Cable-Stayed Bridges

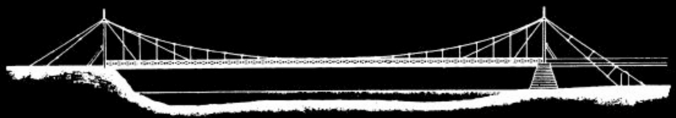
History, Aesthetics, Developments

<u>Lecture Themes</u>

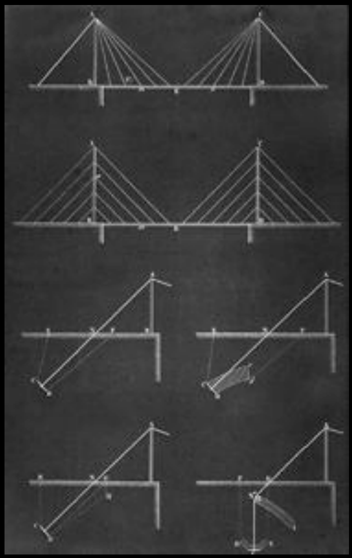
Germany rebuilds, role of technology & society in creating new forms
Understanding cable-stayed bridge form: cable, pylon, deck, material
Contrasting cable-stayed bridges with suspension bridges
Unique challenges and solutions in multi-span cable-stayed bridges
National experiences beyond Germany: America, Japan, China
Potential for play and future forms for cable-stayed bridges

www.structurae.de
Saale River Bridge, Nienburg.
Source: Walther, René Ponts haubanées

Collapse of the Salle River Bridge



1818 reconstruction

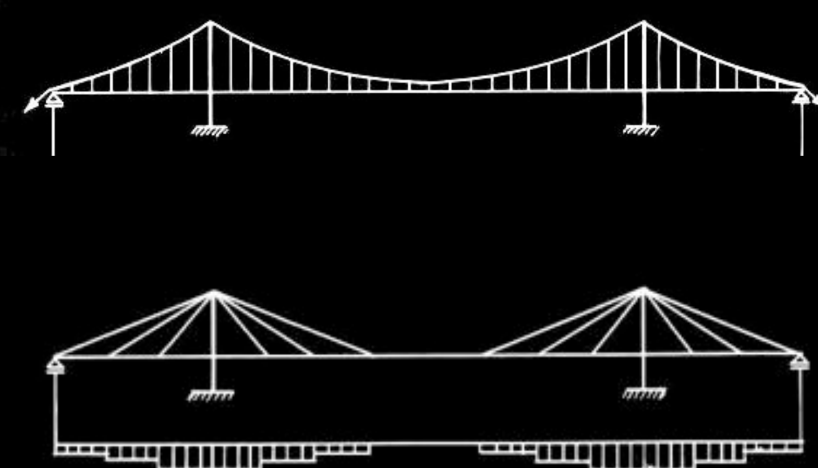


Navier
1823
Memoir on Suspension Bridges

1830, Scotland, still in service

L, Bucknell perspectives professor; R, W. McCosh current owner

www.structurae.de Nicolas Janberg



(a) deck axial forces

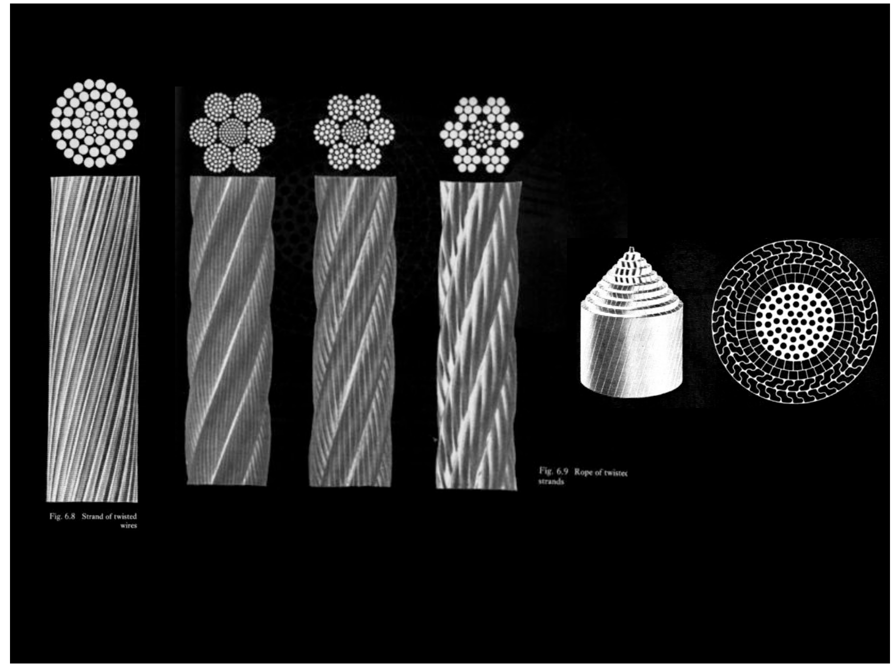
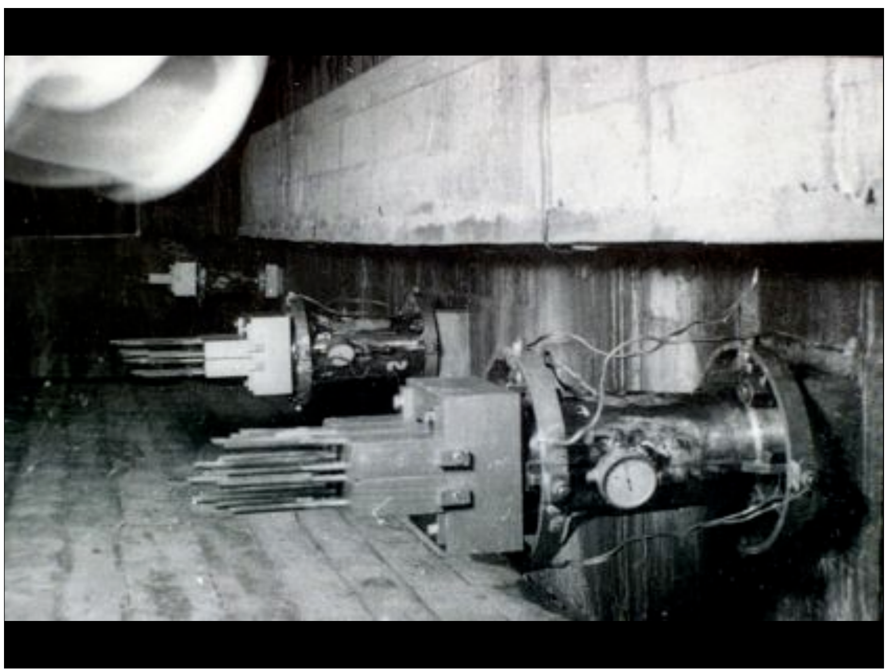
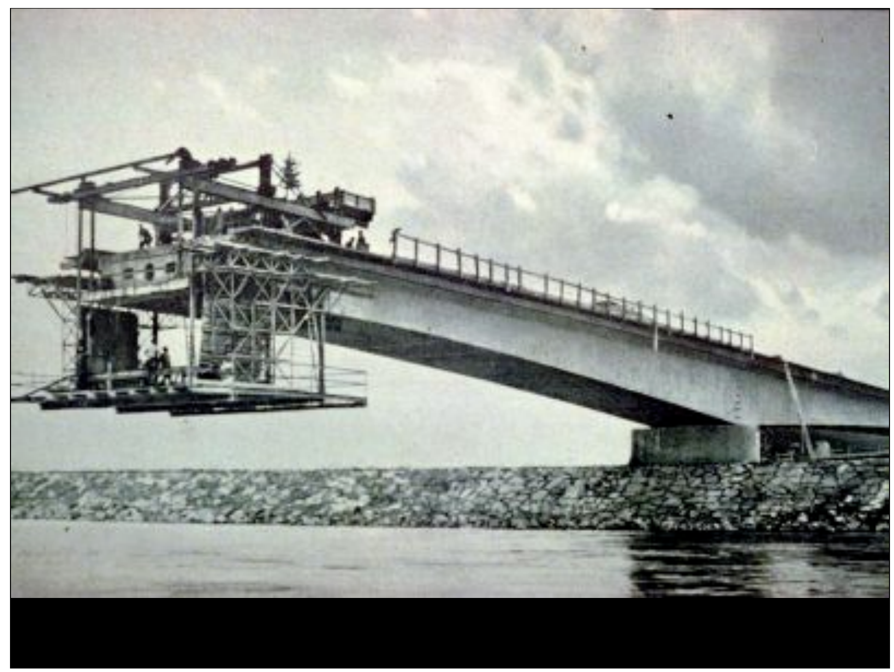


Fig. 6.8 Strand of twisted wires
Fig. 6.9 Rope of twistec strands





Germany rebuilds

F. Dischinger
1887-1953

1955 Stromsund Br
(Dischinger designed,
1st modern cable-stayed)

1957 Theodor Heuss Bridge

F. Leonhardt

www.structurae.de

1961 Severinsbrücke

1962 Norderelbe Br.

1969 Kniebrücke

Janberg - www.structurae.de

1967 Rees Br.

Holzmann – www.structurae.de

1974 Köhlbrand

Janberg – www.structurae.de

1979 Rheinbrücke Flehe

German cable-stayed bridges 1955-1979
Dischinger, Leonhardt, Holmberg, others.

How do innovations arise?

How are innovations related to the culture in which they arise?

How did new technology influence the development?

German cable-stayed bridges 1955-1979
Dischinger, Leonhardt, Holmberg, others.

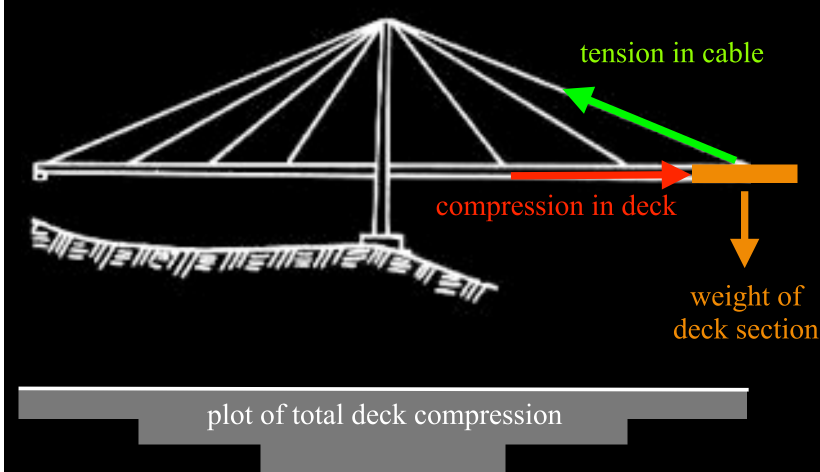
How do innovations arise?
Pressing social need (15,000 bridges destroyed in the war) and a system that ultimately proved economical for intermediate spans.

How are innovations related to the culture in which they arise?
Truss bridges also would have worked (cheaper too!). Germans rejected old forms on aesthetic grounds, instead had an expressed desire for elegance (technic?) which led to experiments in new forms. Also, German design competitions led to innovation in systems

How did new technology influence the development?
Structural analysis innovations allowed for new confidence, but new technology came primarily from construction desires: high strength wire, hydraulic jacking, cantilever construction to name a few.

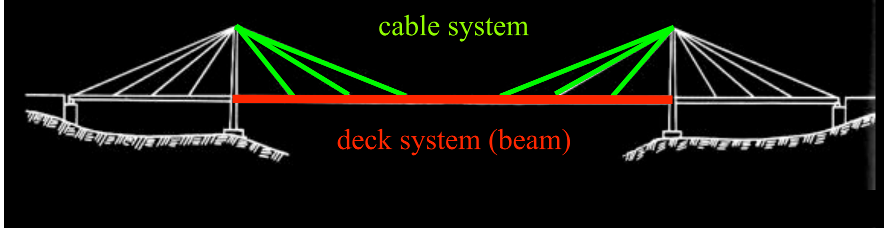
Load Paths in Cable Stayed Bridges

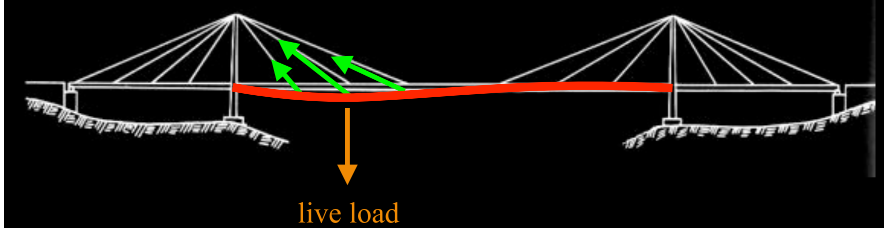
during construction



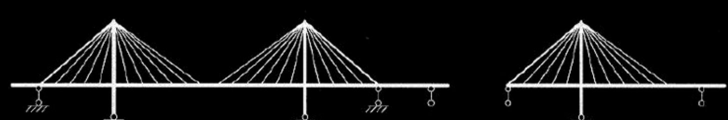
Load Paths in Cable Stayed Bridges

during use





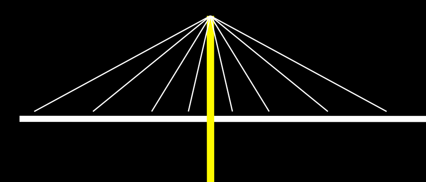
Form

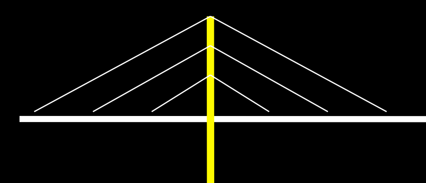


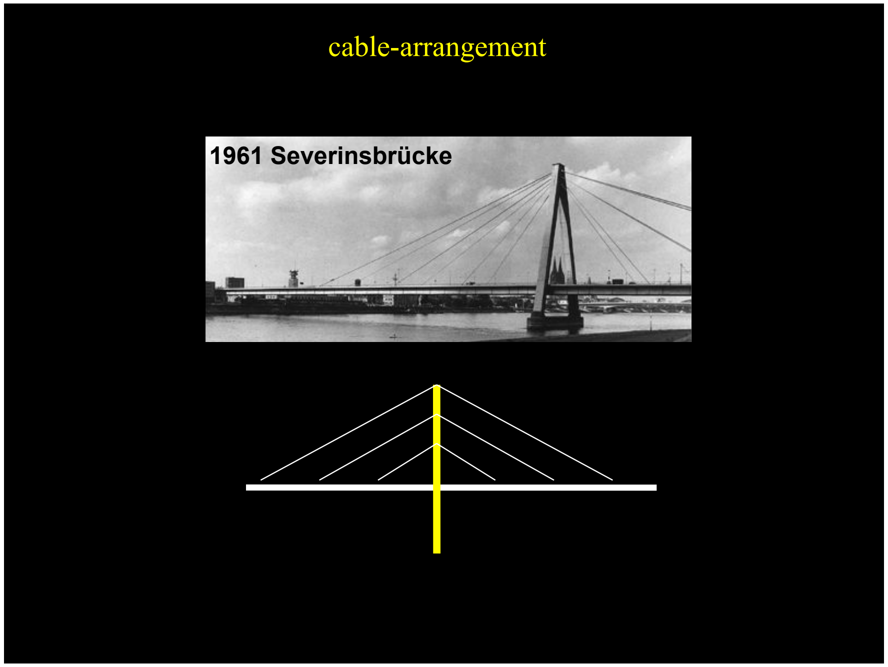
Usually if we speak of cable-stayed bridge design parameters, we have their cable-arrangement, pylon-geometry, the cross-sections and the materials of their deck etc. in mind. But the overall layout is considered to be more or less invariable: a three-span arrangement with two pylons, a main-span and two holding down side-spans, and occasionally half of that with one pylon.

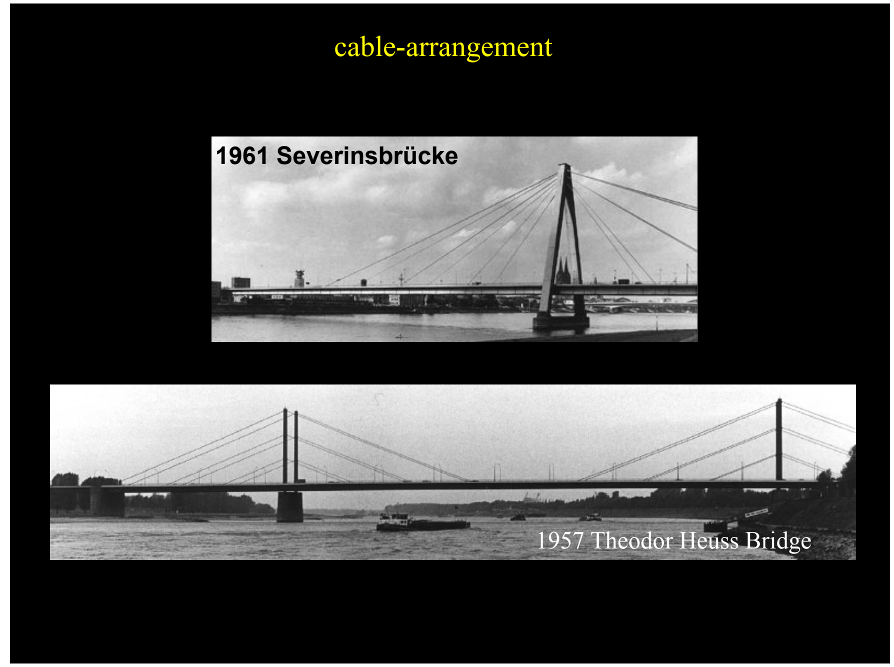
Schlaich, J.

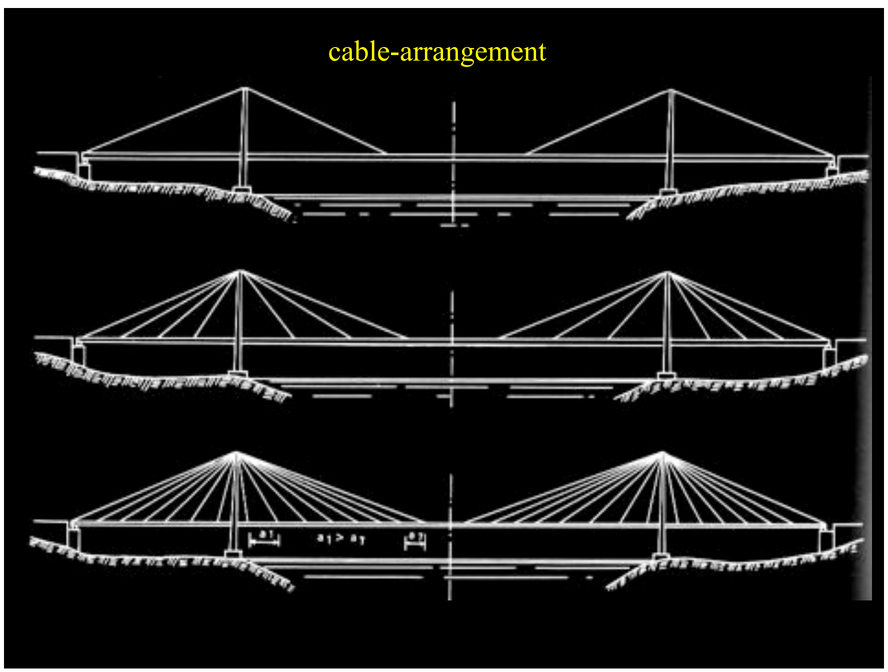
cable-arrangement

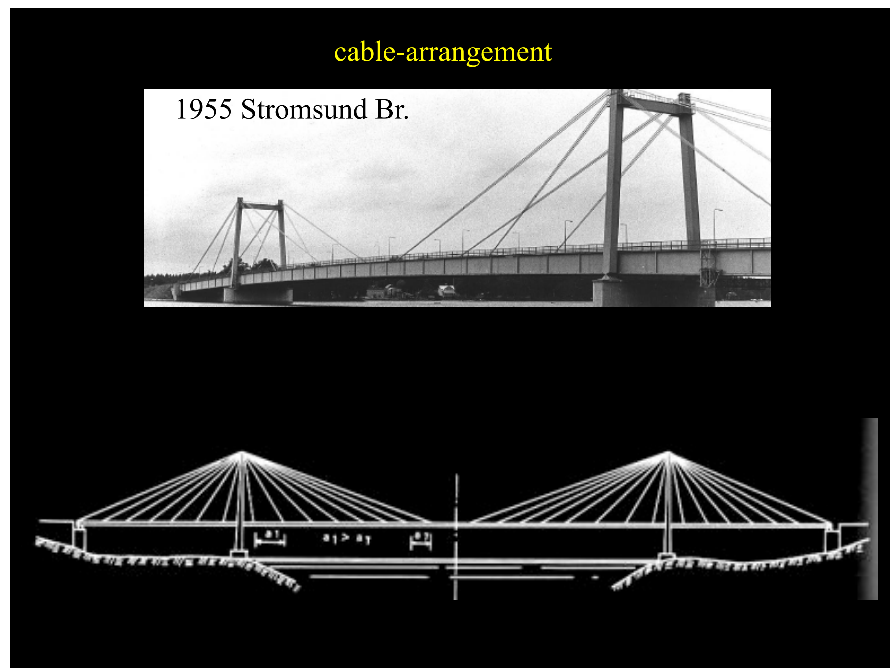




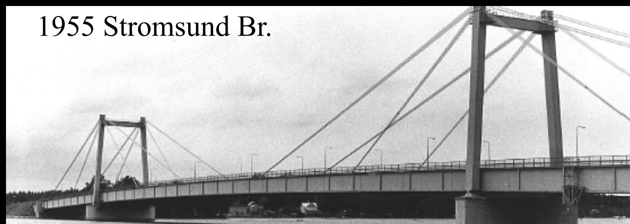

cable-arrangement
1961 Severinsbrücke

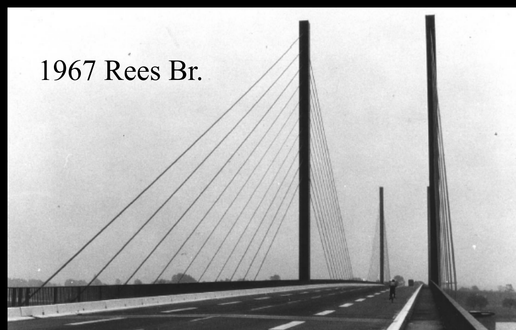

cable-arrangement
1961 Severinsbrücke
1957 Theodor Heuss Bridge


cable-arrangement

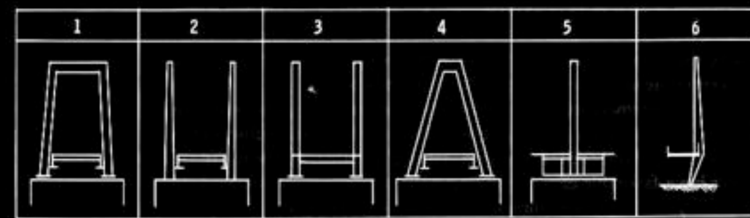

cable-arrangement
1955 Stromsund Br.

cable-arrangement

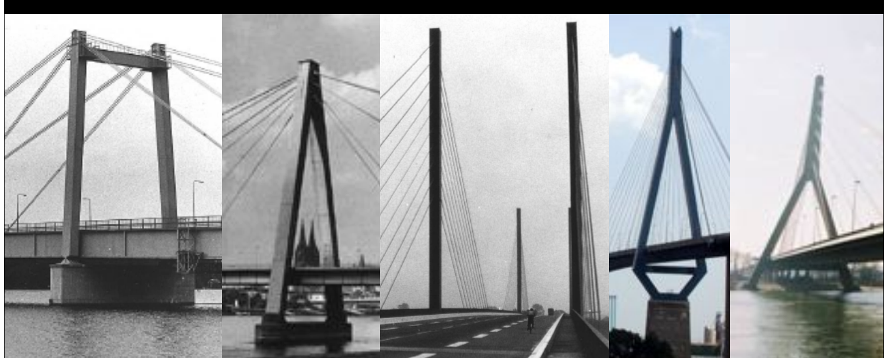




pylon-geometry

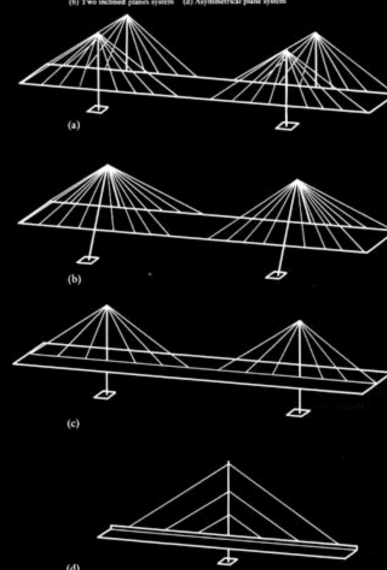


pylon-geometry



pylon-geometry

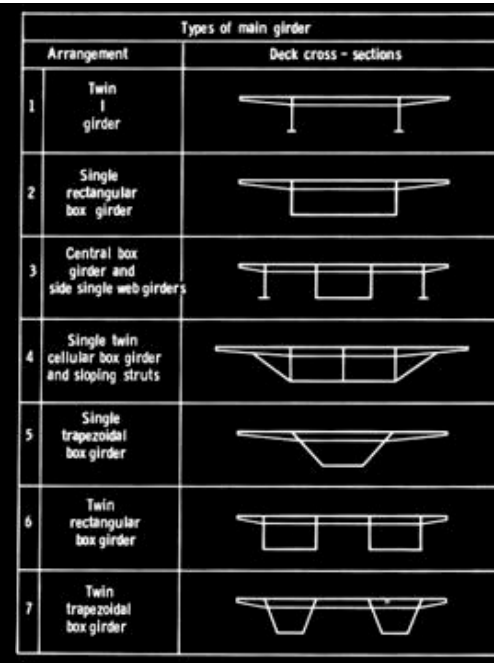
Fig. 1.31 Space positions of cables
(a) Two vertical planes system (c) Single plane system
(b) Two inclined planes system (d) Asymmetrical plane system



cable-stayed pylons/towers

suspension bridge towers

cross-sections



Types of main girder		
	Arrangement	Deck cross - sections
1	Twin I girder	
2	Single rectangular box girder	
3	Central box girder and side single web girders	
4	Single twin cellular box girder and sloping struts	
5	Single trapezoidal box girder	
6	Twin rectangular box girder	
7	Twin trapezoidal box girder	

German examples 1955-1979
Dischinger, Leonhardt, Holmberg, others.

cable-arrangement: fan or harp, single or multiple

pylon-geometry: portal, A, tower, inverted Y (λ)

deck cross-sections: rigid → flexible, continuous

materials: almost exclusively steel

the exception to the German rule

1962
Maracaibo Br.
by
R. Morandi

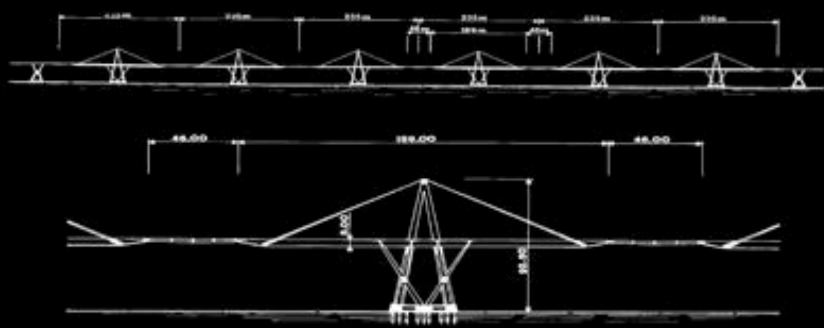
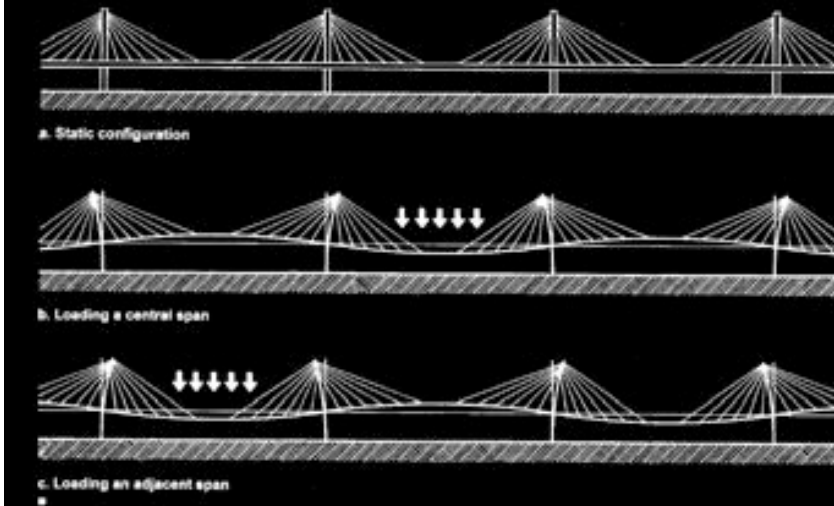


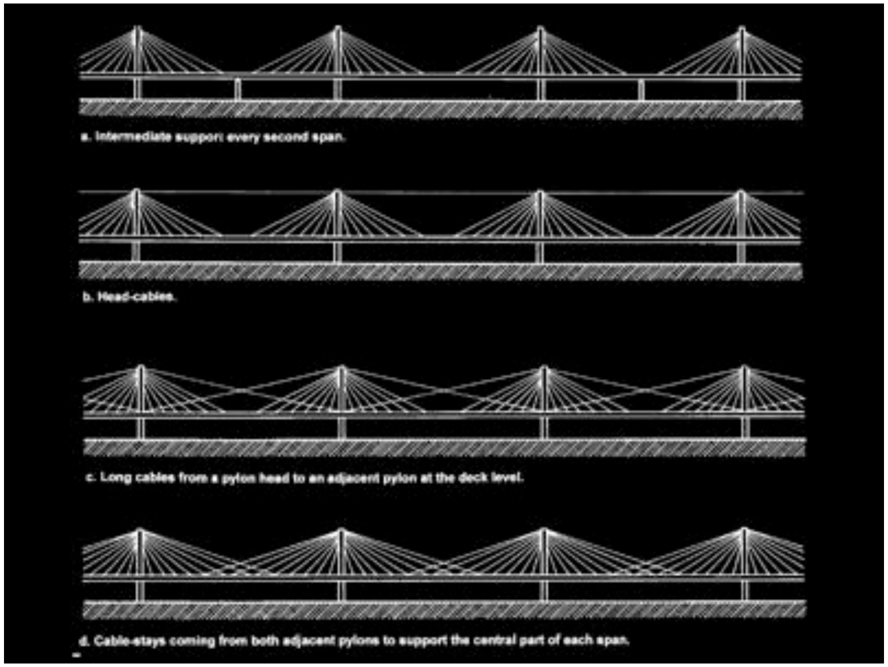
Figure 1 - Structural concept of the Maracaibo Bridge

Challenges in multi-span cable-stayed bridges

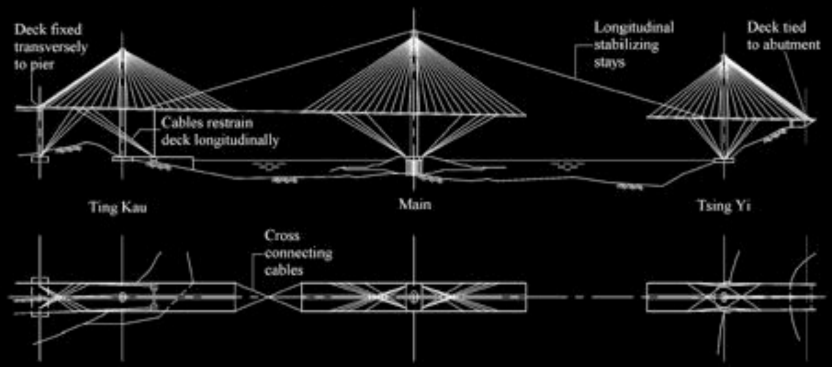


1962
Maracaibo Br.
by
R. Morandi

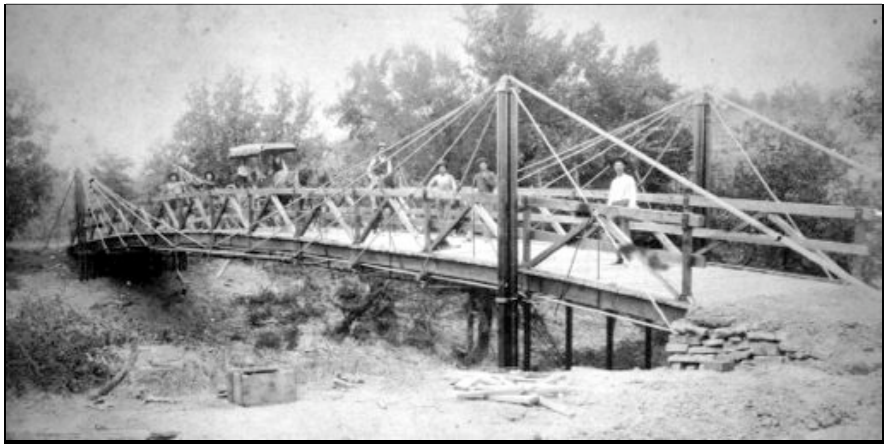
2004
Milau Viaduct
by
M. Virlogeux



Temporary wind restraints for Ting Kau during construction



The American Experience



Sunshine Skyway 1987

Dames Point

Fred Hartman Bridge (Houston Ship Channel) 1995

image courtesy www.engr.uky.edu

Stay Cable Vibrations

Stay Cable Vibrations

Google Map View 12 March 2013

The Japanese Experience

1977 Rokko Br.

Hitsuishijima and Iwagurojima

metmuseum.org

Hitsuishijima and Iwagurojima

Great Seto Bridge (some projects are on a grand scale!)

Meiko Nishi Br.

Yokohama Bay Br.

“experiments” in cable-stayed forms

J. Schlaich

Usually if we speak of cable-stayed bridge design parameters, we have their cable-arrangement, pylon-geometry, the cross-sections and the materials of their deck etc. in mind. But the overall layout is considered to be more or less invariable: a three-span arrangement with two pylons, a main-span and two holding down side-spans, and occasionally half of that with one pylon.

However, the cable-stayed bridge concept offers more and can adapt to very special boundary conditions…the outcome may be e.g. one out of a large number of feasible multi-span arrangements, or a combination of cable-stayed and cable-supported. Other situations may call for cable-stayed bridges, where the deck is not straight in plan but curved, or even for convertible or folding decks.

Schlaich, J.

Fig. 2: "Obere Argen Bridge": Proposal

Fig. 16: Folding Bridge, Kiel, completed 1998

Fig. 12: Model of the Railroad Bridge, Bad Cannstatt (under design)

Tension in architecture vs. engineering in Cable-stayed bridges - Calatrava

http://www.civilprojectsonline.com/wp-content/uploads/2011/04/Alamillo-Bride-small.jpg

154857d1326374029-margaret-hunt-hill-bridge-img_8033_1.jpg

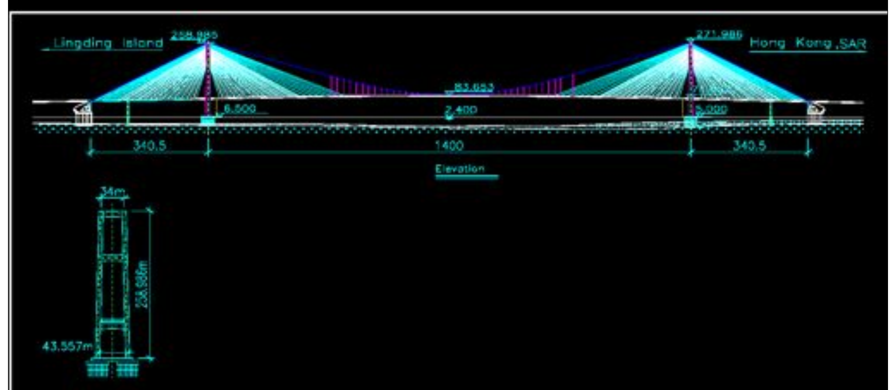
http://vlprice.files.wordpress.com/2011/10/6.jpg where do we go from here?

Longest cable-stayed bridges in the year 2000

No.	Name	Span	Traffic	Country	Year
1	Tatara Bridge	890 m	Road	Japan	1999
2	Normandie Bridge	856 m	Road	France	1995
3	Qingzhou Minjiang Br.	605 m	Road	China	1998
4	Yangpu Bridge	602 m	Road	China	1993
5	Meiko Chuo Bridge	590 m	Road	Japan	1997
6	Xupu Bridge	590 m	Road	China	1996
7	Skarnsund Bridge	530 m	Road	Norway	1991
8	Tsurumi Fairway Bridge	510 m	Road	Japan	1994
9	Øresund Bridge	490 m	**Road+rail**	Denmark/Sweden	2000
10	Iguchi Bridge	490 m	Road	Japan	1991

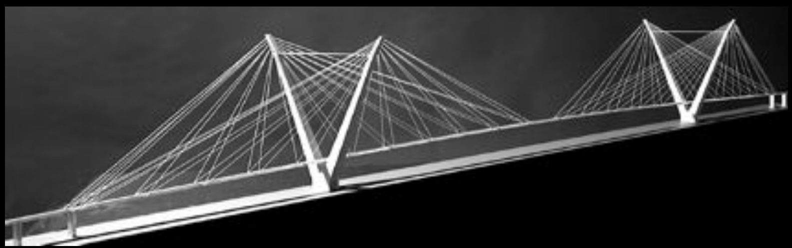
Table 1. The ten longest cable-stayed bridges at the turn of the millennium

(2008 Sutong Br. in China., 1088m became the longest)



7 of the 10 longest cable-stayed bridges are now in China

Since 2000 over ½ of all long-span cable stayed bridges (>20) have been completed in China.



UMass notes

- Journal entry due midnight 3/25
- Exam next week Thursday, study guides available on course website ce.jhu.edu/perspectives
- HW7 makeup due March 27th

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Germany rebuilds, role of technology & society in creating new forms
Understanding cable-stayed bridge form: cable, pylon, deck, material
Contrasting cable-stayed bridges with suspension bridges
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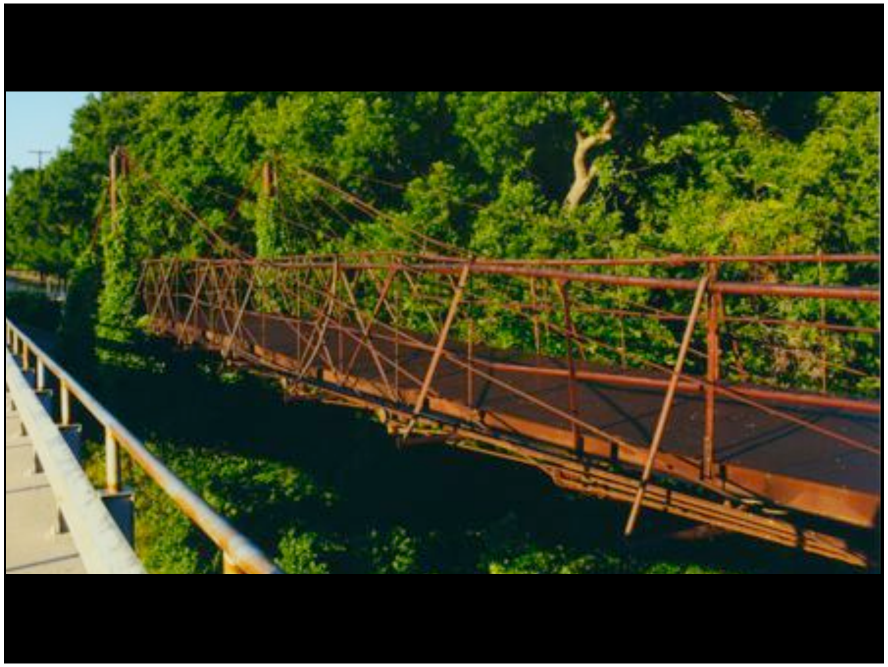
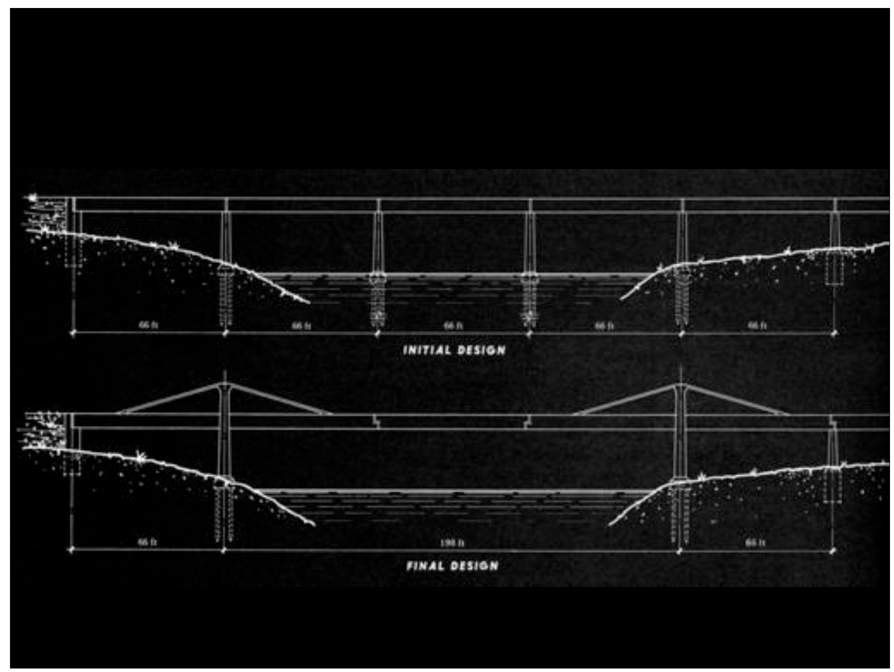
Ancillary and Superseded Slides

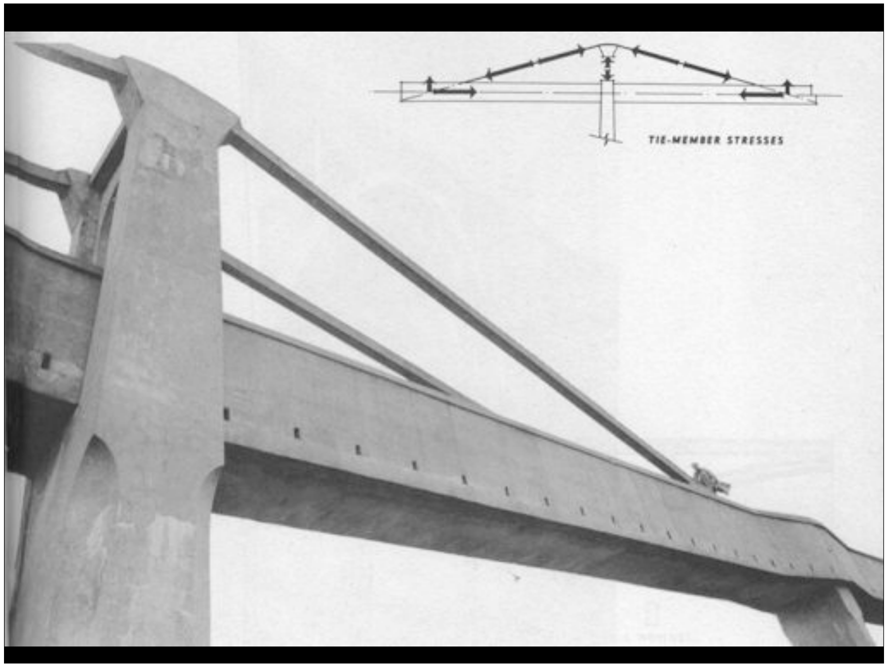
Swiss cable-stayed
Christian Menn's designs
(we will learn more about Menn...)

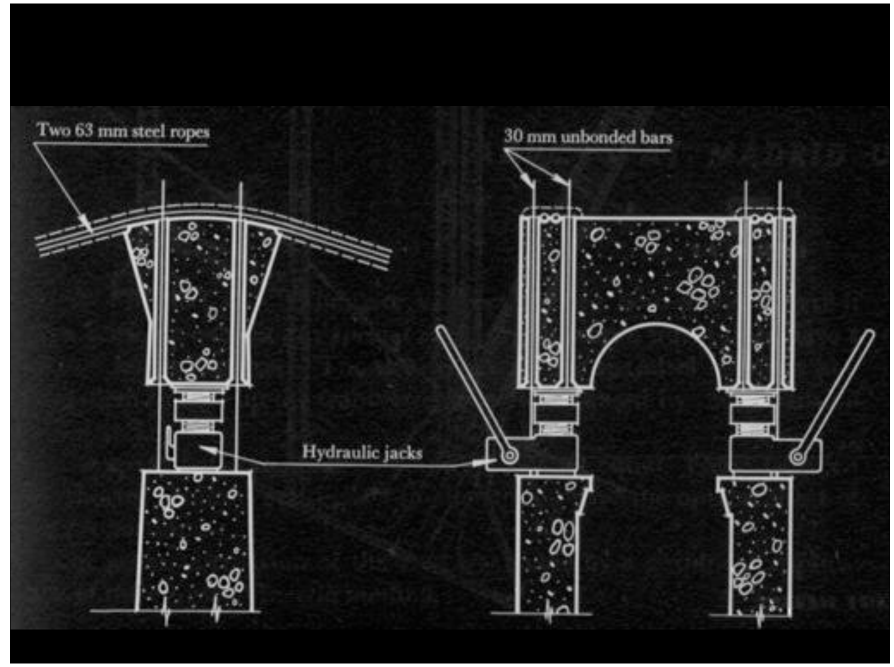
Mathis – www.structurae.de

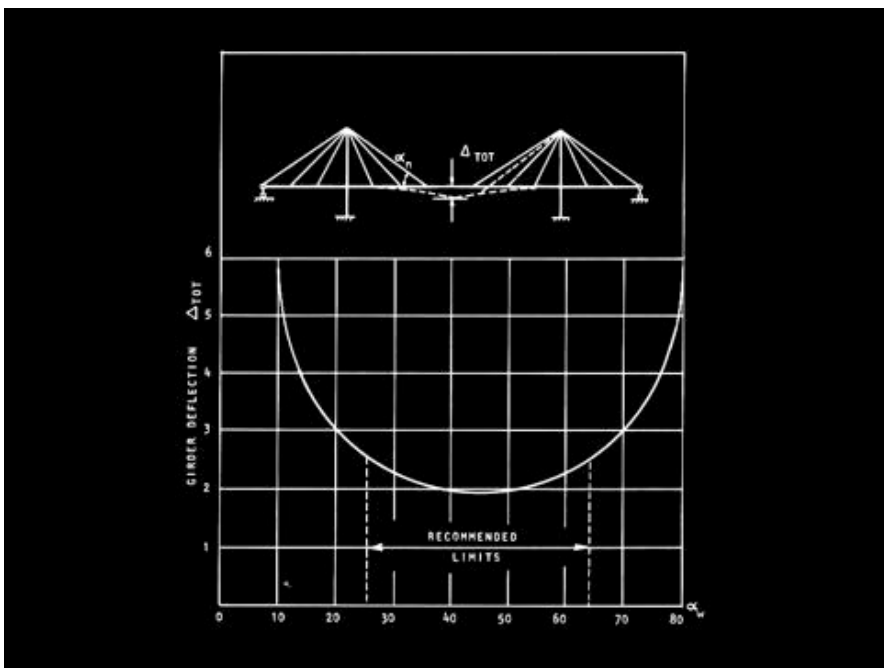



Québec
Trois-Rivières
Sherbrooke
Maine
New
Hampshire
Massachusetts
Rhode
Island


INITIAL DESIGN
FINAL DESIGN


TIE-MEMBER STRESSES


Two 63 mm steel ropes
30 mm unbonded bars
Hydraulic jacks


α_n
Δ_{TOT}
GIRDER DEFLECTION Δ_{TOT}
1
2
3
4
5
6
RECOMMENDED
LIMITS
0
10
20
30
40
50
60
70
80
α_n

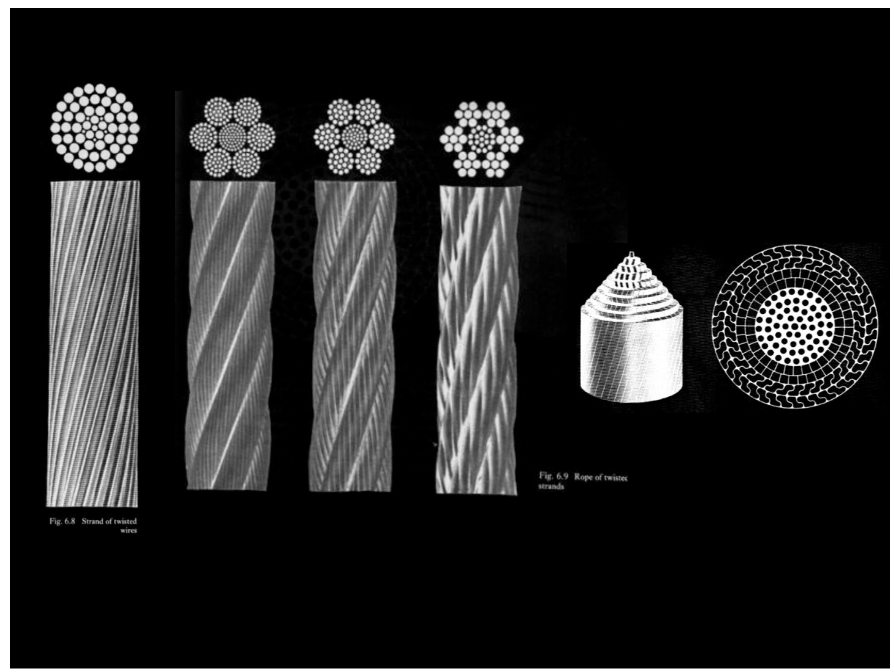
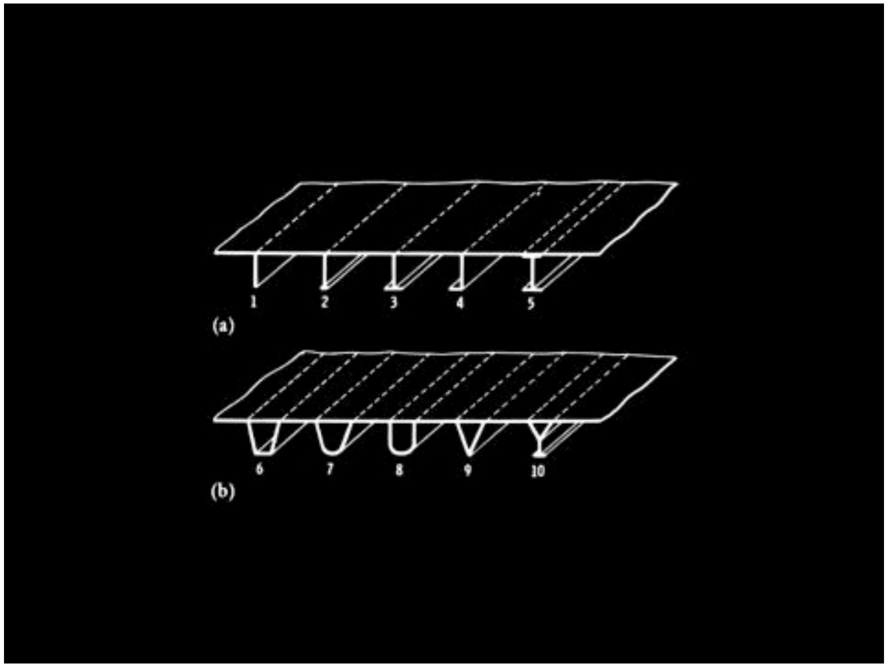
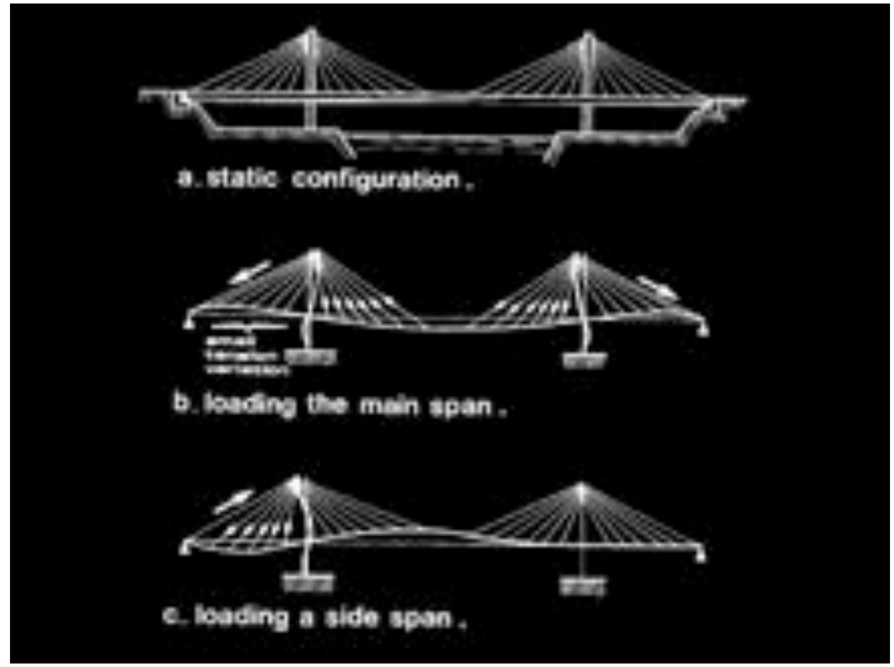
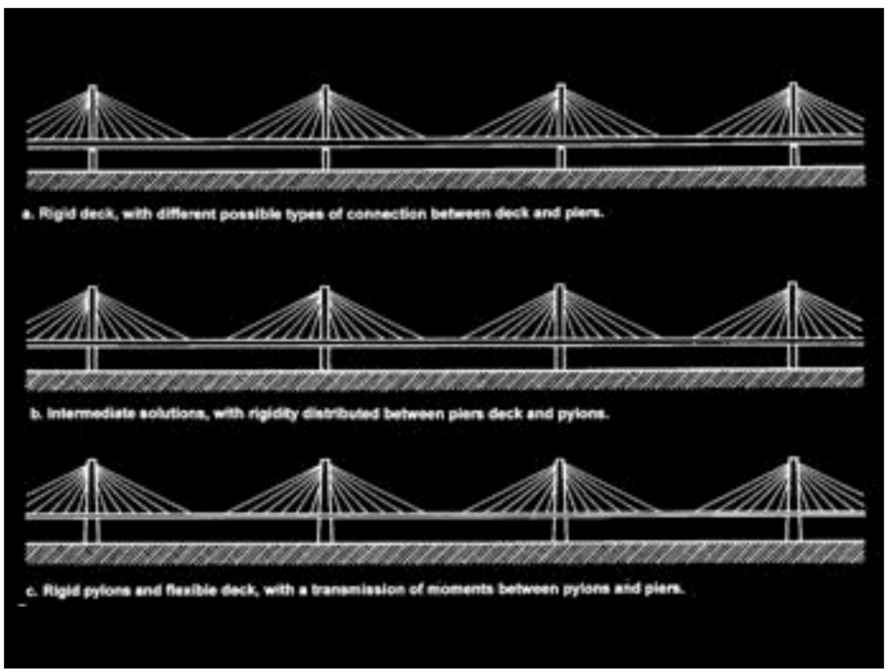


Fig. 6.8 Strand of twisted wires
Fig. 6.9 Rope of twistec strands


1
2
3
4
5
(a)
6
7
8
9
10
(b)


a. static configuration.
b. loading the main span.
c. loading a side span.


a. Rigid deck, with different possible types of connection between deck and piers.
b. Intermediate solutions, with rigidity distributed between piers deck and pylons.
c. Rigid pylons and flexible deck, with a transmission of moments between pylons and piers.

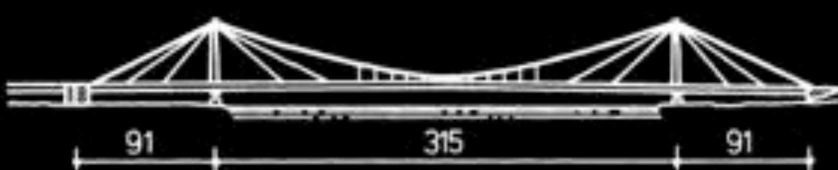


Fig.3 Dischinger's proposal for a bridge between Köln and Mühlheim.