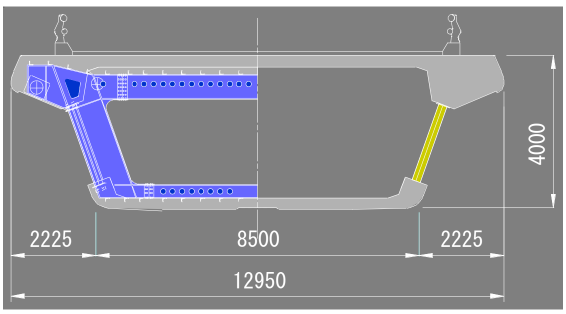
Horizontal Tension ：Steel
Vertical Compression：Steel & Concrete

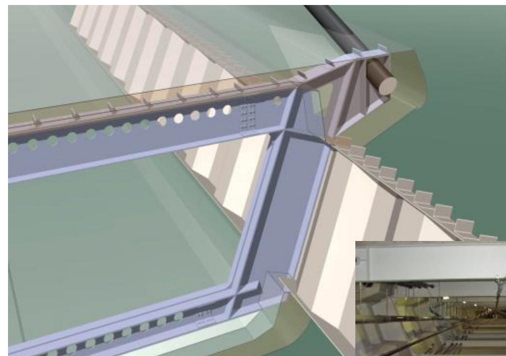
Himi Bridge (2004, Corrugated Steel Web)



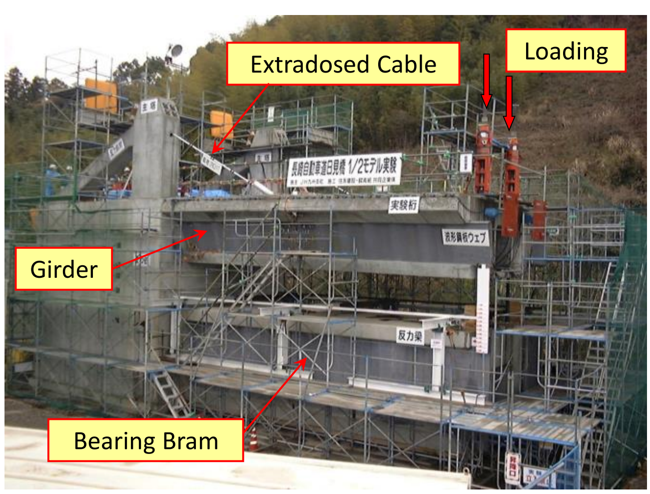
Stay Cable Anchorage in Girder

Steel Diaphragm of Himi Bridge for Corrugated Steel Web





Half Size Model Test



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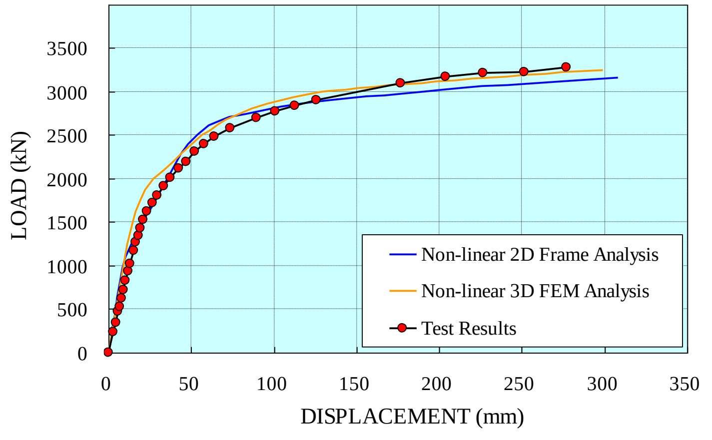
Test Results



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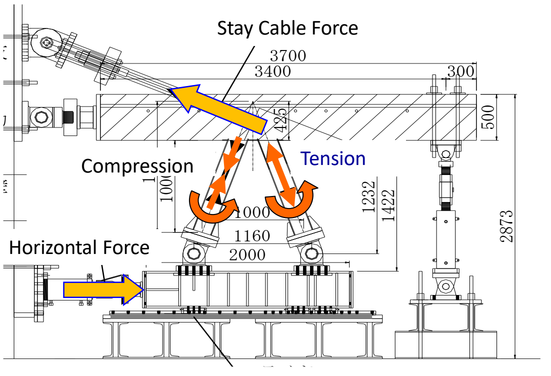
Fudo Bridge (2010, Composite Truss)

Test for Truss Connection (Half Size)



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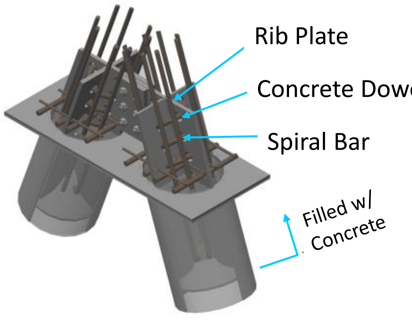
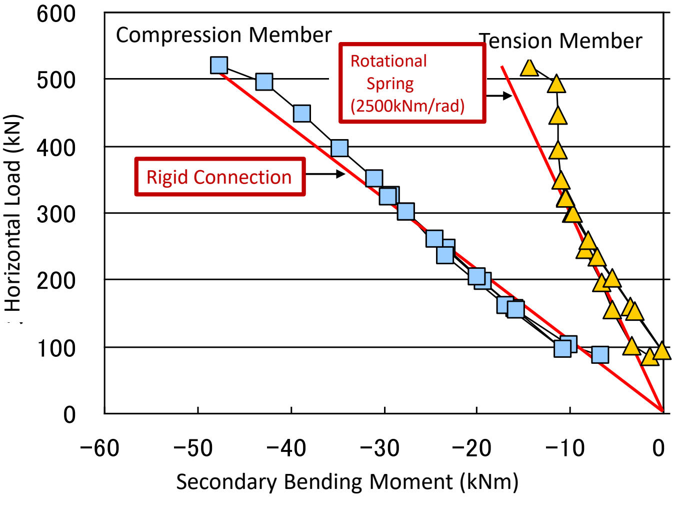
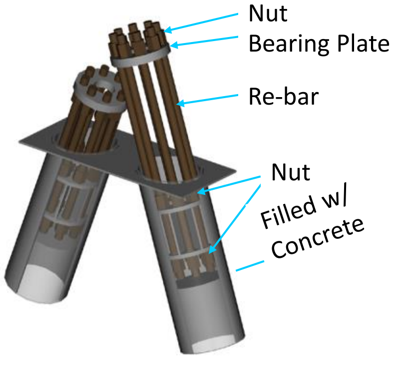
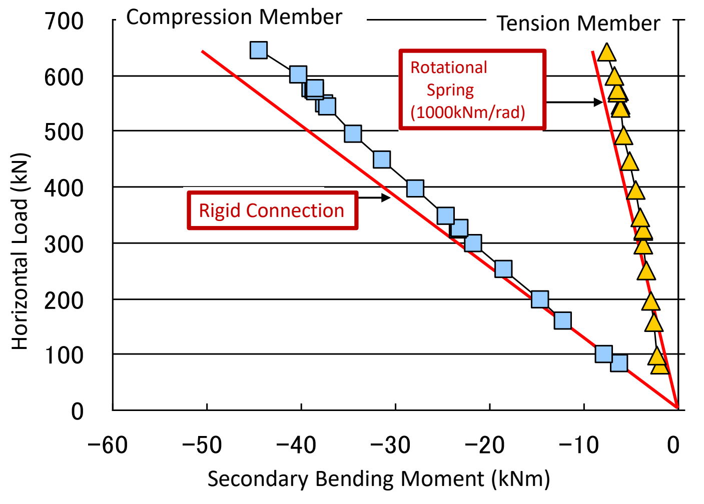
Perforated Dowell Connection



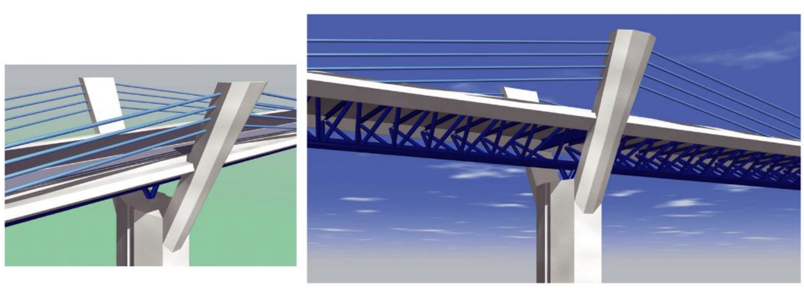


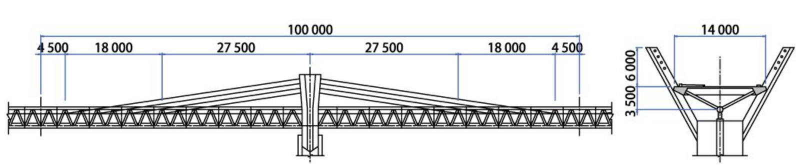
Re-bar Connection



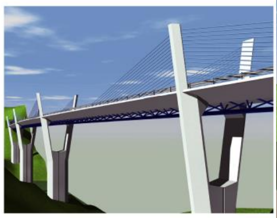


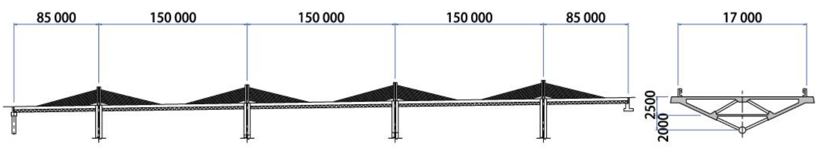
EDB with Composite Truss Girder





EDB with Composite Truss Girder



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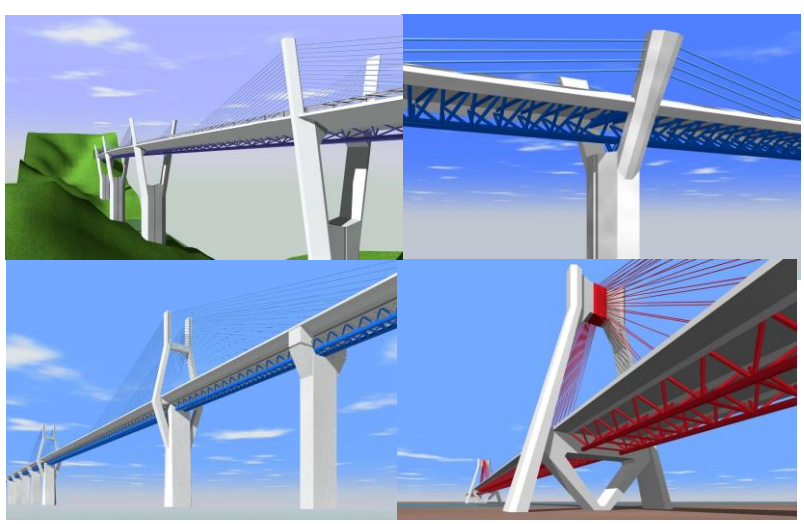
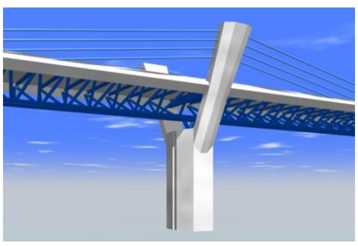
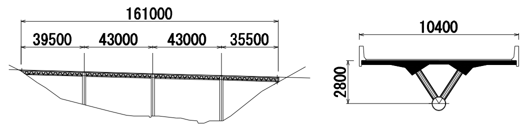
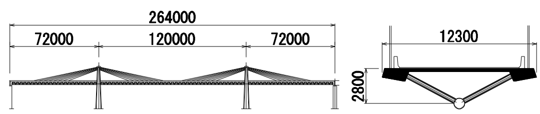
EDB with Composite Truss Girder



Axial Forces in Truss

Bridge Type	Axial Force
(A) Girder Bridge (max.span : 43m)  Average thickness of concrete t=370mm	1380kN
(B) Extradosed Bridge (max.span : 120m)  Average thickness of concrete t=440mm	1590kN

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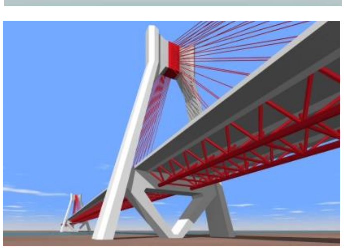
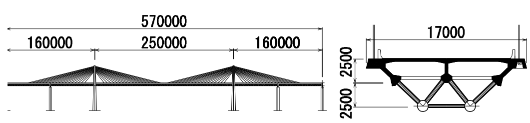
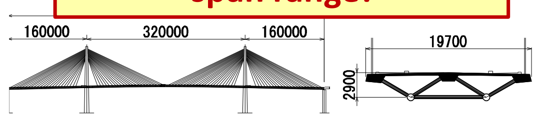
Axial Forces in Truss

Bridge Type	Axial Force
(C) Extradosed Bridge (max.span : 250m)  Average	1420kN
(D) Cable  Average thickness of concrete t=380mm	1590kN

Composite truss can make axial forces constant in all span range!

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Mukogawa Bridge (2016)

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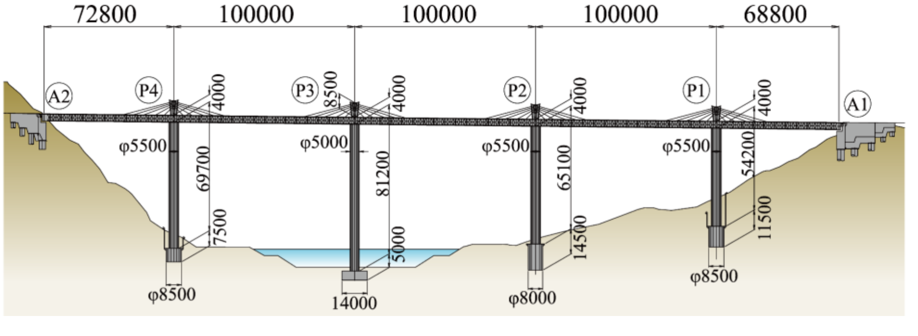
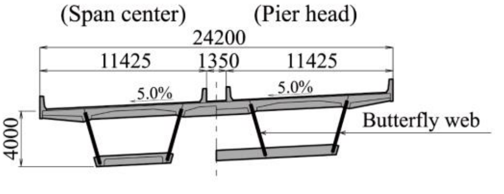
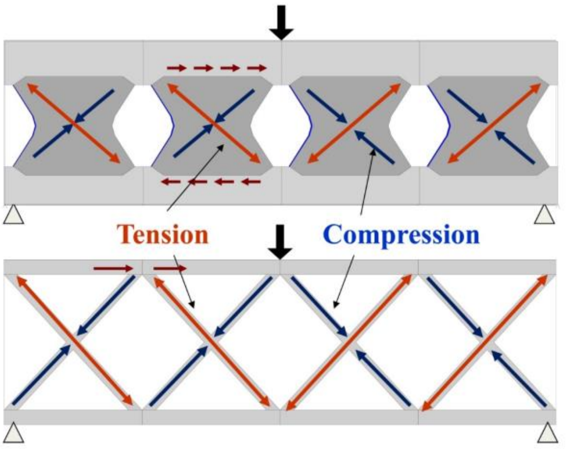
Mukogawa Bridge (2016)





Structural Behavior of Butterfly Web Bridge

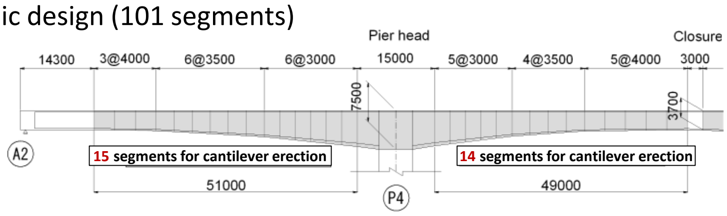
✓ Structural Behavior of Butterfly Web = Double Warren Truss



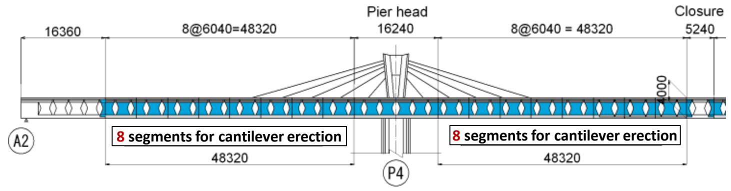
Construction of Mukogawa Bridge

Effects of the Extradosed Structure with Butterfly Webs

Basic design (101 segments)



Detail design (54 segments)



- ✓ Number of days required for cantilever construction reduced.
- ✓ The weight of superstructure was reduced up to 20% from the basic design.

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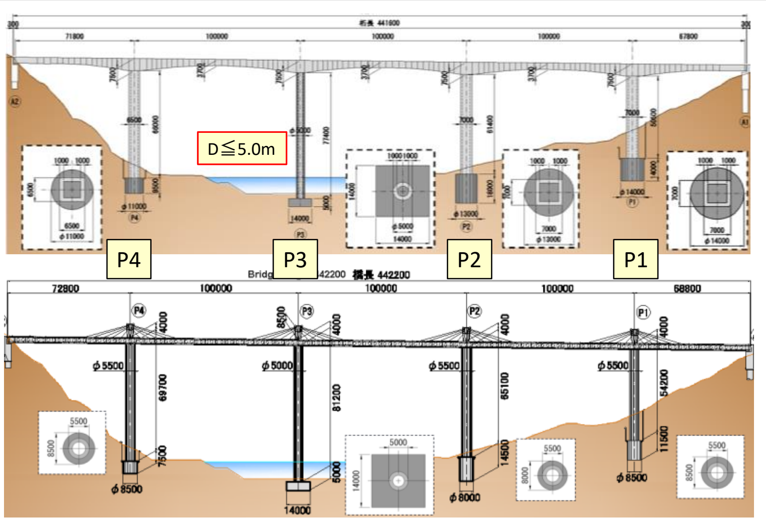
Effects of the Extradosed Structure with Butterfly Webs



- ✓ Total weight of super- and sub-structures was reduced by about 35%.

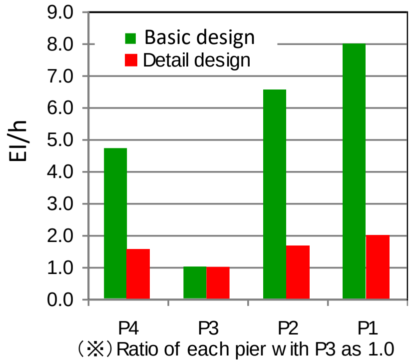
Basic design

Natural period	Longitudinal (temporary)	Transverse (temporary)
Basic plan (s)	1.59	2.90
Detail design (s)	2.29	3.82

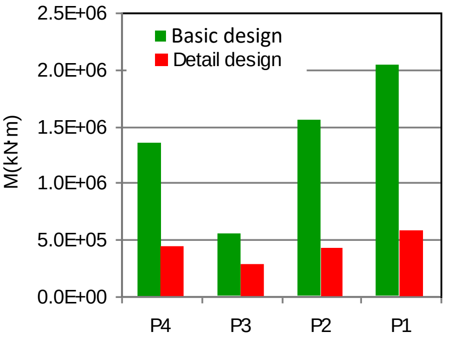
Detail design

Effects of the Extradosed Structure with Butterfly Webs

Improved seismic performance



Ratios of flexural rigidity (EI) to height (h) of the piers



Bending moment at the bottom of the piers

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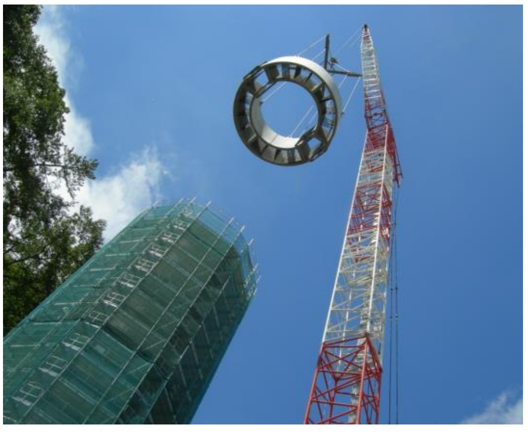
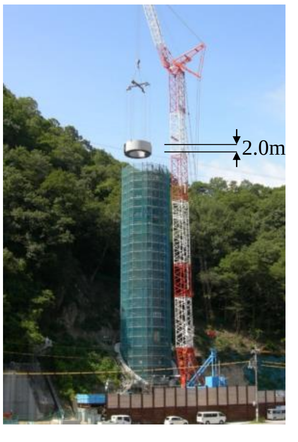
Construction of Piers





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Construction of Superstructure

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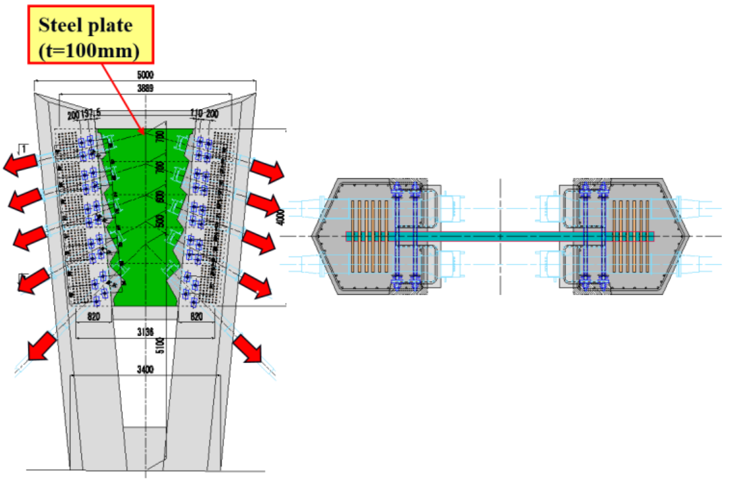
Tower Detail



Mukogawa Bridge

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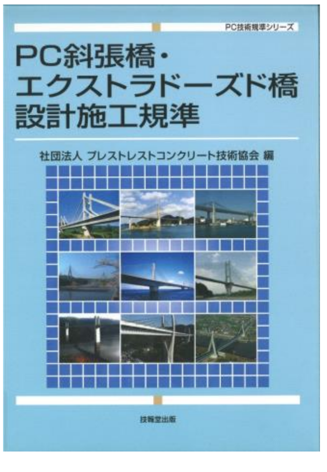
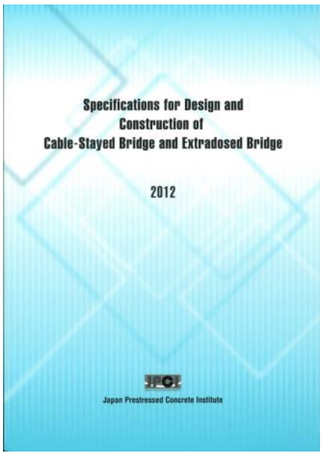
Specifications for CSB & EDB by JPCI

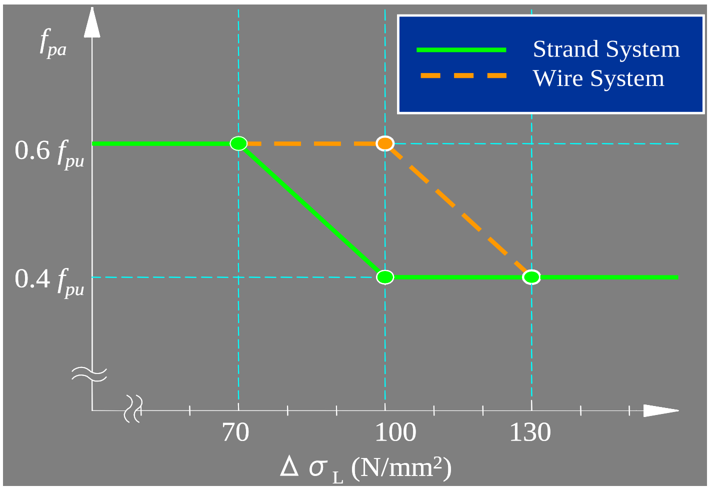
(2009)



(2012)



Allowable Stress of Stay Cables



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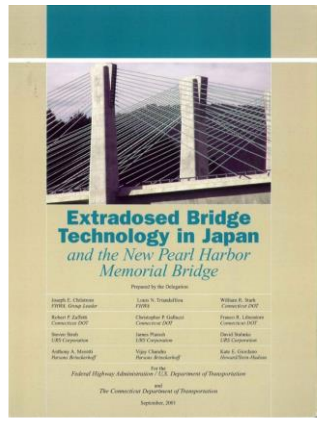
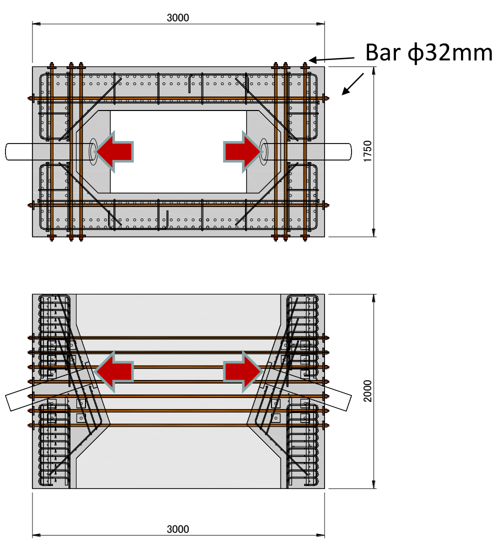
EDBs have been extended after Odawara

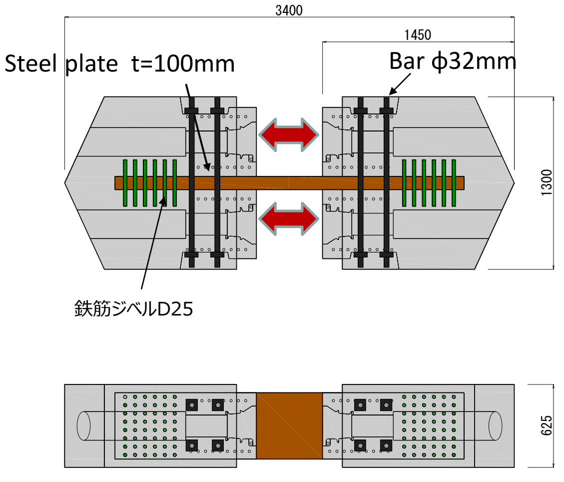
US Mission for EDB



Development of Cable Stay Anchorage (Concrete Type)



Development of Cable Stay Anchorage (Single Steel Plate Type)



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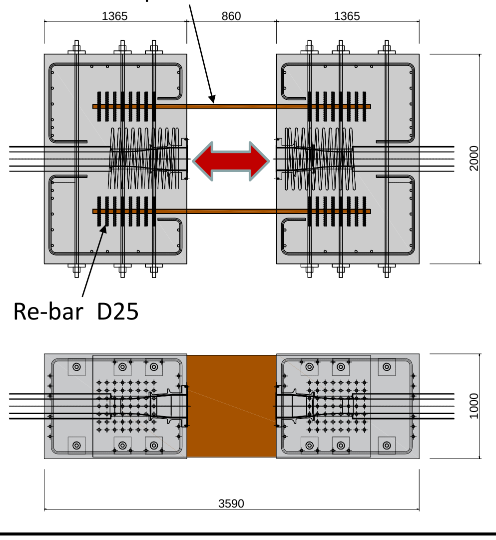
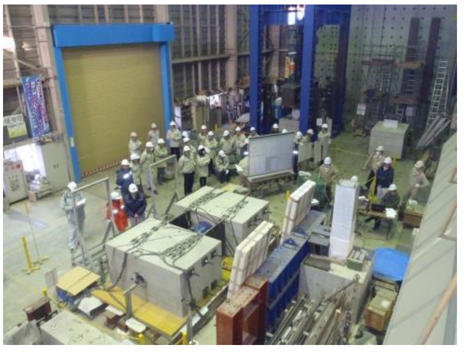
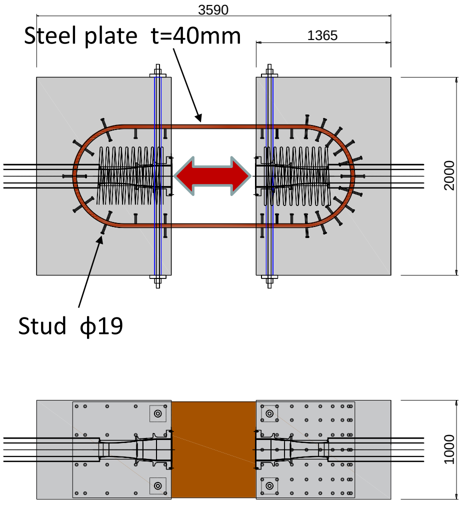
Development of Cable Stay Anchorage (Double Steel Plate Type)





Development of Cable Stay Anchorage (Advanced Steel Plate Type)

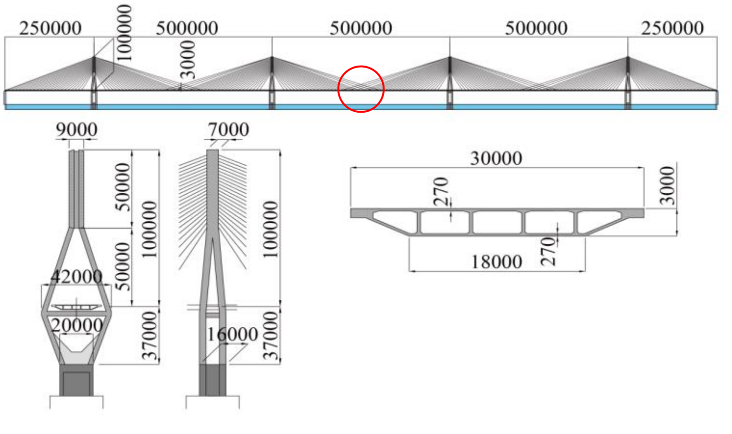


New Saddle (Chao Phraya River Crossing Bridge)

Future

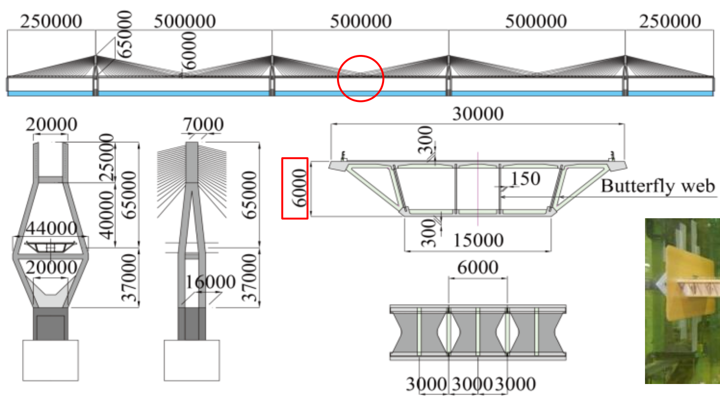
Future Application of Butterfly Web Bridge

500m multi-span cable-stayed type



Future Application of Butterfly Web Bridge

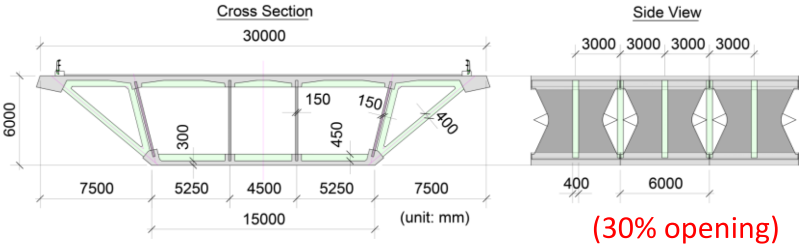
500m multi-span extradosed type



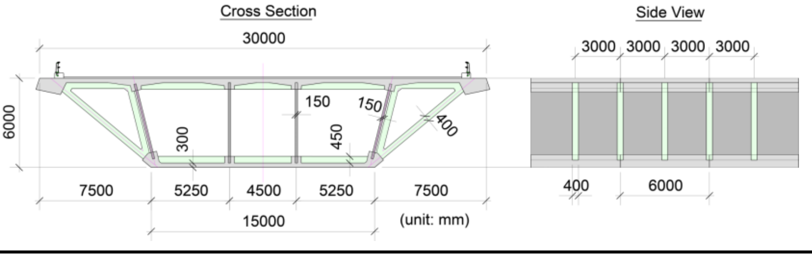
✓30% Opening leads to good performance in wind tunnel test.

Wind Tunnel test

Girder Configuration



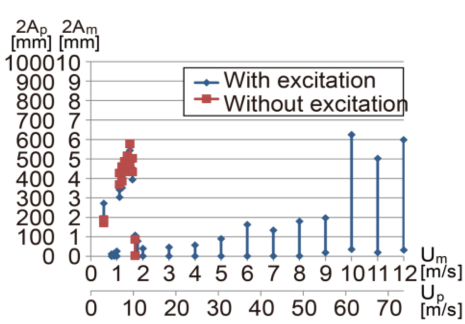
(30% opening)



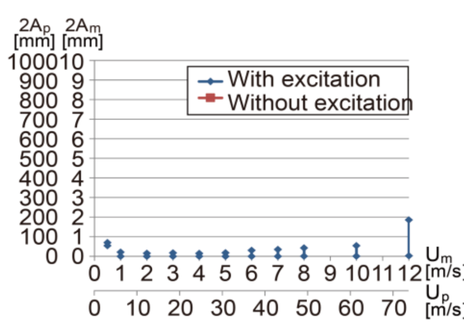
Wind Tunnel Test Setup (1/100)

- Girder Heaving 1st Mode : 3.13 sec
- Girder Torsional 1st Mode : 1.47 sec
- Logarithmic Decrement : 0.004

Flexural Vibration Test



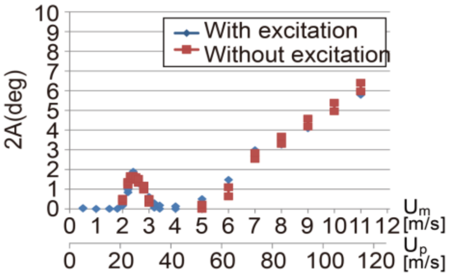
Conventional Web



Butterfly Web

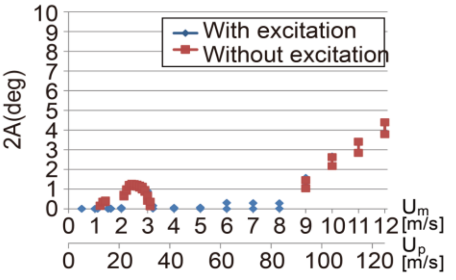
No vortex shedding

Torsional Vibration Test



Conventional Web

Torsional Vibration : 2 degrees
25m-sec
Torsional Flutter : 60m-sec

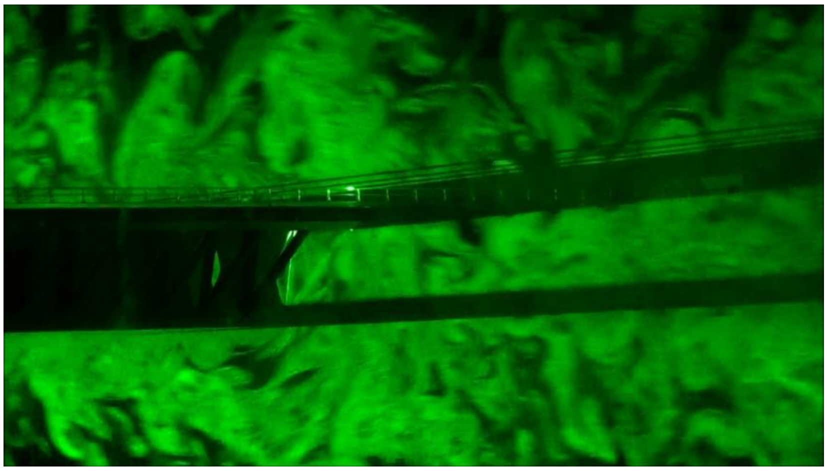


Butterfly Web

Torsional Vibration : 1 degrees
25m-sec
Torsional Flutter : 90m-sec

Conventional Box Girder

Butterfly Web Girder



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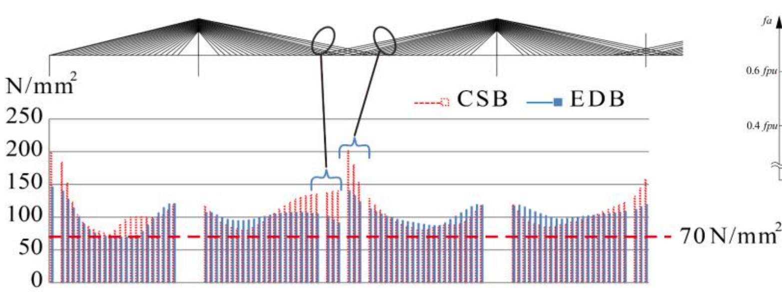
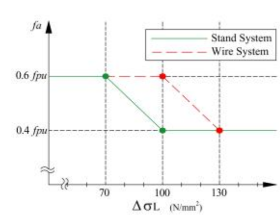
SUMITOMO MISTUI CONSTRUCTION

Stay Cable Stress Change due to Live Load

- ✓ Structural behavior can be simulated by NLFEM



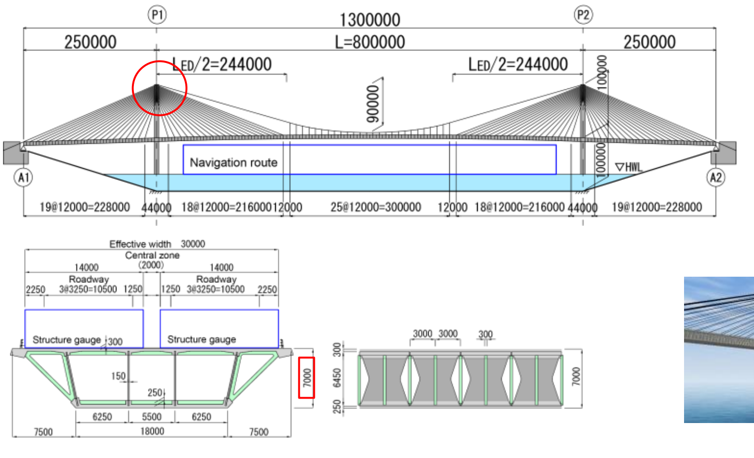


Comparison of Material Quantities

			CSB	EDB
Concrete	Girder	m^3	48900	43700
	Pylon	m^3	18500	14400
Rebar		ton	15960	13410
Prestressing steel		ton	259	261
Stay cables		ton	6030	6300

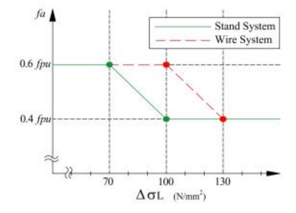
Future Application of Butterfly Web Bridge

800m-span hybrid cable supported bridge (Extradosed + Suspension)



Comparison of Material Quantities

	Unit	Case 1	Case 3
Stay Cable	t	2,873	2,536
Main Cable	t	11,170	5,639
Hanger	t	55	29
PC tendon	t	541	505
Total	t	14,639	8,709



Concluding Remarks

- The extradosed bridge enables engineers to apply consistent design principles to cable-stayed bridges and ordinary girder bridges.
- Proposed stay cable design method is effective in consistent design approach.
- The extradosed bridge greatly increases the degree of freedom for the design of cable-supported structures.


Thank you for your attention