Challenge to “the First in the World”

- Cost efficiency
- Light weight structure
- Manpower and construction time saving
- Overcoming uncompetitive span range
- Low carbon technology

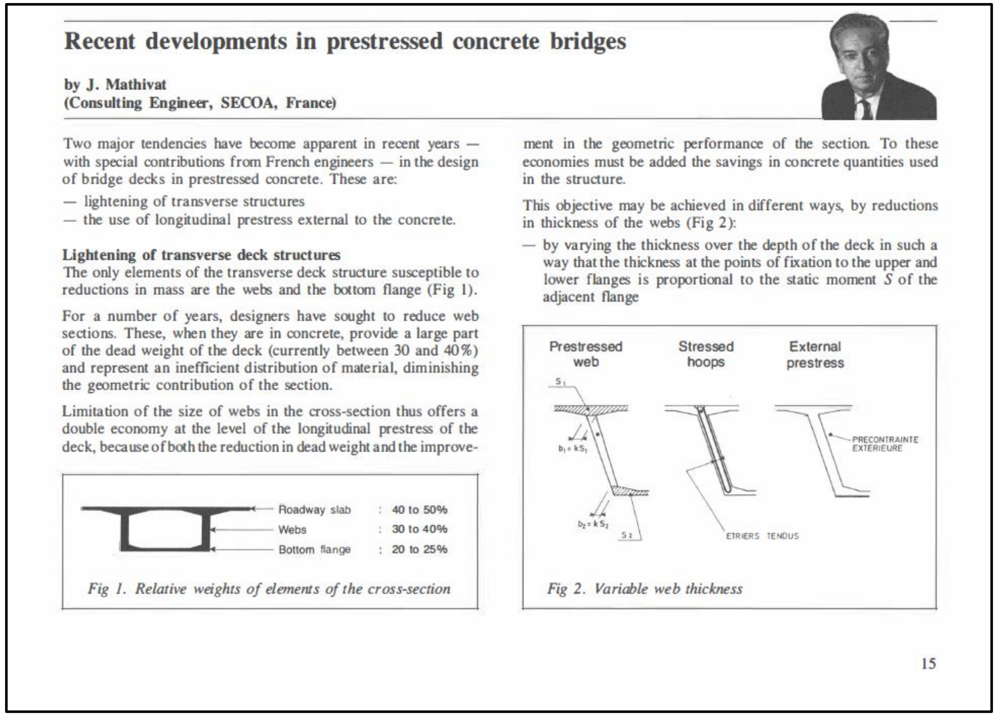
Design and build solved these constrains.

Bridging the Structural Gap

Cost efficiency

Starting point of Challenge

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 double economy at the level of the longitudinal prestress of the deck, because of both 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.

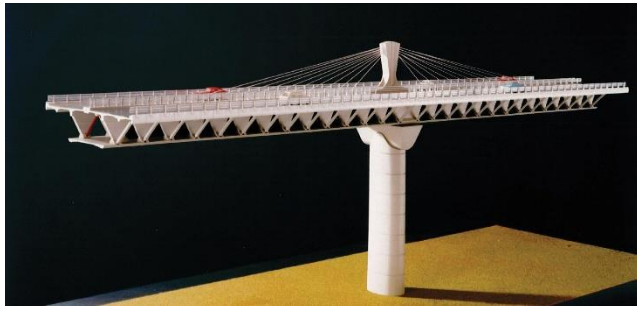
This objective may be achieved in different ways, by reductions in thickness of the webs (Fig 2):

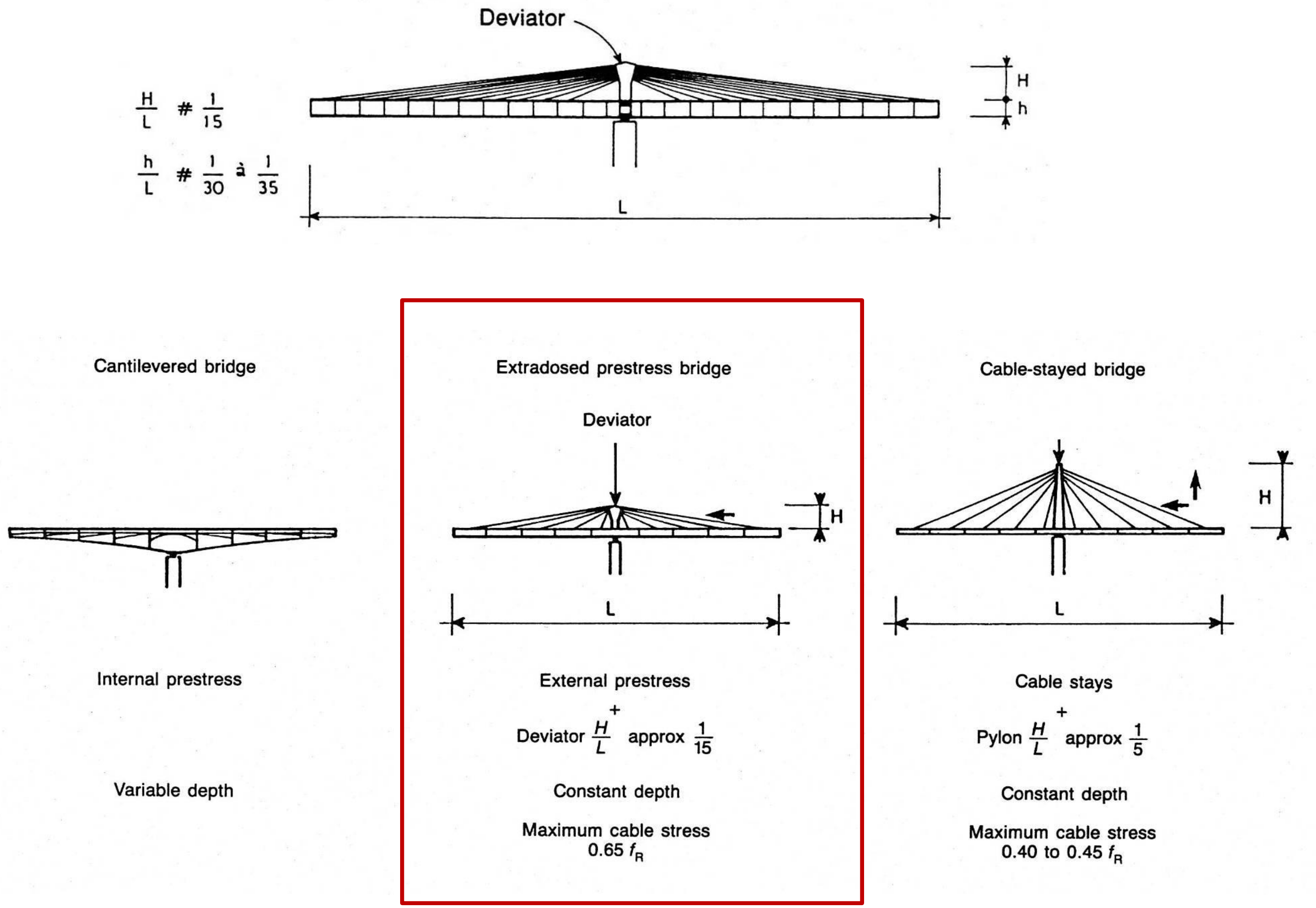
— by varying the thickness over the depth of the deck in such a way that the thickness at the points of fixation to the upper and lower flanges is proportional to the static moment S of the adjacent flange

Fig 1. Relative weights of elements of the cross-section

Fig 2. Variable web thickness

15





First Extradosed Bridge in the World

Odawara Blueway Bridge (1994)

- Development of saddle system
- Flexural fatigue test
- Fretting fatigue test
- Epoxy coated strand

- High damping rubber damper
- 0.6fpu for extradosed cables

Another Four Extradosed Bridges

Tsukuhara Bridge (1997)

- Construction using ultra large form travelers

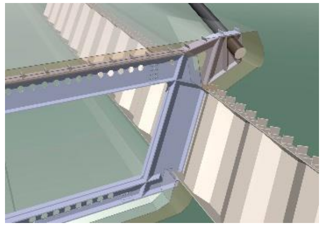
Ibigawa Bridge (2001)

- 400-ton precast segments
- Hybrid girder

- Special side span construction method over dike
- Separated stay cable anchorage system

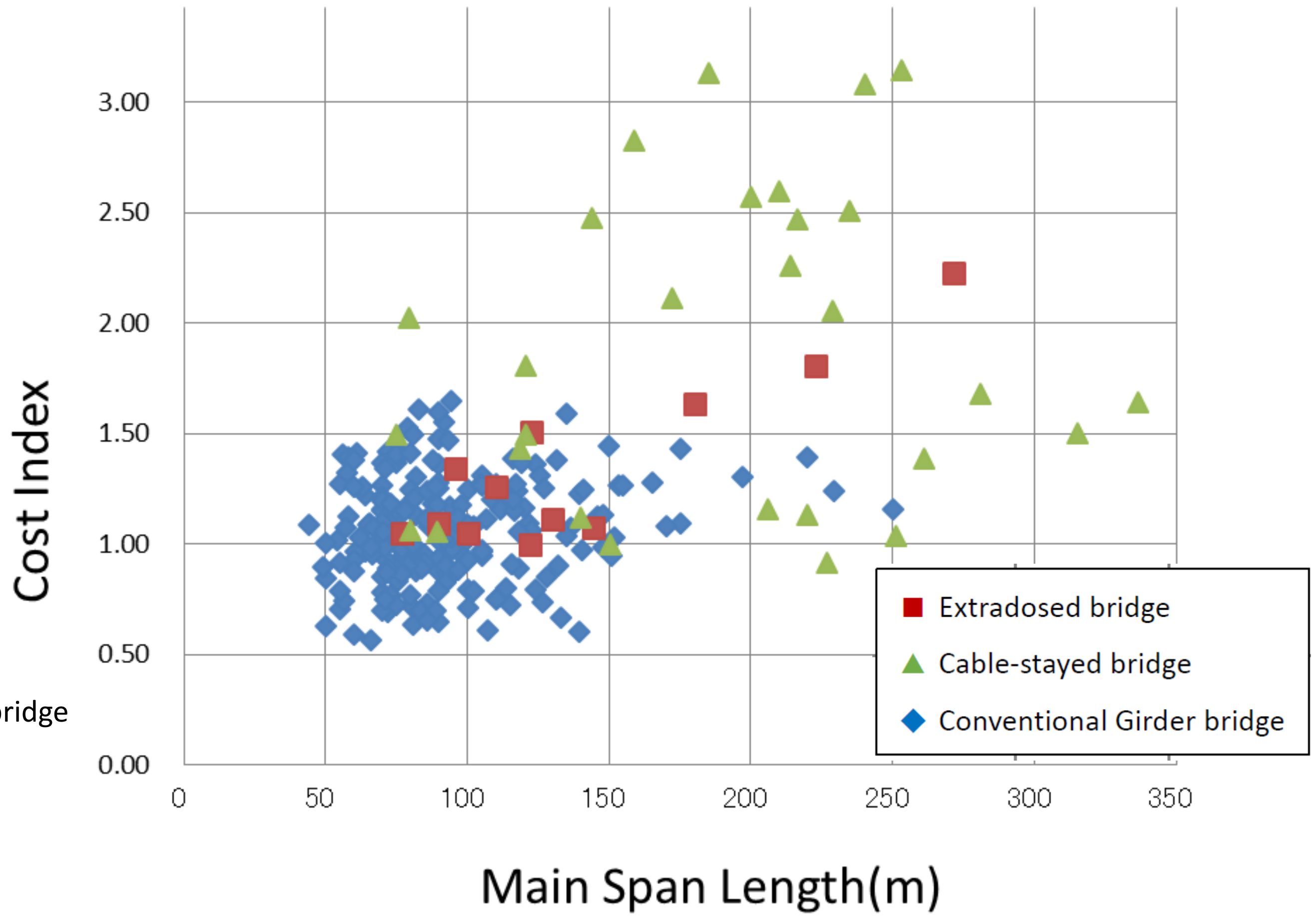
Shin-Meisei Bridge (2004)

- Corrugated steel web
- Stay cable anchorage system



Himi Bridge (2004)

Cost Efficiency of Extradosed Bridges



The base for the index is the cost for a girder bridge with a 100m span (cost index set to 1.0).

- Cost efficiency of extradosed bridge was confirmed

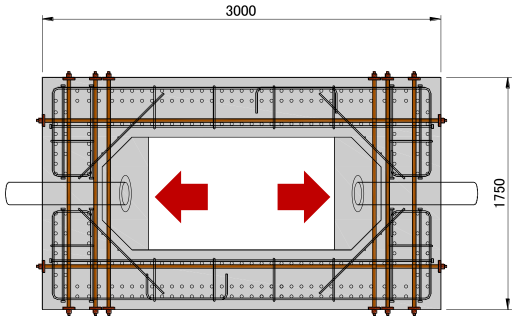
R&D of Extradosed Cable Tower Anchorage System

Mukogawa Bridge (2016)

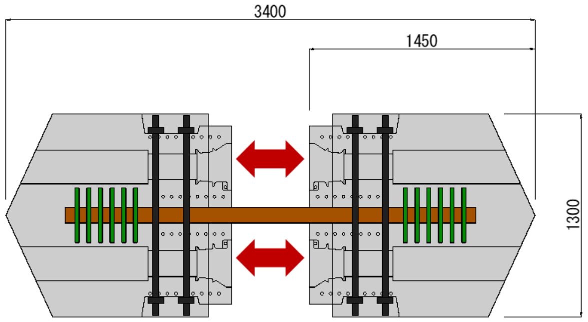
- Tower in the limited space
- 100mm thickness steel plate

Optimization of Extradosed Cable Anchorage System

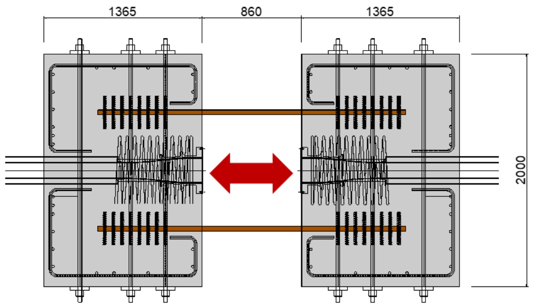
Concrete Box Type (2004)



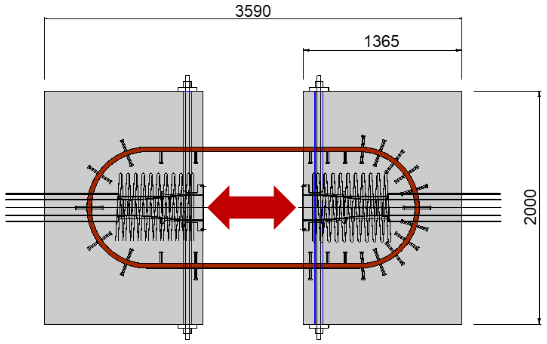
Single Steel Plate Type (2012)



Double Steel Plate Type (2017)



Oval Shape Steel Box Type (2018)



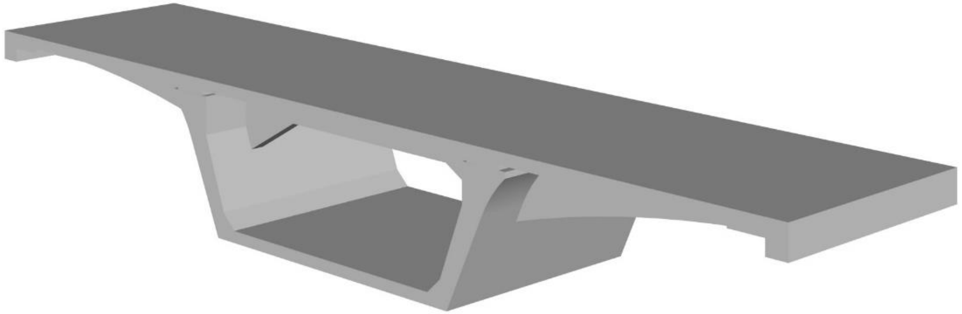
- Steel for tension and concrete for anchoring and compression
- Simpler fabrication of steel

Productivity

Manpower and construction time saving

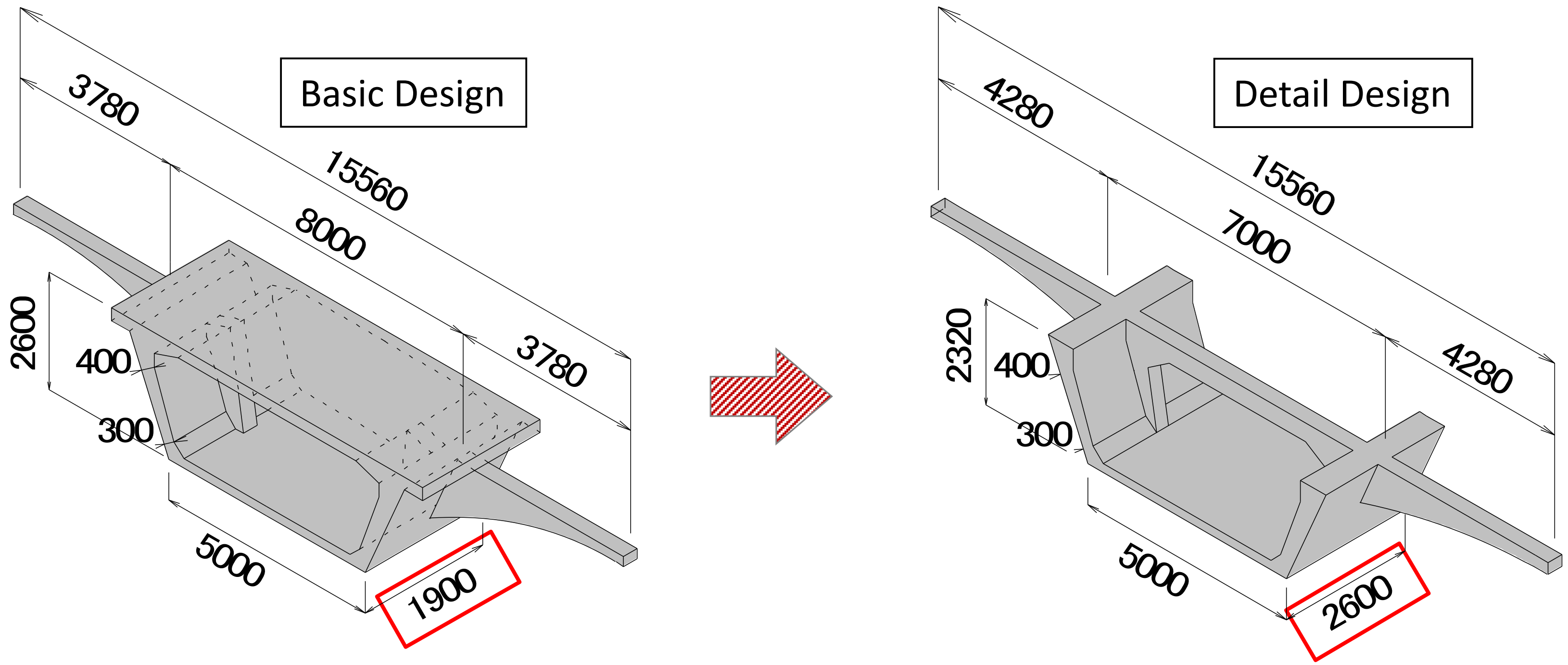
U-shaped Segmental Construction

Furuawa Viaduct (2002)



- Off site fabrication in the urban construction
- Japanese transportation regulation limits segment weight up to 30 tons

Conceptual Design of U-shaped Segment

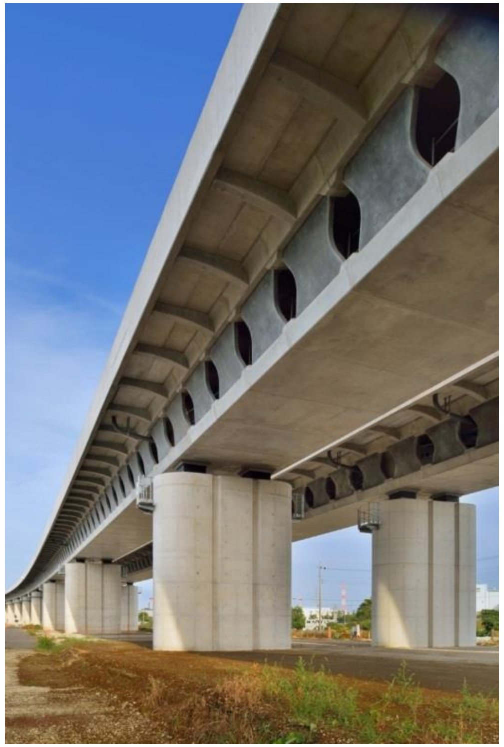


- Number of Segments 1900 segments → 1300 segments **72%**
- Weight of Launching Girder 900 tons → 330 tons **37%**

2Mn Euro saving!!

Further Application of U-shaped Segmental Construction

Okegawa Viaduct (2015)

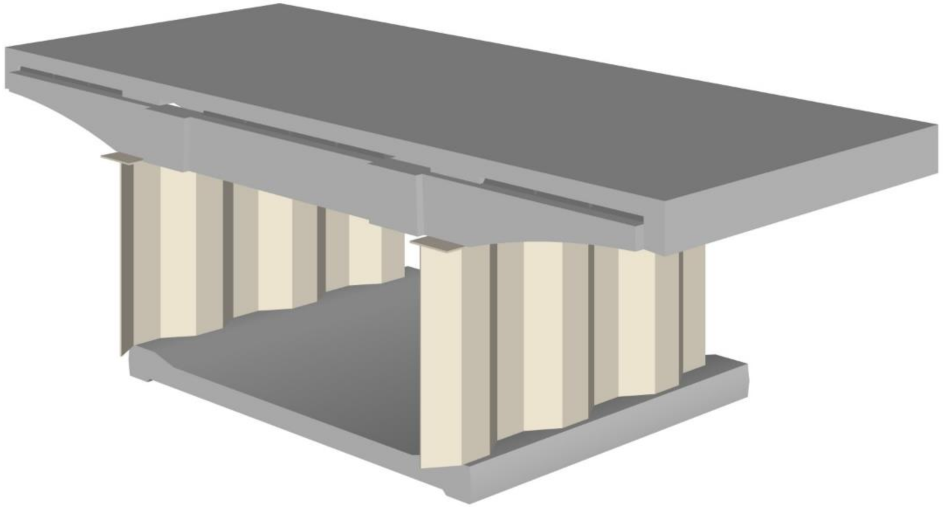


- Prefabrication in SMC concrete factory

- 35,000m^2 construction in 20 months including detail design

Rational Construction for Corrugated Steel Web

Shigaraki Bridge (2005)



Tsukumi Bridge (2005)

- Manpower saving by precast ribs and panels
- 60% reduction of segmental construction cycle time
- Same lifting equipment as CIP construction

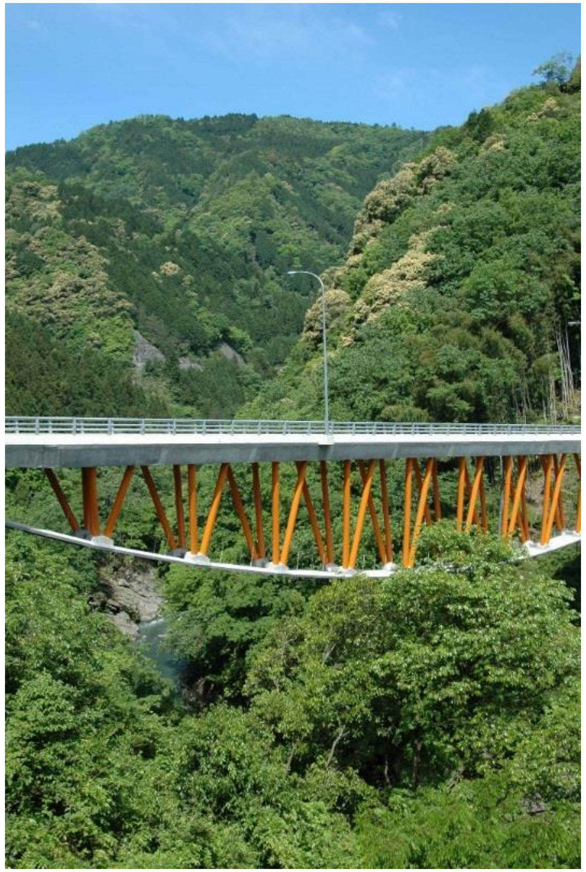
Construction on the Tightrope

Overcoming uncompetitive span range

Unique Construction Using Suspension Structure

Seiun Bridge (2004)

fib Outstanding Structure Award 2006, Winner

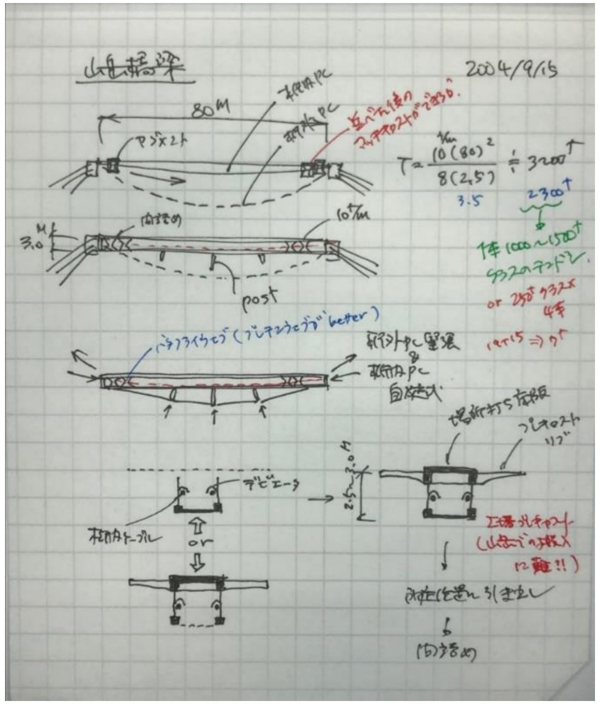


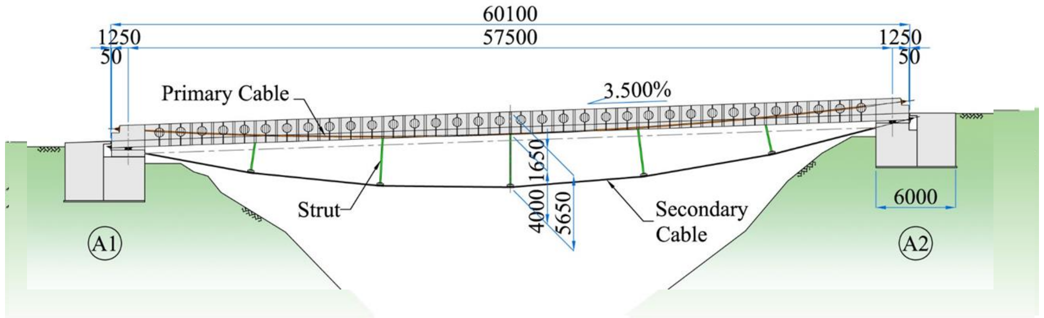
- New structure for single span of 50m to 100m range
- Unstable construction <u>from bottom to top</u>

Improvement of Construction Using Suspension Structure

Seishun Bridge (2006)

Conceptual design (1999)



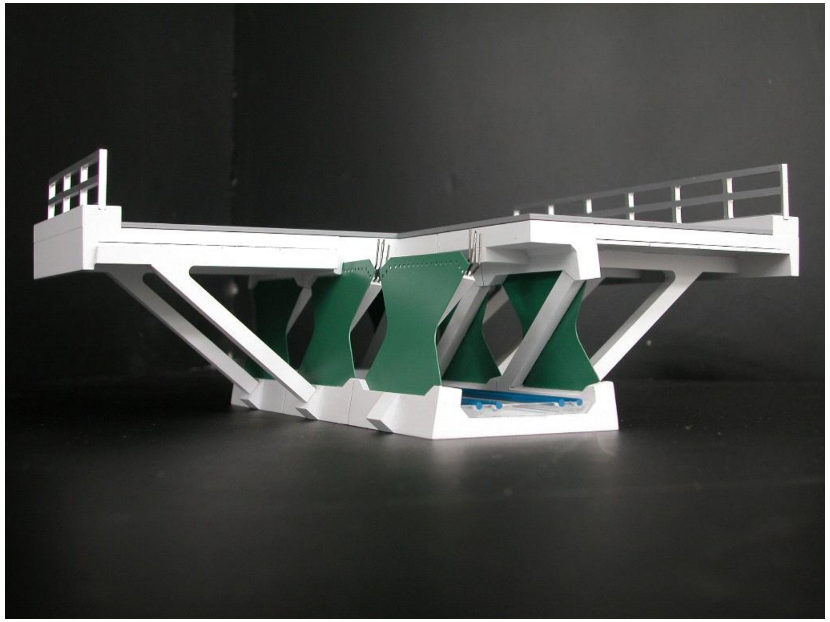


- Stable construction <u>from top to bottom</u>

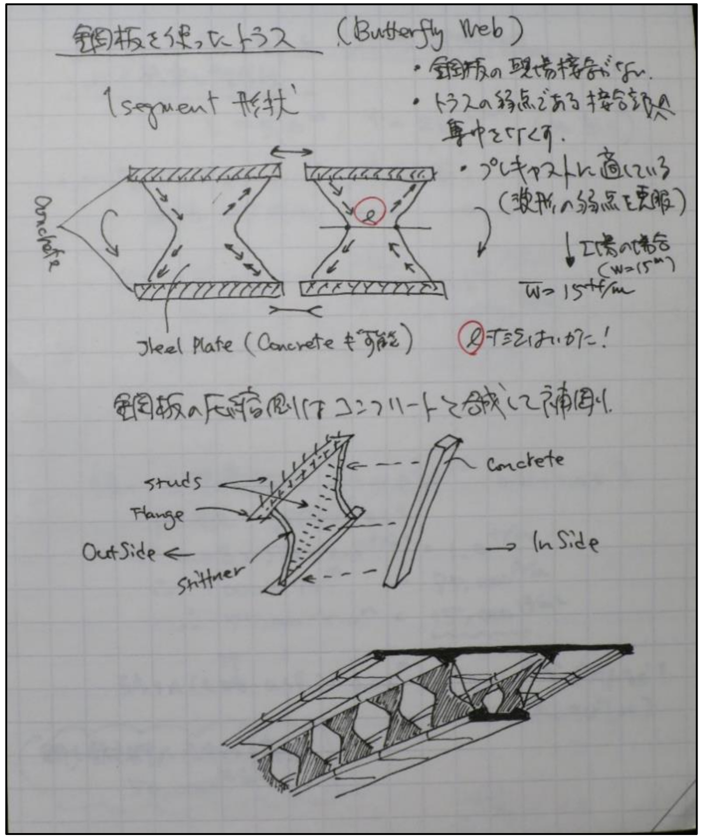
New World

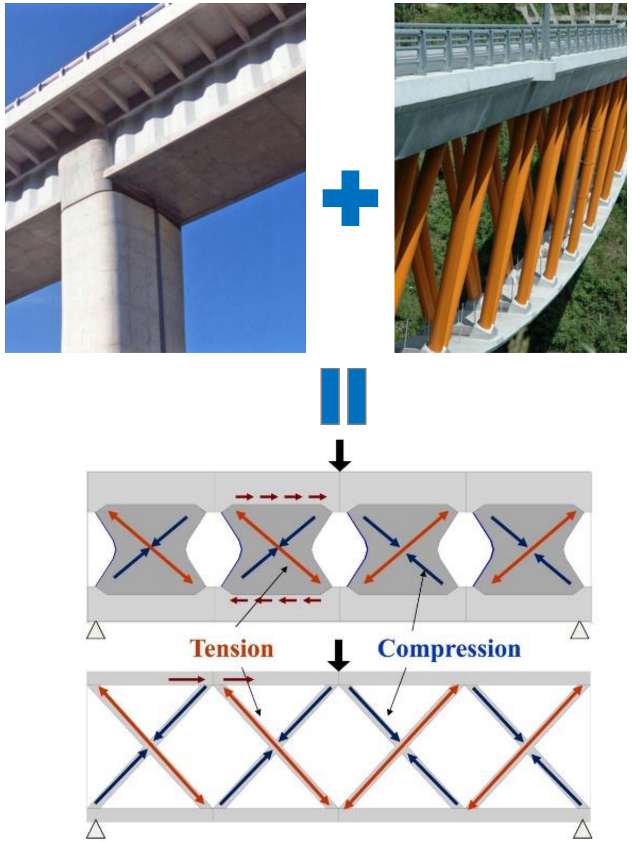
Light weight structure

Butterfly Web Bridge



Conceptual design of butterfly web bridge (1999)

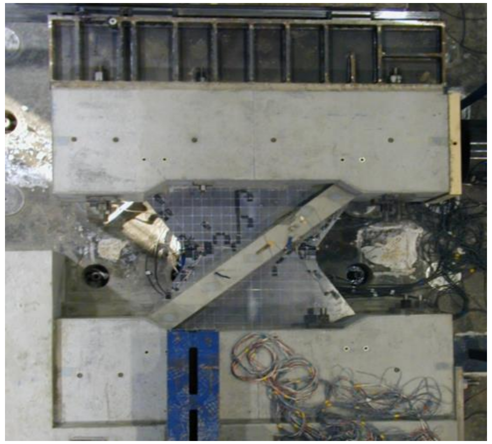




- Steel panel to fiber reinforced concrete panel
- Composite structure with different types of concrete

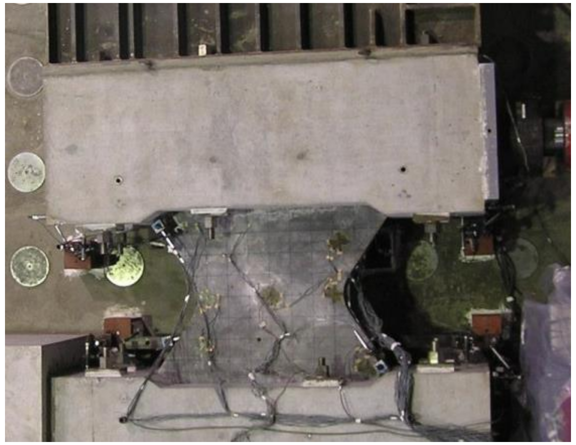
Series of Tests for Butterfly Web Bridge

Steel Panel Test (2003)



Steel Panel Beam Test (2005)

Concrete Panel Test (2006)



Concrete Panel Beam Test (2011)

- Verification of fracture mode (behavior of segmental joins)
- Establishment of design method for steel and concrete butterfly panel

First Application of Butterfly Web Bridge

Takubogawa Bridge (2013)

fib Outstanding Structure Award 2018, Winner

- 13 years from conceptual design to practical field
- 15cm butterfly panel without re-bars make structure 15% lighter
- Construction time of superstructure reduced 50%
- Bright inside makes maintenance easier

Another Achievements of Butterfly Web Bridge

Okegawa Viaduct (2015)

Akutagawa Bridge (2015)

Mukogawa Bridge (2016)

Bessodani Bridge (2020)

Nakatsugawa Bridge (2028)

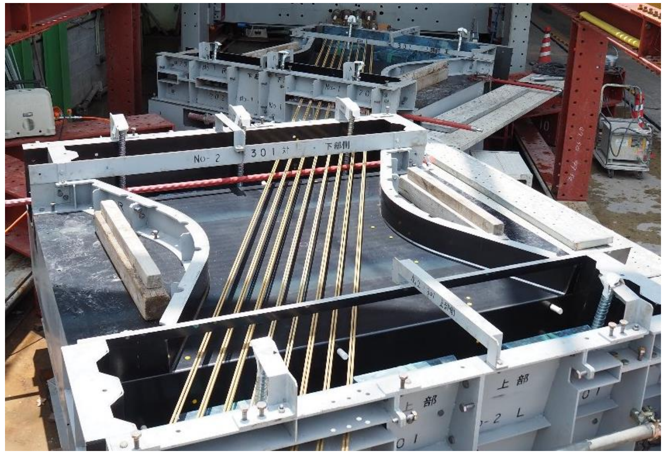
- Three box girder, two extradosed and one non-metallic bridge

New Normal after “Great Reset”

Low carbon technology

Non-metallic Bridge

Bessodani Bridge (Dura-bridge, 2020)



- R&D for non-metallic bridge has been implementing since 1984
- Ultra-highly durable bridge can eliminate CO_2 emissions in the use stage
- Aramid FPR for internal and external tendons

Further Development and Back to Roman Concrete?

Dura-bridge

Dura-slab

Refurbishment of Tadeno Bridge (2021)

Zero Cement Concrete + Aramid FRP Tendons (2019)

- Low carbon concrete and ultra-highly durable bridge can eliminate CO_2 emissions up to 90% in LCA
- Zero cement concrete which has 150 MPa can build light weight structures (More CO_2 reduction)

Concluding Remarks

- Design, Build and R&D are completed inside SMC.
- Results of R&D are verified by practical fields immediately.
- SMC has seven precast concrete factories which can support R&D.
- SMC has allowed to participate fib activities for long time. And I was stimulated from many overseas bridge designers.
- My biggest regret….

I would be truly grateful to AFGC for the great honor bestowed upon me.

Merci beaucoup à l'AFGC pour le grand honneur qu'elle m'a fait.