Cost Reduction by Wind Resistant Design

--Example of Severn Bridge--

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New Trends in Europe after World-War Ⅱ

» —Back Grounds —

» Shortage of Steel after W-War Ⅱ

» Strong Demands for Economical Construction

» Technology Development for Short-Fabrication/ Short-Erection

→ **These Evoked New Concept of Suspension-Bridge**

West Germany・・・・Invention of "Cable-Stayed Bridge" & "Steel Deck Plate"

» Cable-stayed bridges are more economical than suspension bridges until 1500m span by recent research.

» Steel deck plates will remarkably reduce dead loads as a result steel and construction fee become small.

Ex. : Koeln - Muehlheimer Bridge （Suspension Br.）

① Steel of Old bridge　12,800 ton →　New one only 5,800 ton　（55％ reduction）

②New bridge　→　250％ (Load capacity)

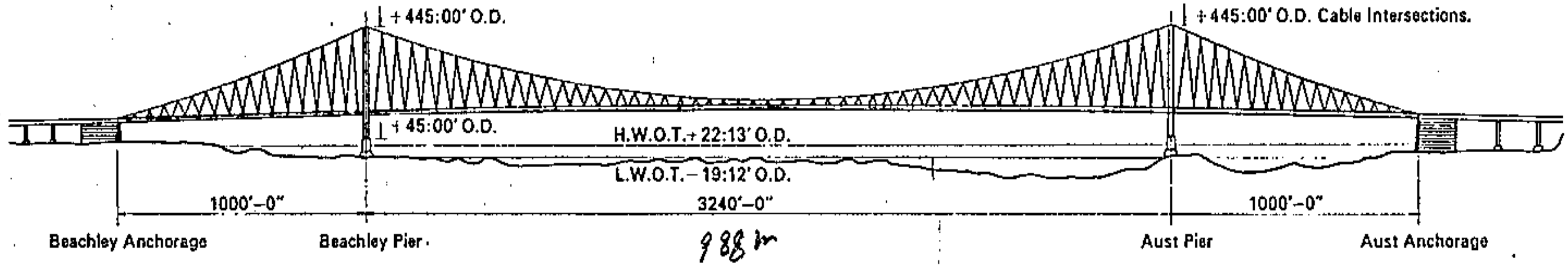
③Erection of Steel Structure was only one year !!

Koeln - Muehlheimer Bridge

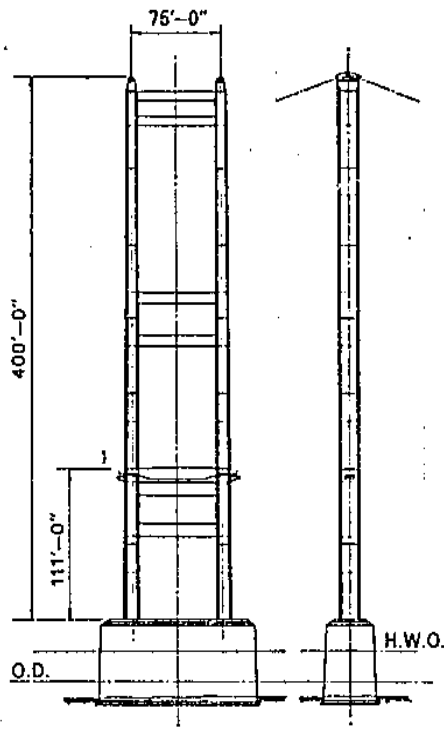
Center Span 315m

Severn Bridge

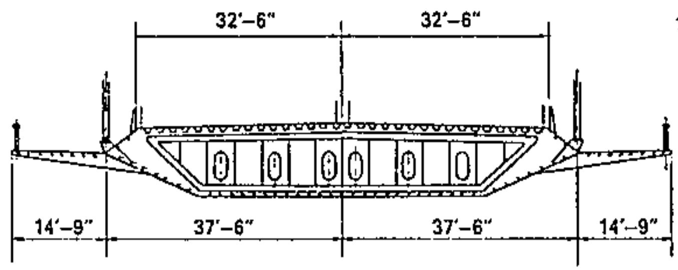
--- Evolution of Suspension Bridge---



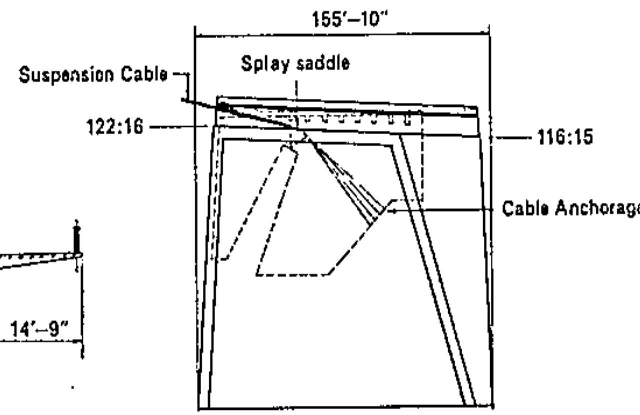
Elevation of Bridge



Elevation on Main Tower



Typical Cross Section



Elevation of Anchorage

Characteristics

- » Streamlined Box-Section Deck
- » High Aerodynamic Instability
- » Inclined Hanger System with Large Damping
- » Economical Tower with Single Cell

20% Cost Down comparing with truss deck

Plated Box

- Surface requiring external painting much reduced
- Box sealed off with no maintenance required
- High torsion stiffness
- Light weight compared with truss deck

  → Saving in cable, towers and anchorages

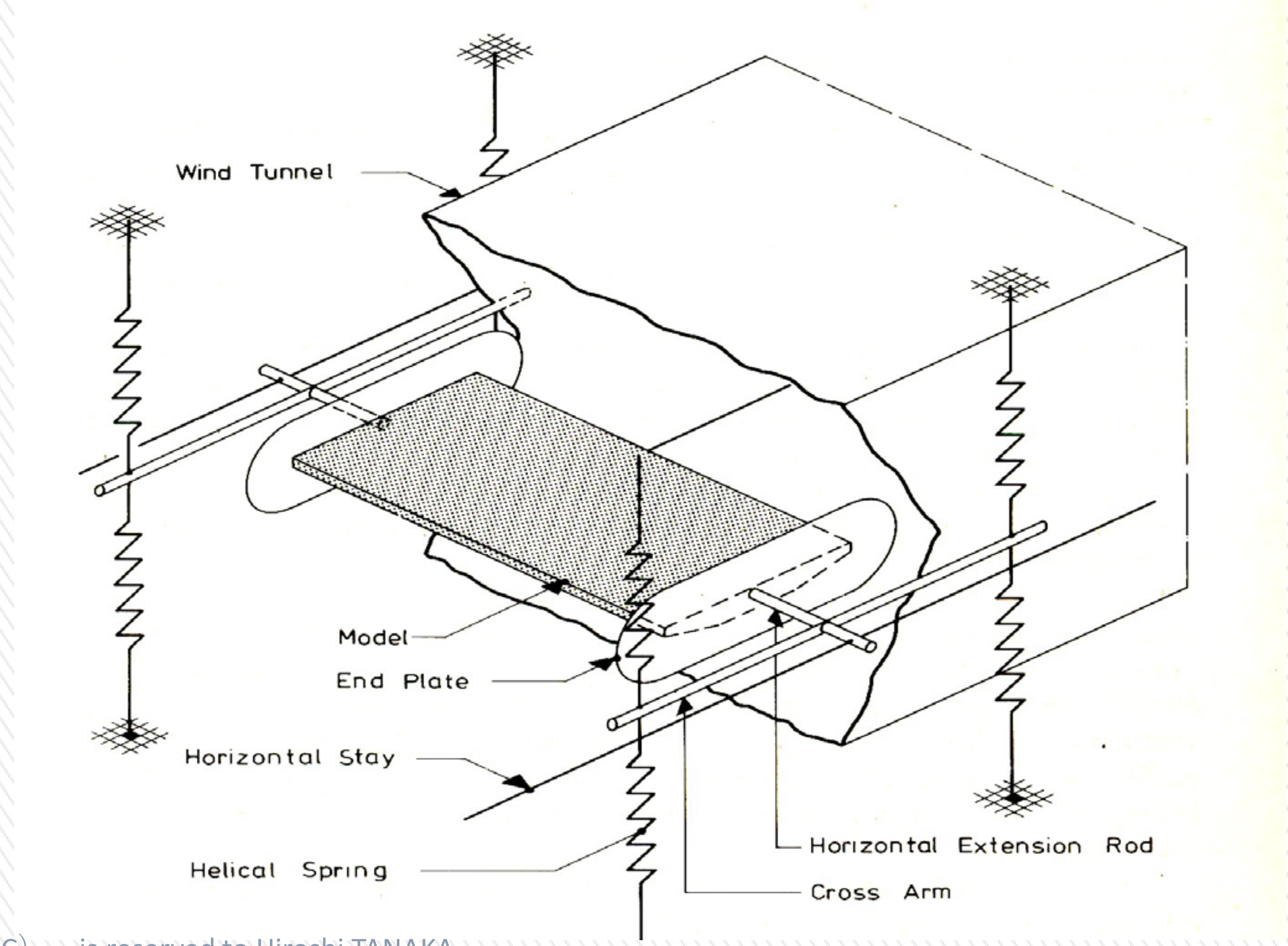
Cable weight is 30% smaller than that of Forth Bridge

Advantage of Box Section

- One third of that for the trusses in drag force
- Reduction in wind drag force
- Particularly significant in towers which sustain 70% of the wind force on the deck as a lateral reaction at the top.

AERODYNAMIC TESTS

» 2D-Section Model Test



AERODYNAMIC TESTS

» Finding New Section Deck Configuration

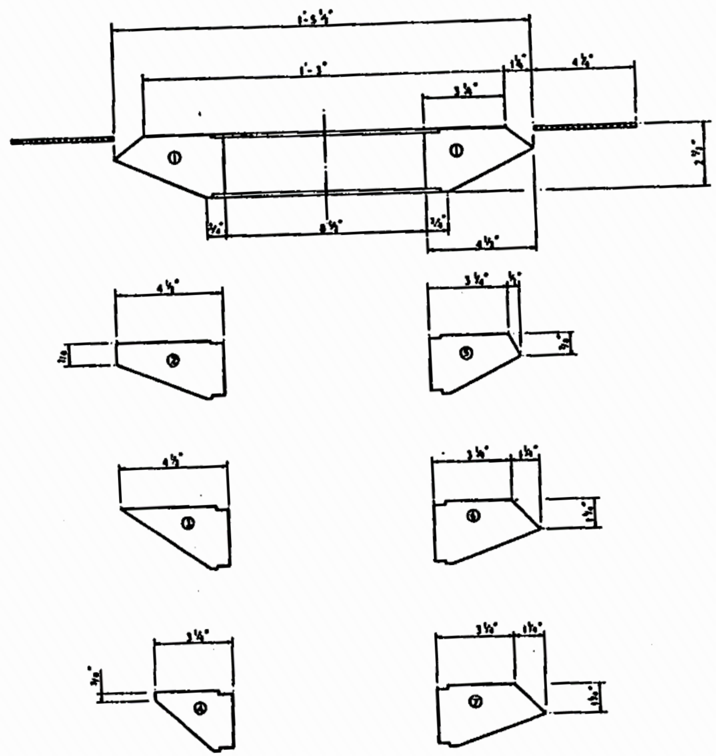
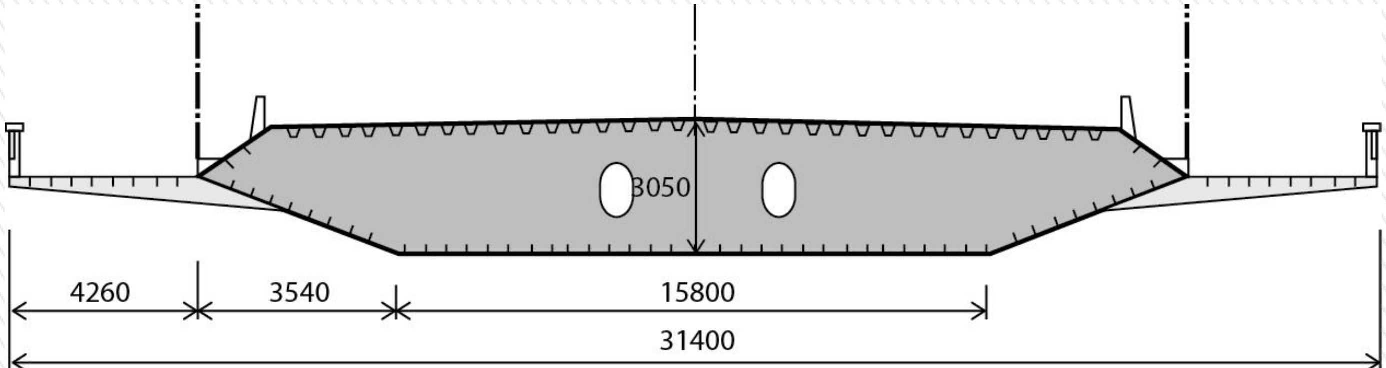


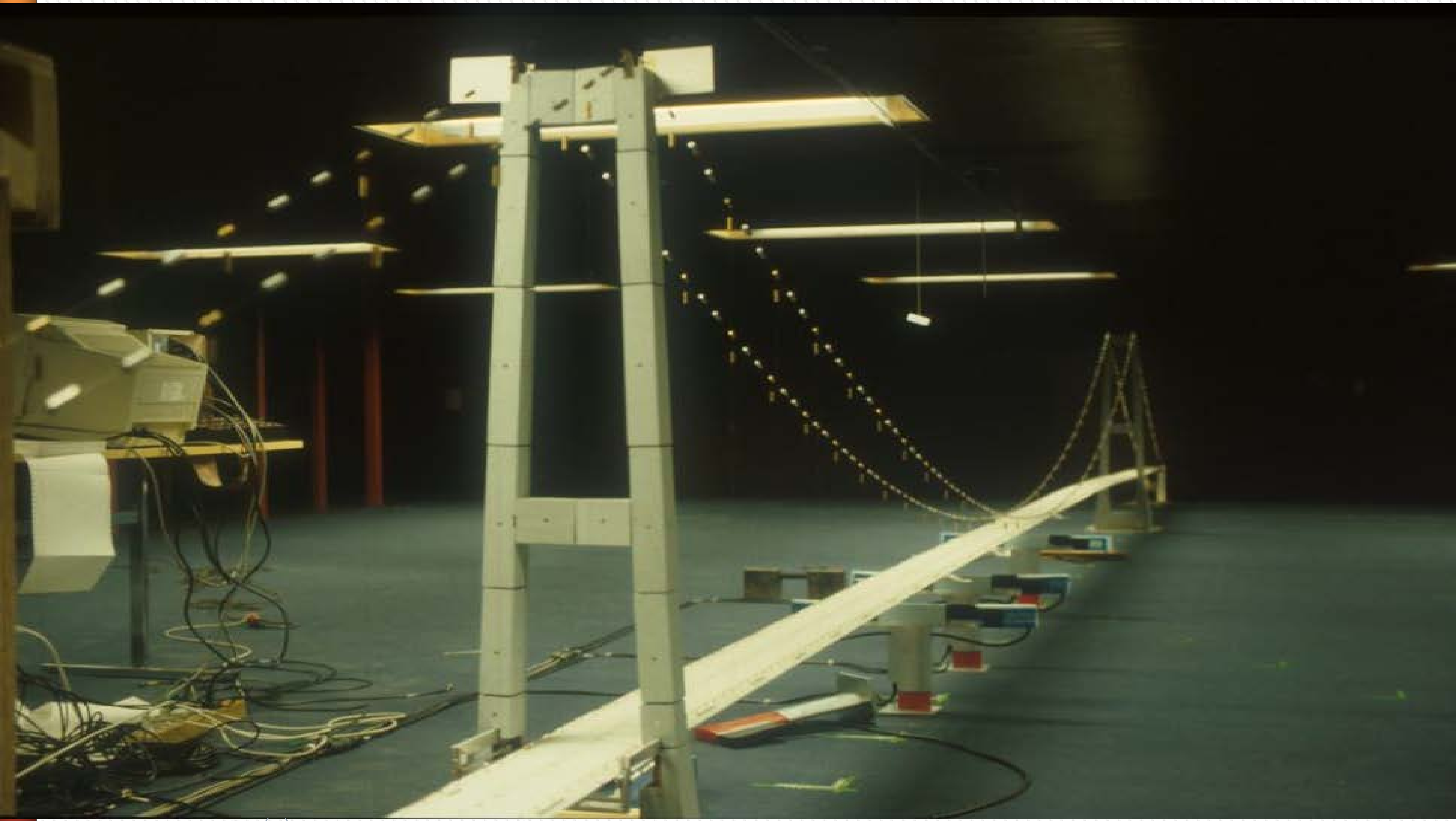
Fig. 2. Simple experimental deck model

Flutter Speed Vcr is 67.7 m/s



3D-Full Model Wind Tunnel Tests

- Final Aero-check of Bridges



Severn Bridge & Forth Bridge

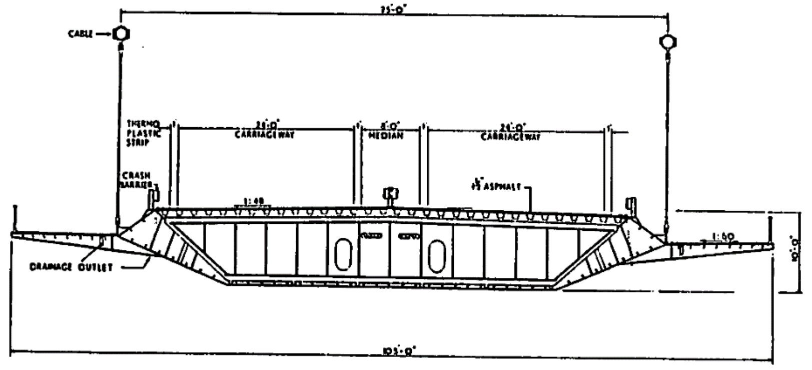
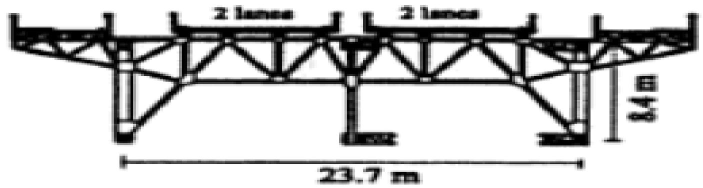


Fig. 7. Deck cross-section

Stream Lined Type Steel Box Deck
Drag is small



Forth Road (1964)

Old American Type Steel Truss Deck
Drag is large

Merit & Demerit of Box Section

» Eddy (Small Vortex) will be produced by truss sections but box sections will not.

» Wind tunnel model will be easily fabricated.

» Automatic welding system was firstly applied Severn Bridge but this will make bridge with smaller damping.

→ Application of Inclined Hangers

Inclined Hangers

Increase of Damping

Afterwards this details were found to be weak for fatigue

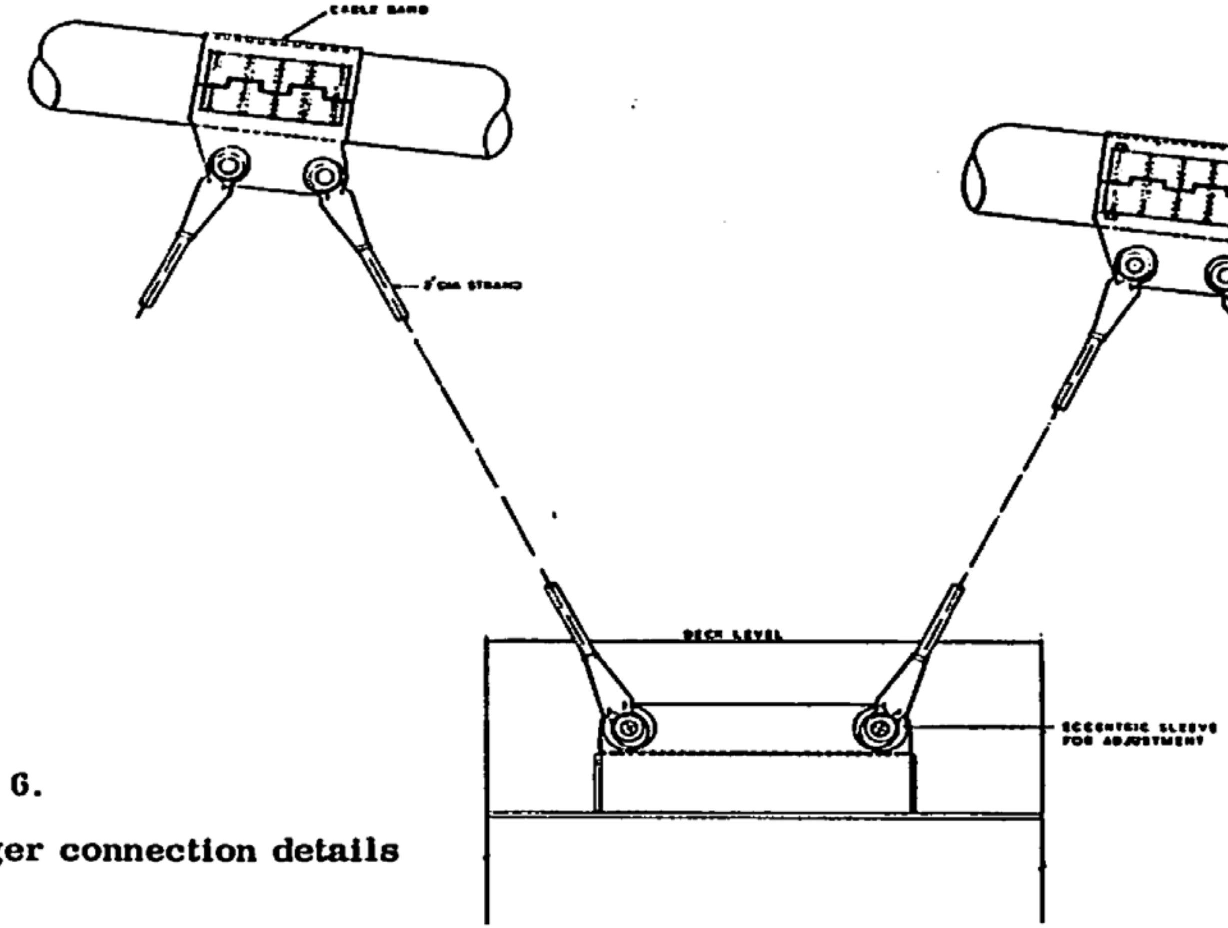


Fig. 6.

Hanger connection details

Rope Hysteresis of Hanger

Increase of Damping

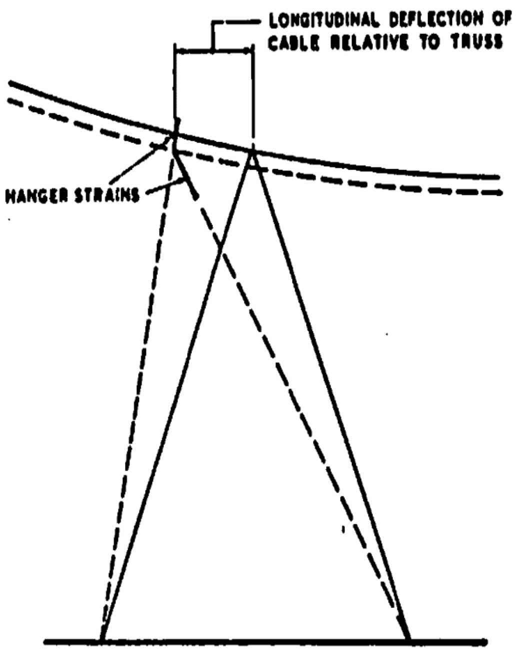
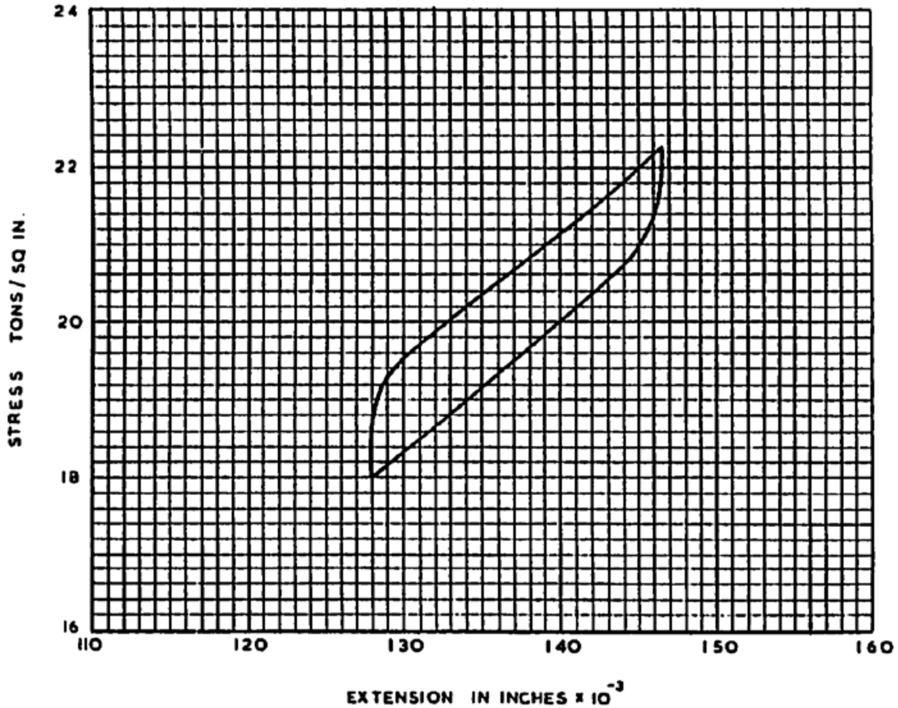


Fig. 4 (left)

Hanger strain du[e to]
bridge oscillation

Fig. 5 (below)

Typical hysteresis curve for hanger strand.



Structural Design of Box

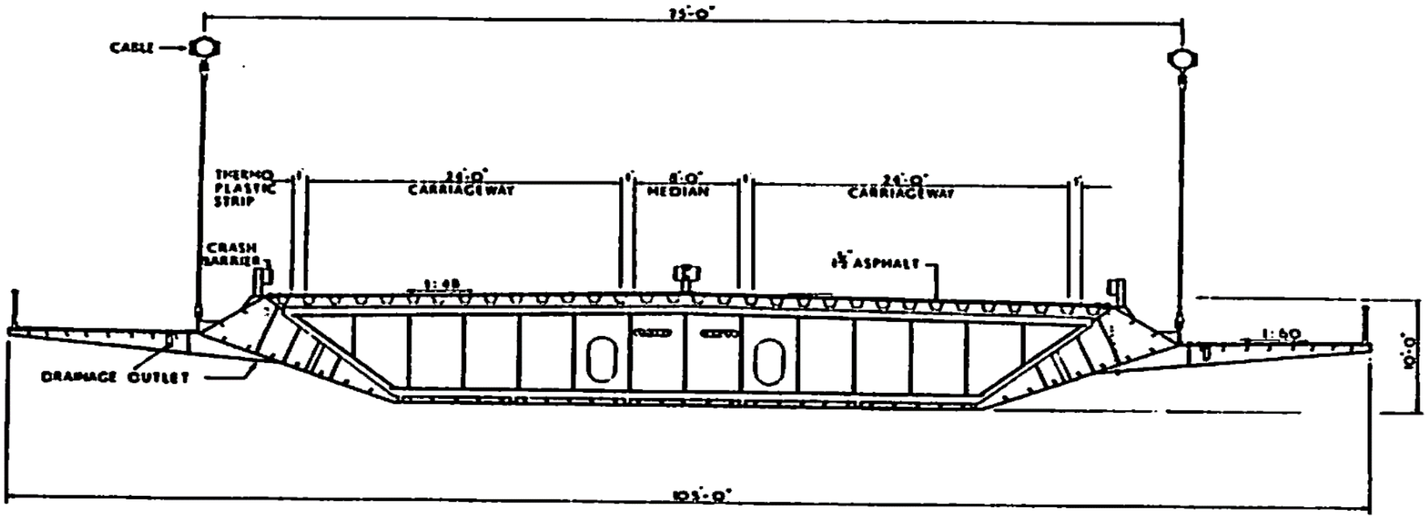


Fig. 7. Deck cross-section

Deck height is only 1/3 of Forth Bridge

Deck → 10 % Cost Down

Comparing with truss deck

Details of Deck

- Deck plate t=12mm (t= 14mm is better now)
- U-stiffener 6mm (t= 8mm is better now)

Afterwards this details were found to be weak for fatigue

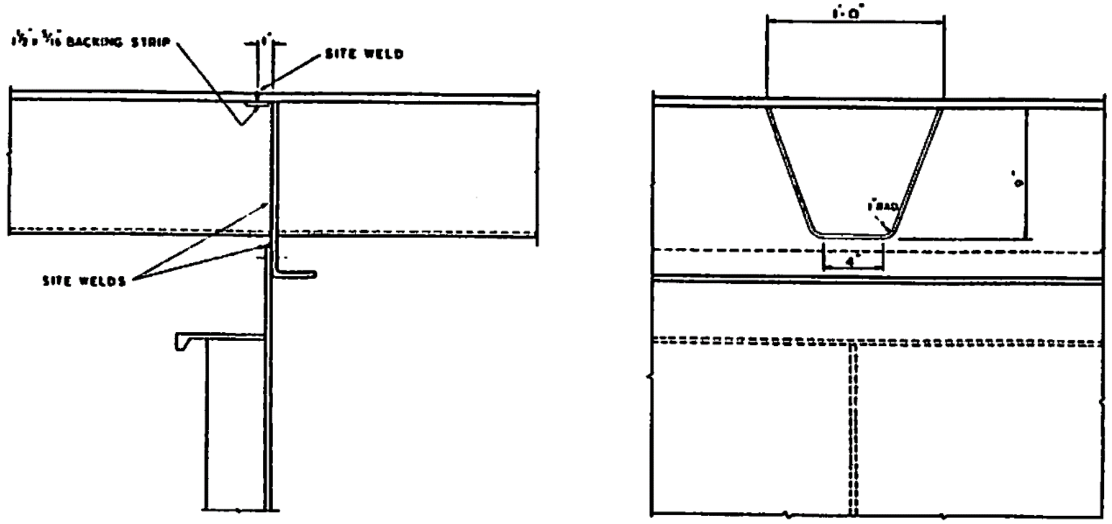


Fig. 8. Detail of deck site connection

The Design of Towers

Weight is almost half of Forth Bridge's tower

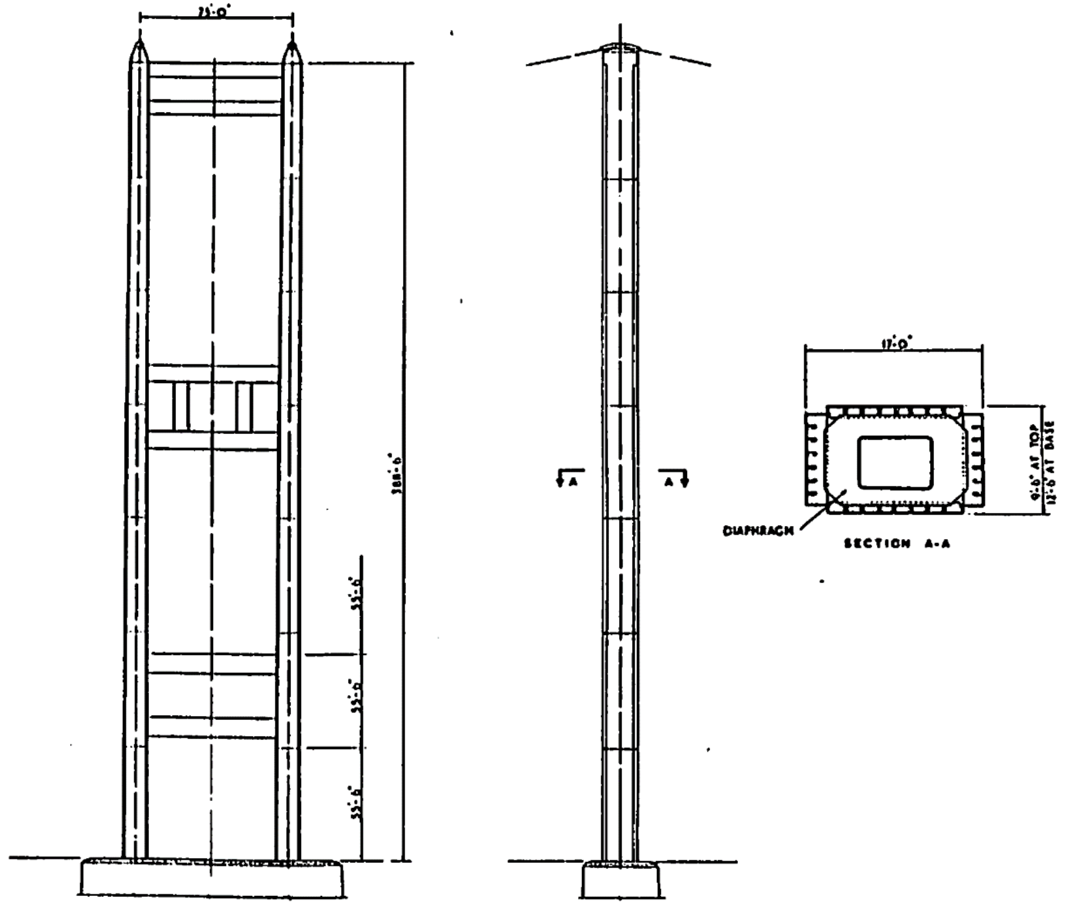
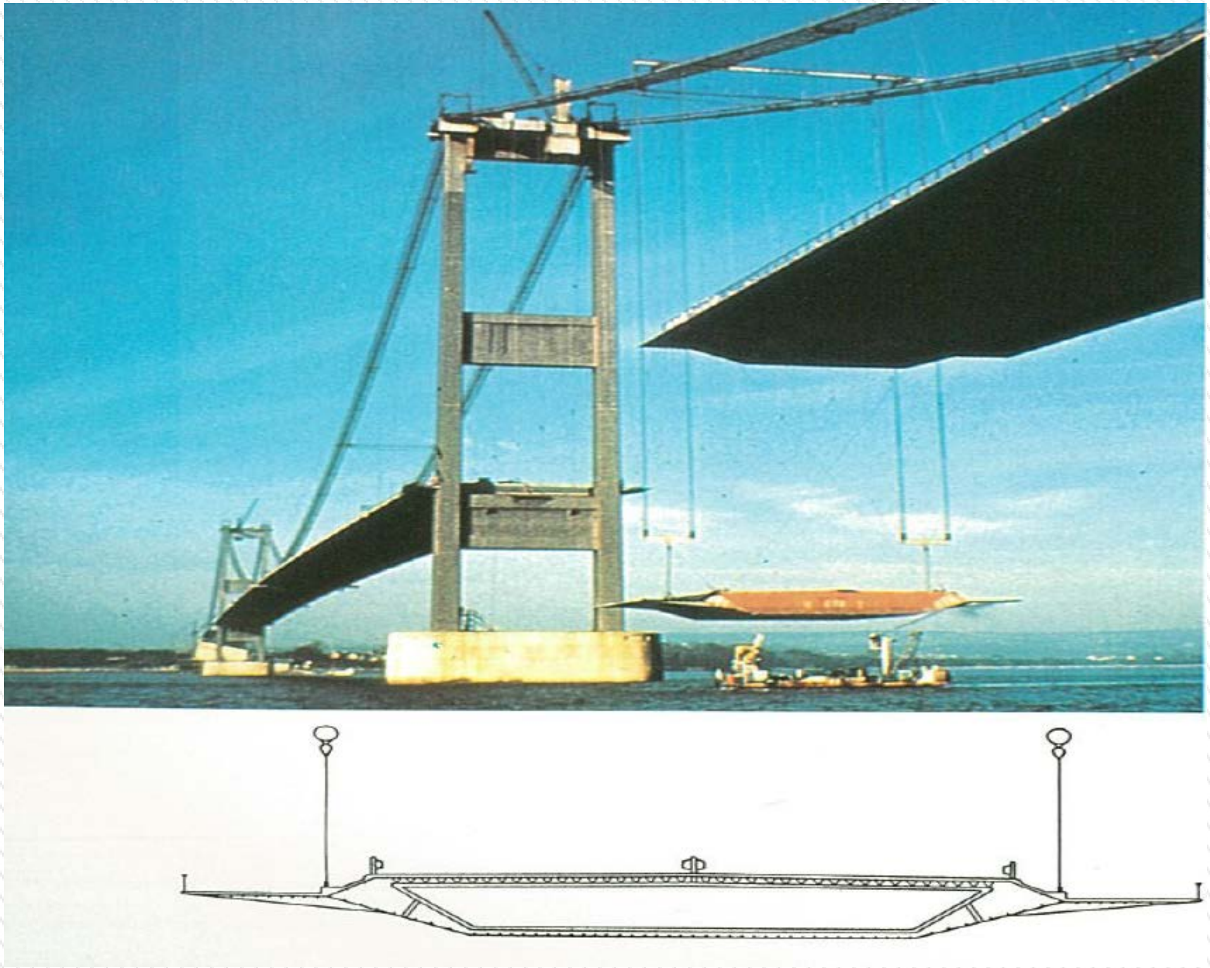


Fig. 10. Tower layout

Erecting a Deck Unit

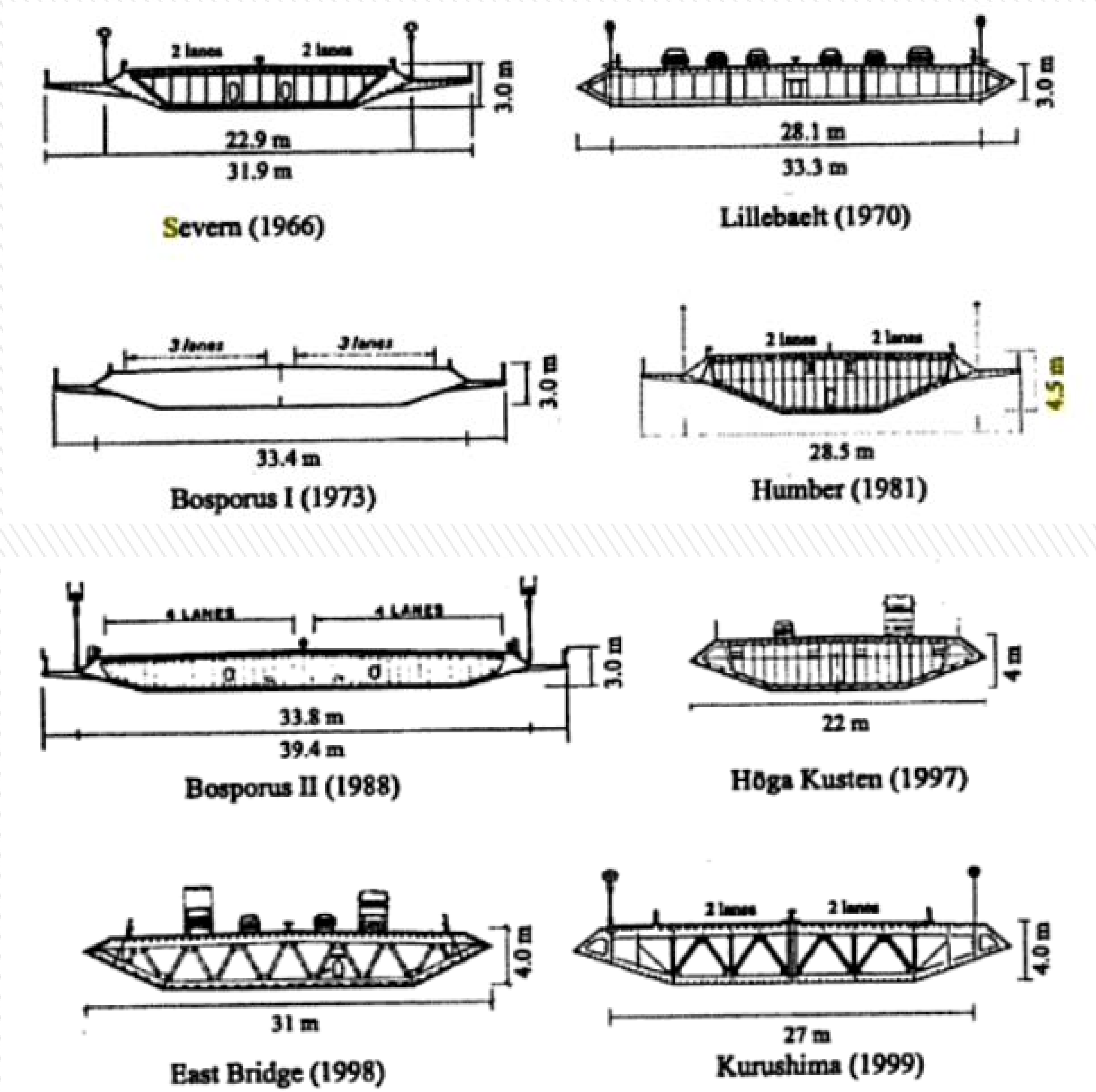
17m length deck erection →Short time erection



Moving on the River

Easy Transportation without Barge

Evolution of Box Deck after Severn Bridge



acts and Figures

OST
ubstructure £2 million. Superstructure £6 million.

IMENSIONS
lain span 3,240 ft. Two side spans each 1,000 ft. Overall idth 104 ft. 6 in.

UBSTRUCTURE

IERS
nder towers. 132 ft. long by 40 ft. wide by 63 ft. high, 5,000 tons. Aust Pier is on the Great Ulverstone Rock, eachley Pier rests on two 60 ft. diameter concrete cylinders n bed rock 33 ft. below river bed.

NCHORAGES
55 ft. long by 110 ft. wide by 140 ft. high, 90,000 tons each. argely hollow, they anchor the ends of the main cables and ach anchorage resists a pull of nearly 20,000 tons.

UPERSTRUCTURE

OWERS
ach tower is 400 ft. high and weighs 1,300 tons. It is ormed by two cellular legs constructed from welded high ensile steel plates, varying from 1 in. to 9/16 in. thick, and apped by welded steel saddles which take the load of ,600 tons from each cable. Two sides of the leg have a onstant width of 17 ft. and the other two taper, being 12 ft. ide at the bottom of the tower and 9 ft. 6 in. at the top.

MAIN CABLES
20 in. diameter, formed of 8,322 wires each diameter, bunched together with cast steel clamp apart to which are attached the suspender ropes ea diameter. Tension in one cable is 11,400 tons and w each cable and the suspended ropes is 2,600 tons.

ROADWAY
Two 24 ft. carriageways, and one 12 ft. cycle track, 12 ft. footpath cantilevered out at the sides. There box sections 104 ft. 6 in. wide, 60 ft. long and 10 each weighing 127 tons. These were assembled at Cl and floated down the Wye, lifted by special tack main cables and welded together end to end.

MATERIALS
Concrete in substructure, 126,000 cu. yds. superstructure 18,500 tons.

DESIGN
The design differs from that of previous suspension in that the torsionally stiff box combined with the suspenders provides aerodynamic stability and obv need for a stiffening girder. The design provides e by lightening the deck, which is itself cheaper and consequential savings to be made in the cables, tov substructure. The originator of this remarkable Sir Gilbert Roberts, a partner of Freeman, Fox and who has patented it in the U.S.A., Canada, Italy, and Germany. The foundation problem was solve late Vernon Bartlett, of Mott, Hay & Anderson.

Conclusion

- Severn Bridge firstly applied box deck
- Aerodynamically stable section was developed
- Fabrication became easy with auto-welding
- Erection became fast and safe by long deck blocks
- **20% Cost Down** comparing with truss deck
- **Severn Bridge was the evolution of suspension bridge in the 20th Century**

My Opinion: Wind resistant design is the key technology for cost-down. Therefore Samsung must make efforts to develop it.

References

» Sir Gilbert Roberts, The Severn Bridge
- A New Principle of Design-
Symposium on Suspension Bridge/Lisbon 1966

» L. T. C. Rolt , The Severn Bridge
- The Story of its History and Construction
Ministry of Transport and the Welsh Office