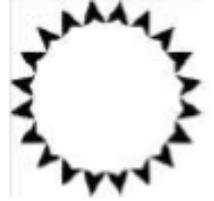




EP-USP

PEF2602
Estruturas na Arquitetura I I - Sistemas Reticulados

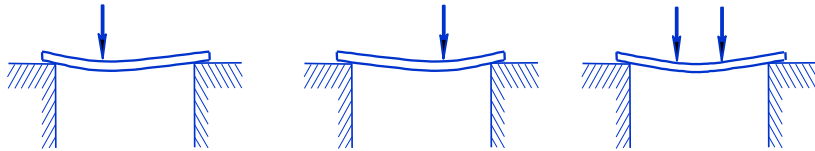


FAU-USP

- Aula 5: [*Parte I – Introdução aos cabos e arcos*
Parte II – Estudo do cabo parabólico
- Aula 6: *Parte III – Cabos e arcos poligonais*

Ruy Marcelo Pauletti, Leila Meneghetti Valverdes, Luís A. G. Bitencourt Jr.





(a) *uma estrutura rígida, como uma viga, não muda drasticamente de forma, ao variar do carregamento*



(b) *uma estrutura flexível, como um cabo, muda drasticamente de forma, ao variar do carregamento*

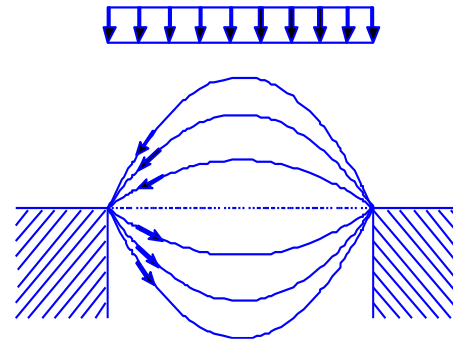
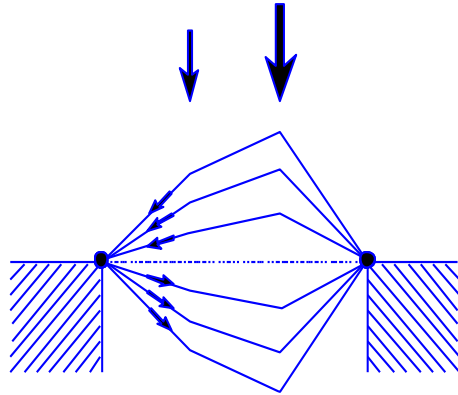


Passarela semi-destruída em Mardan, Paquistão – agosto 2006



Formas funiculares:

Aquelas que equilibram um conjunto de cargas, sem o surgimento de esforços de flexão.



To fill the vacancy of the ensuing page, I have here added a *decimate* of the *centesime* of the Inventions I intend to publish, though possibly not in the same order, but as I can get opportunity and leisure; most of which, I hope, will be as useful to Mankind, as they are yet unknown and new.

1. *A way of Regulating all sorts of Watches or Time-keepers, so as to make any way to equalize, if not exceed the Pendulum-Clocks now used.*

2. *The true Mathematical and Meechanical form of all manner of Arches for Building, with the true buttments necessary to each of them. A Problem which no Architectonick Writer hath ever yet attempted, much less performed.* abccc ddeeeeee fgg iiiiiiiii lllmmmmnnnnnoopr rrrsstttttuuuuuuuuux.

3. *The true Theory of Elasticity or Springiness, and a particular Explication thereof in several Subjects in which it is to be found: And the way of computing the velocity of Bodies moved by them.* ceiiinosssttuu. ut vis, sic tonfic

4. *A very plain and practical way of counterpoising Liquors, of great use in Hydraulicks.* Discovered.

5. *A new sort of Object-Glasses for Telescopes and Microscopes, much outdoing any yet used.* Discovered.

Hooke's anagram for the "law of the arch"
 , from Hooke, Robert (1635-1703),
*Lectiones Cutlerianæ, or A collection of
 lectures: physical, mechanical,
 geographical, & astronomical.* London:
 Printed for John Martyn, 1679.

abcccddeeeeffggiiiiiiiill
 mmmmmnnnnnoopr rrrssttttt
 uuuuuuuvx

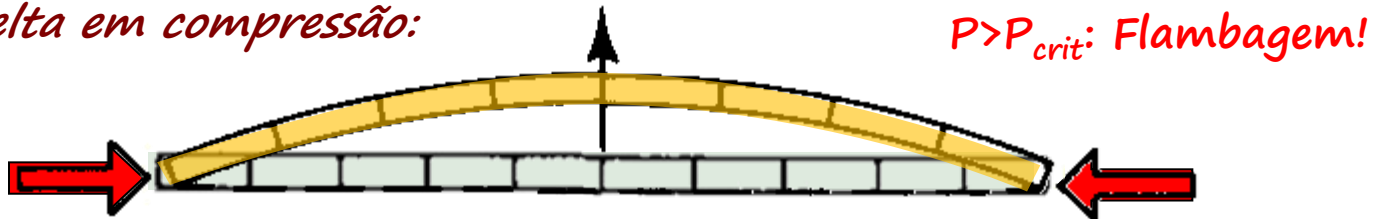
*ut pendet continuum flexile,
 sic stabit contiguum rigidum inversum*

Estados de Solicitação Interna

- Barra curta em compressão:



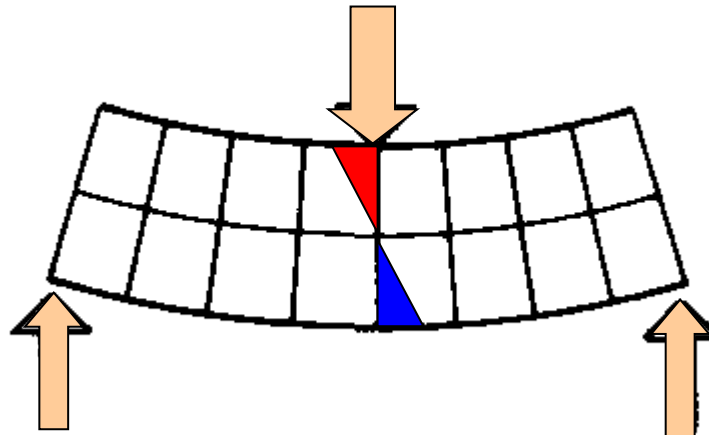
- Barra esbelta em compressão:



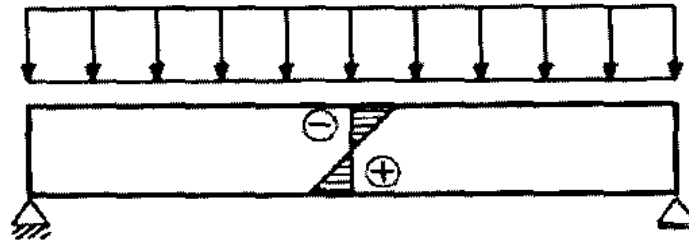
- Barra esbelta em tração:



- Barra sujeita à flexão:

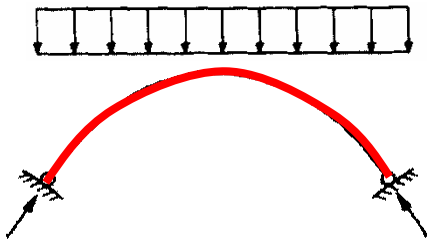


Flexão

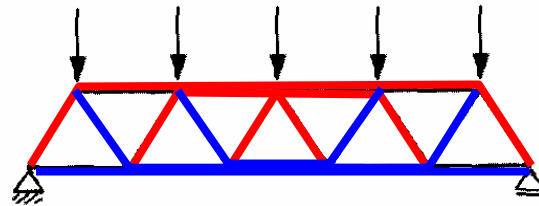


Compressão / Tração

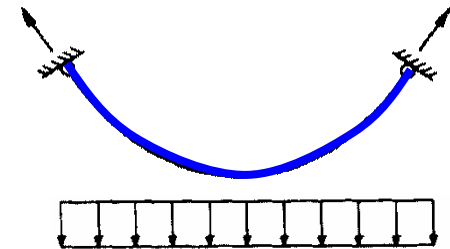
Compressão:
Arcos



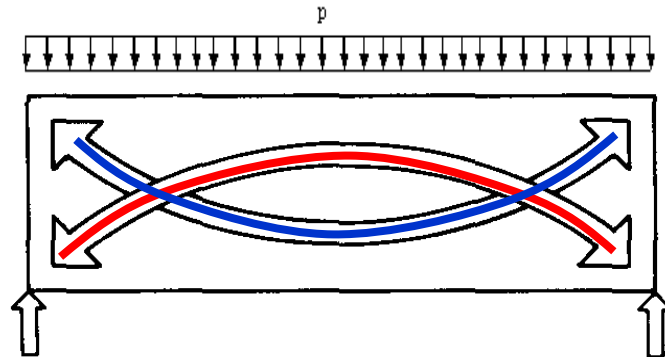
Tração + Compressão = Flexão
Vigas



Tração:
Cabos

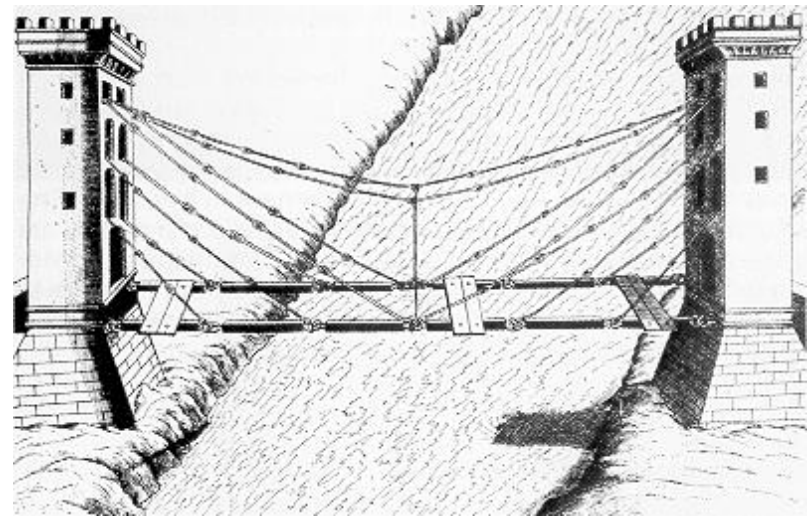
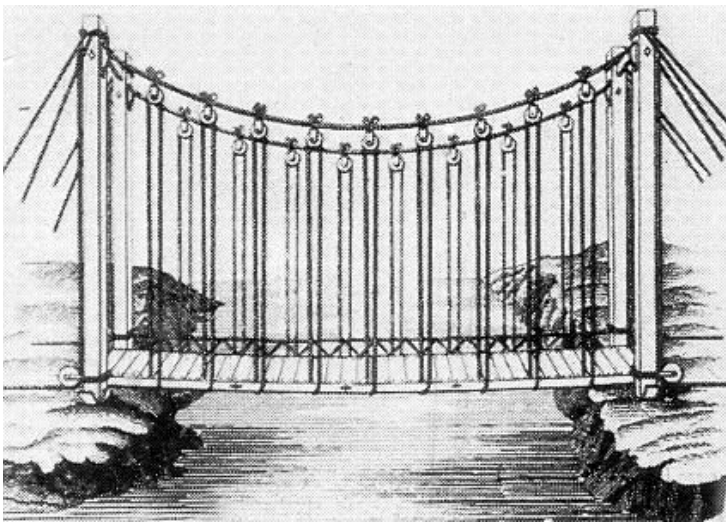


Flexão :
'Efeito Arco' x 'Efeito Cabo'

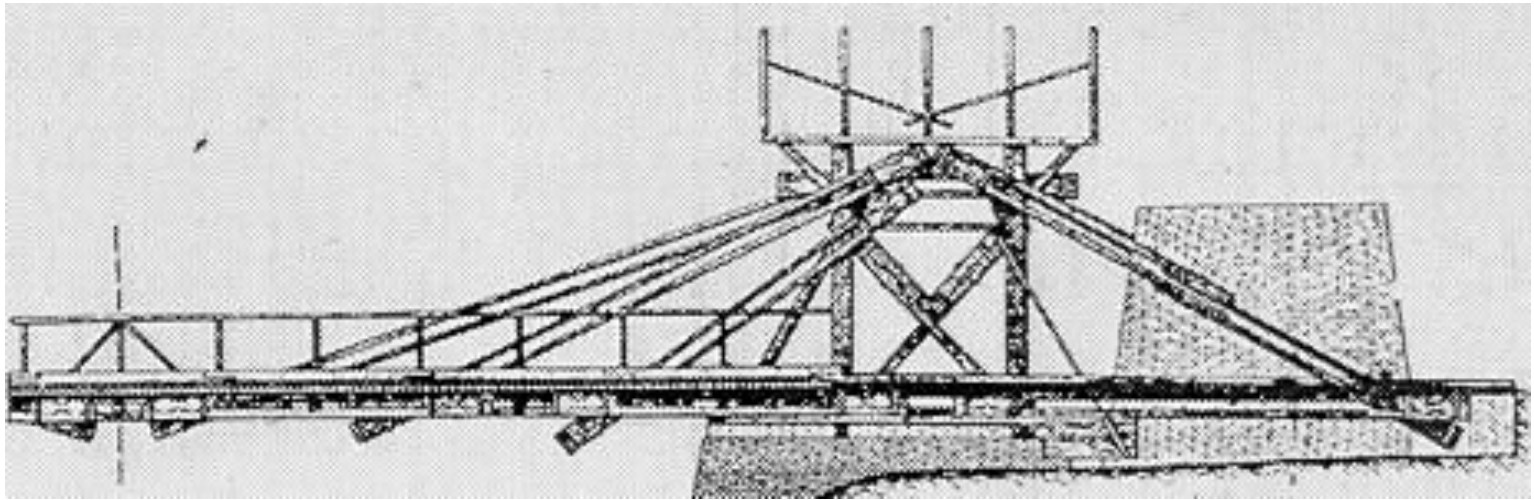


Cabos





Esquemas de Fausto Veranzio para pontes suspensas e estaiadas (1617)



Esquema de Immanuel Loscher, para uma ponte estaiada de madeira (1784)



Kazura Bashi Bridge, Japan (reconstruída a cada três anos, desde ~1200 DC)



*Ponte sobre o estreito de Menai
(1826, vão livre 177m)*



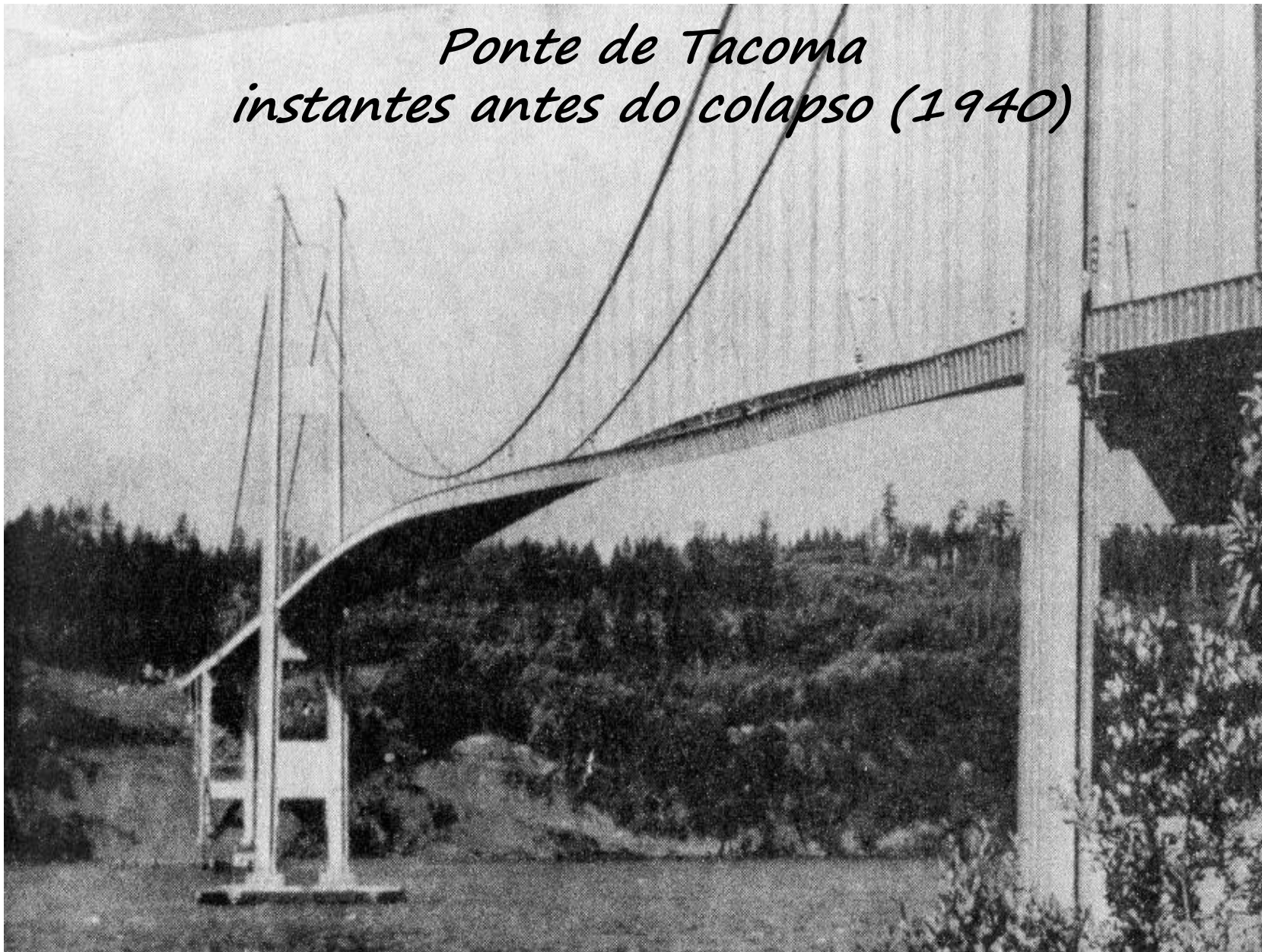
*Ponte do Brooklyn
(Nova Iorque, 1883, vão livre 486m)*





*Ponte Golden Gate
(São Francisco, 1936, vão livre 1281m)*

*Ponte de Tacoma
instantes antes do colapso (1940)*





*Ponte Akashi-Kaikyo
(Japão, 1998, vão livre 1990 m)*

Çanakkale Bridge (2022)
2,023 m (6,637.1 ft)
Gelibolu – Lapseki (Dardanelles) Turkey



*Glass bridge in Huangchuan,
Guangdong Province, China (January 2020)
Architectural Design and Research Institute of Zhejiang University (UAD),*



The 526-meter long structure is paved with a 4.5cm thick tempered laminated glass that allows visitors to gaze down at the canyon floor over 200 meters below.

Images: Lianzhou Qingtian Tourism Development.





*San Francisco Bay Bridge
Eastern span replacement*

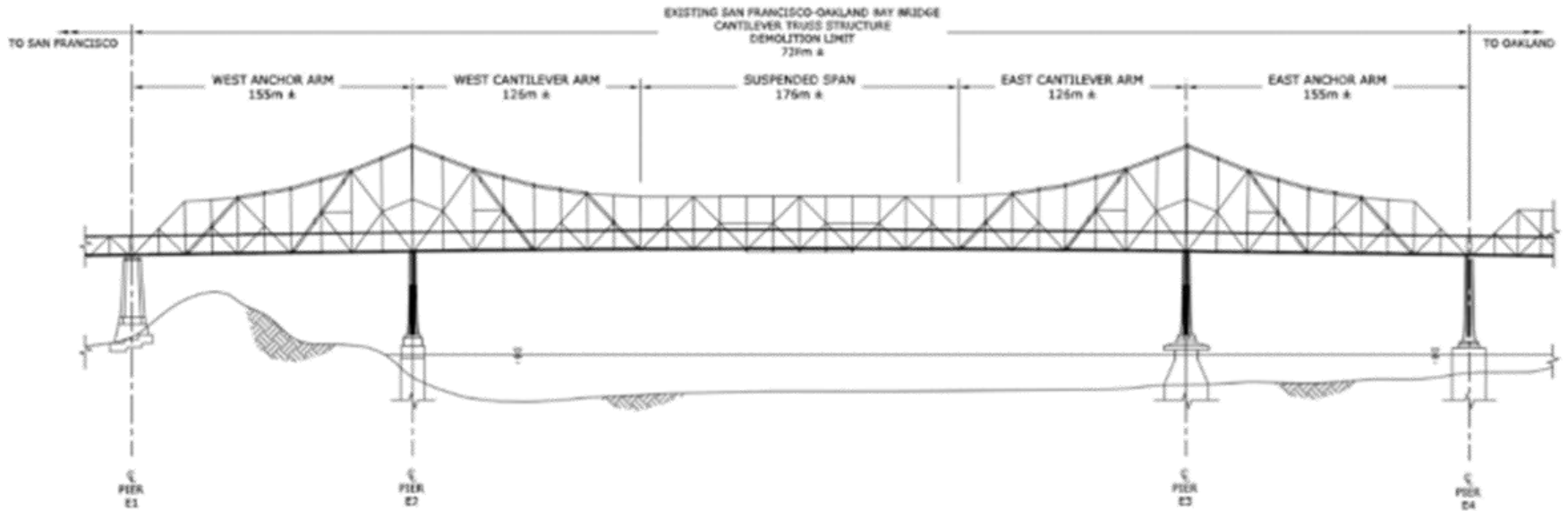
(385 max vão livre)

Altura 160m

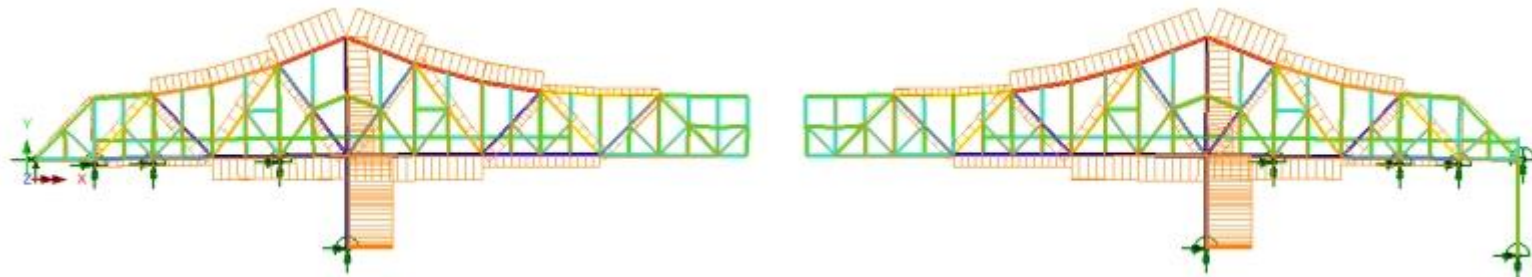
*Construction:
2002-2013*







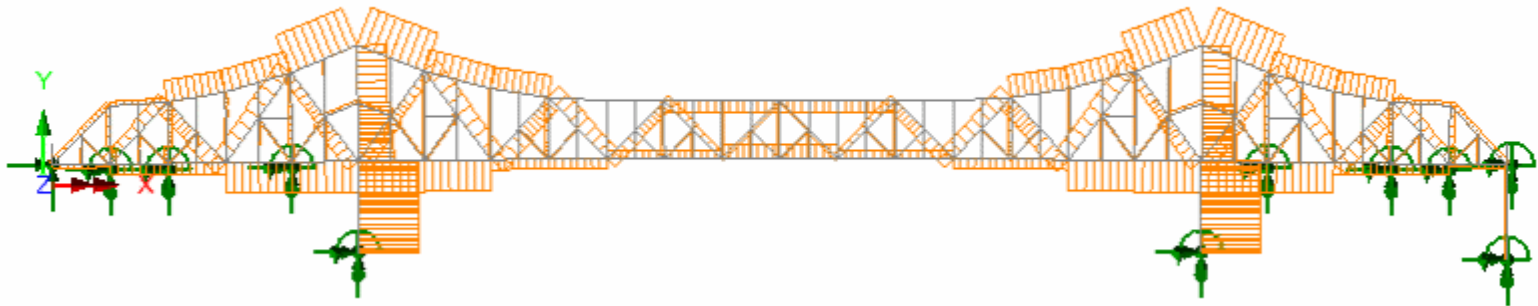
In-service axial forces prior to dismantling being carried out, with the suspended span easily identifiable



Axial forces in truss members after initial dismantling at midspan.

https://www.lusas.com/case/bridge/bay_bridge_east_main_span_demolition.html





Animation of axial forces in members during dismantling





*Ponte de São Vicente (1914).
Vão livre 180m*

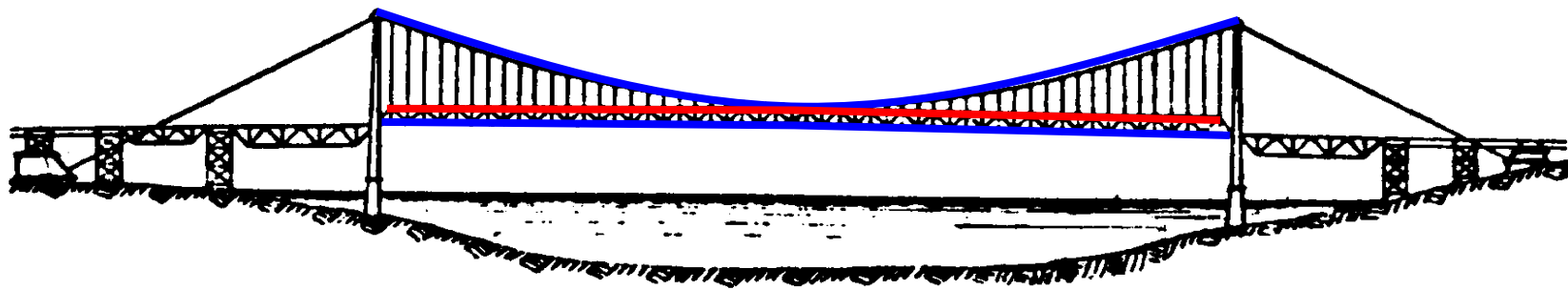


*Ponte Hercílio Luz
(Florianópolis, 1926, Vão livre 339 m)*

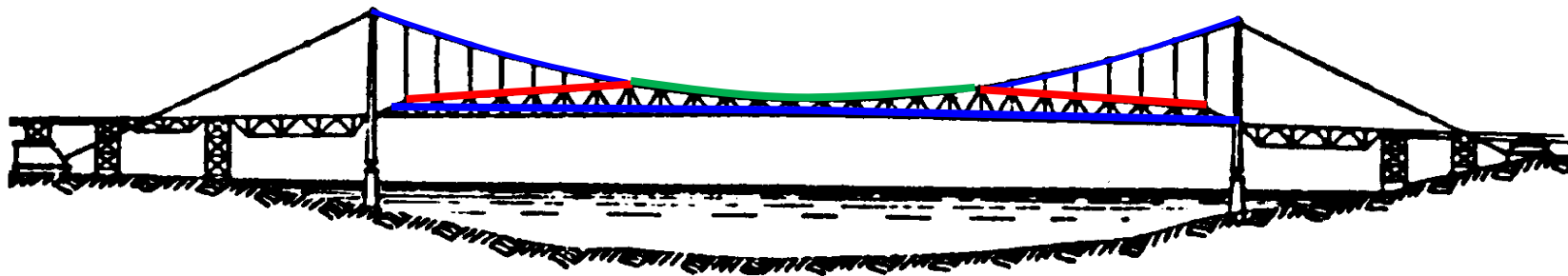


Ponte Hercílio Luz

Esquemas original e executado

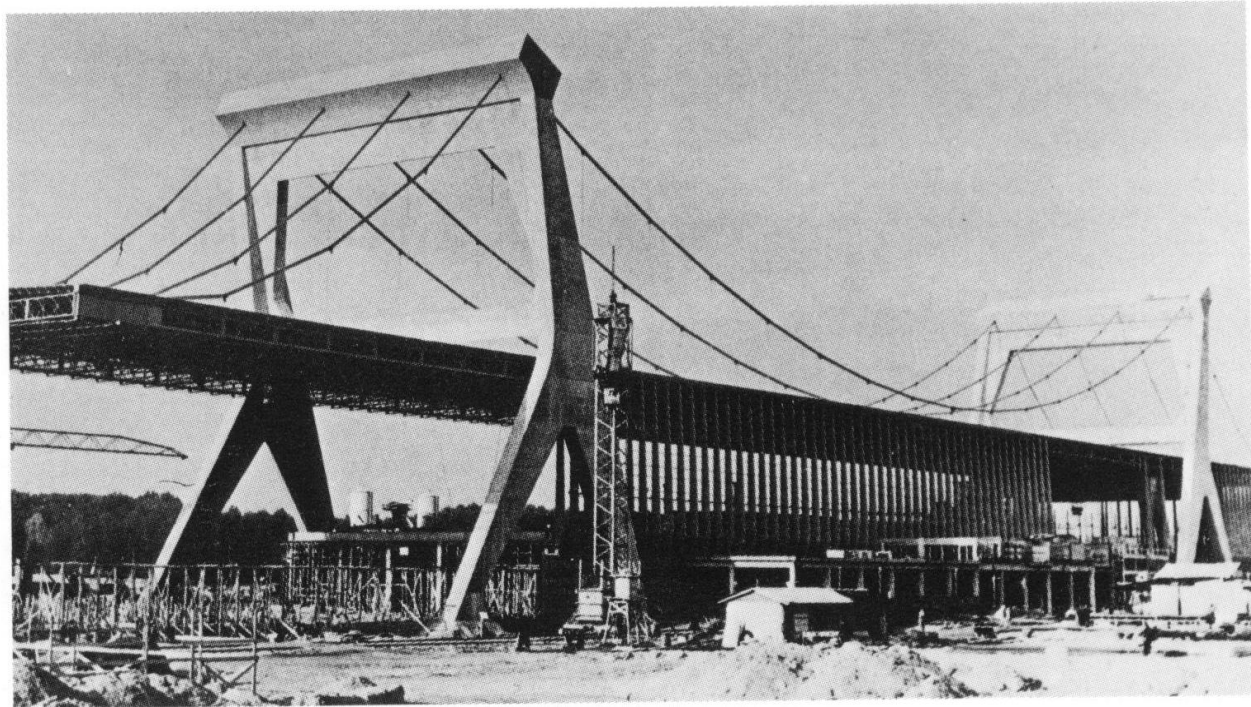
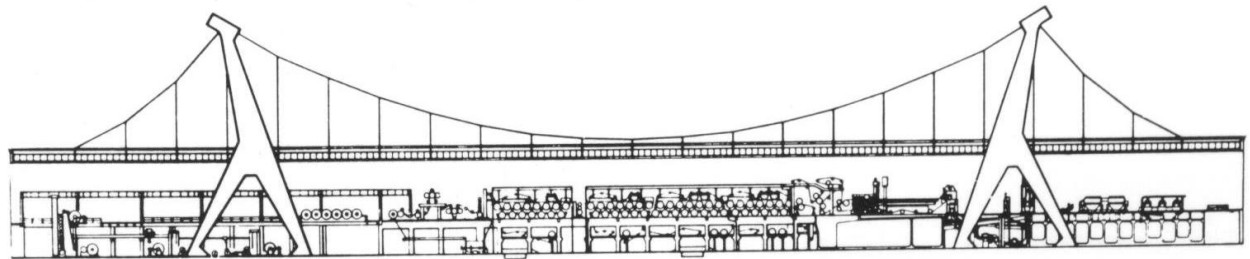
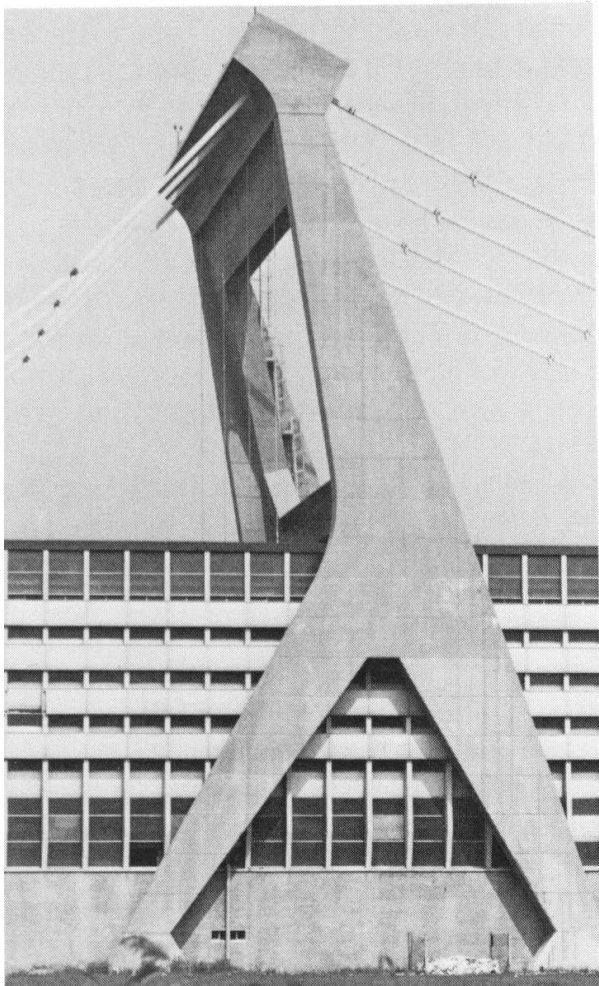


Projeto Original



Projeto Executado

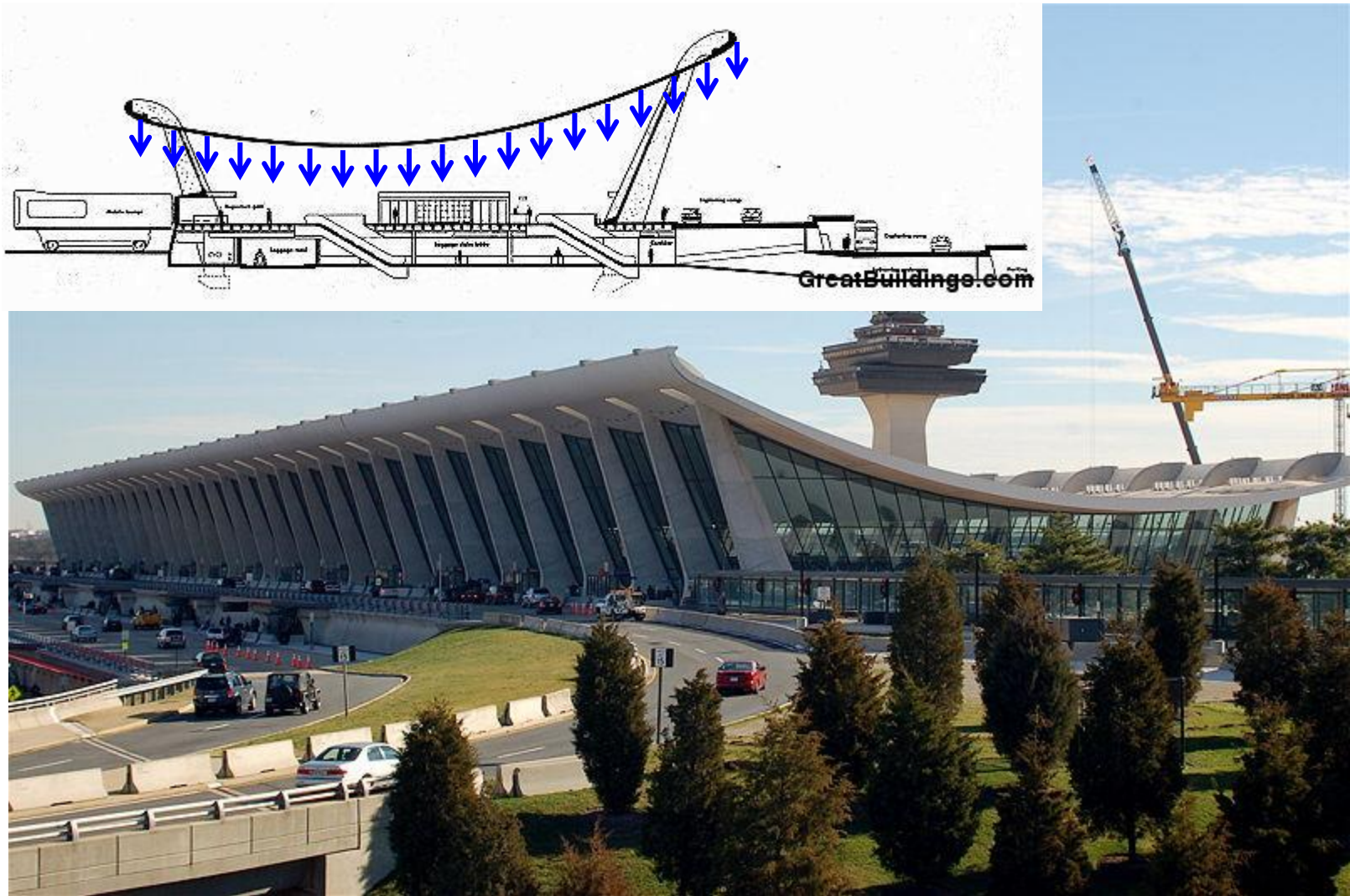
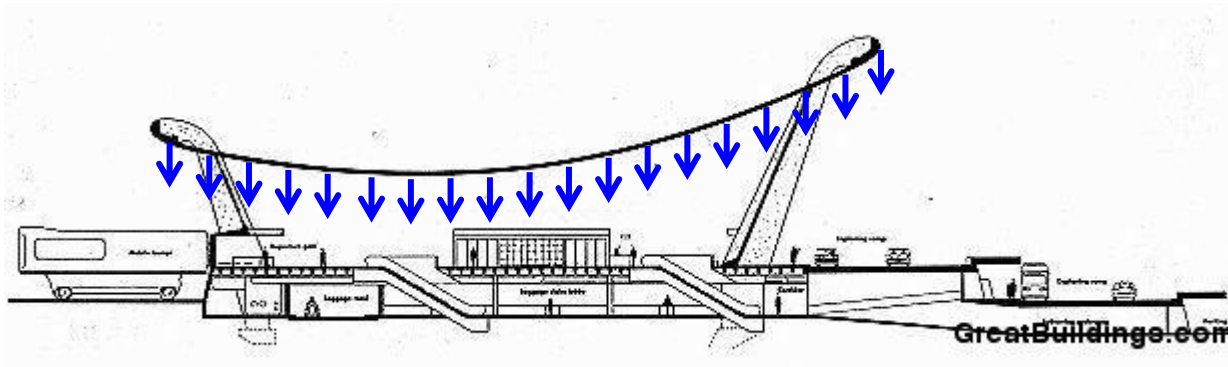


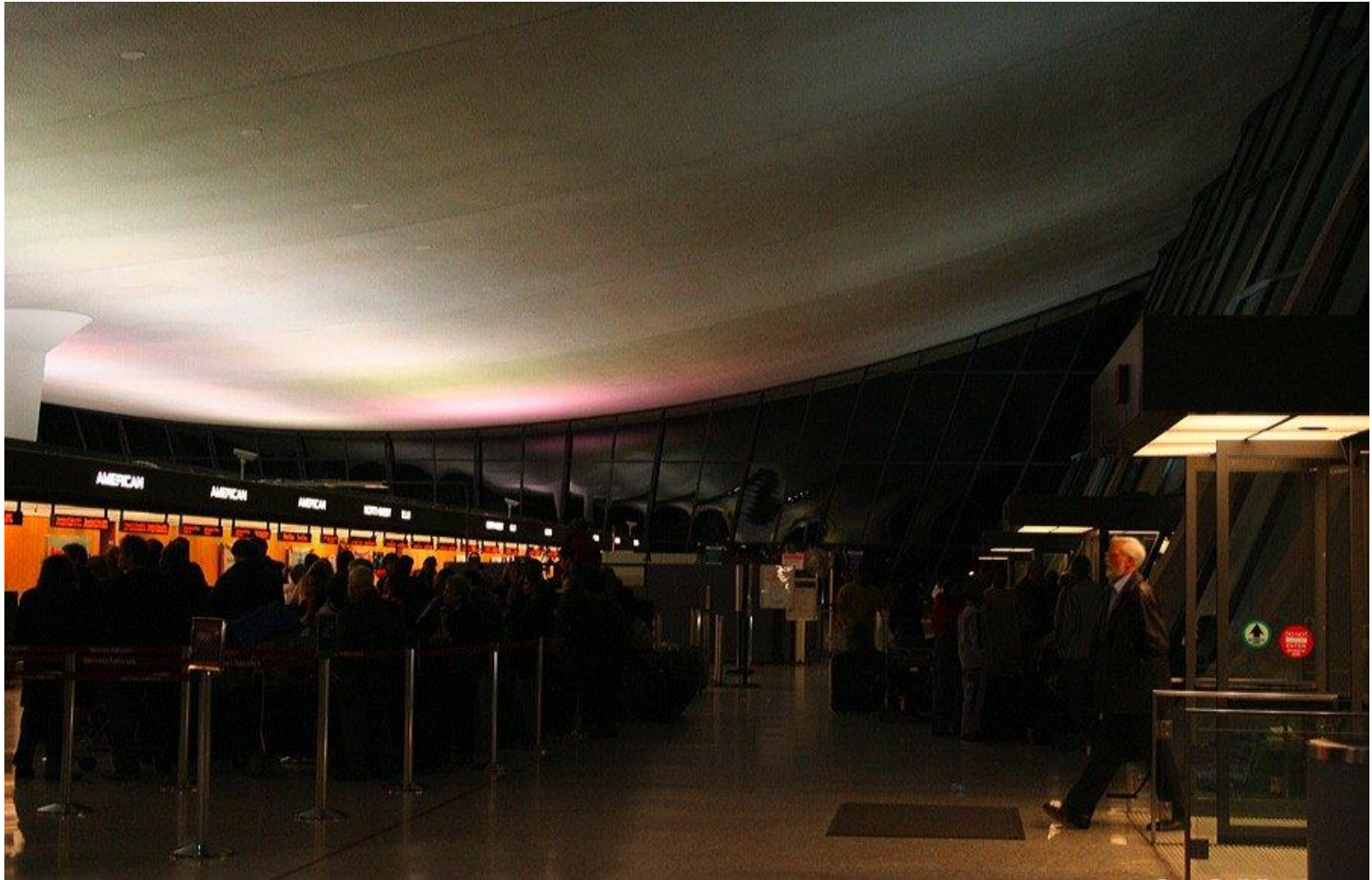


Fábrica de papel em Mântua (P. Nervi, 1963)

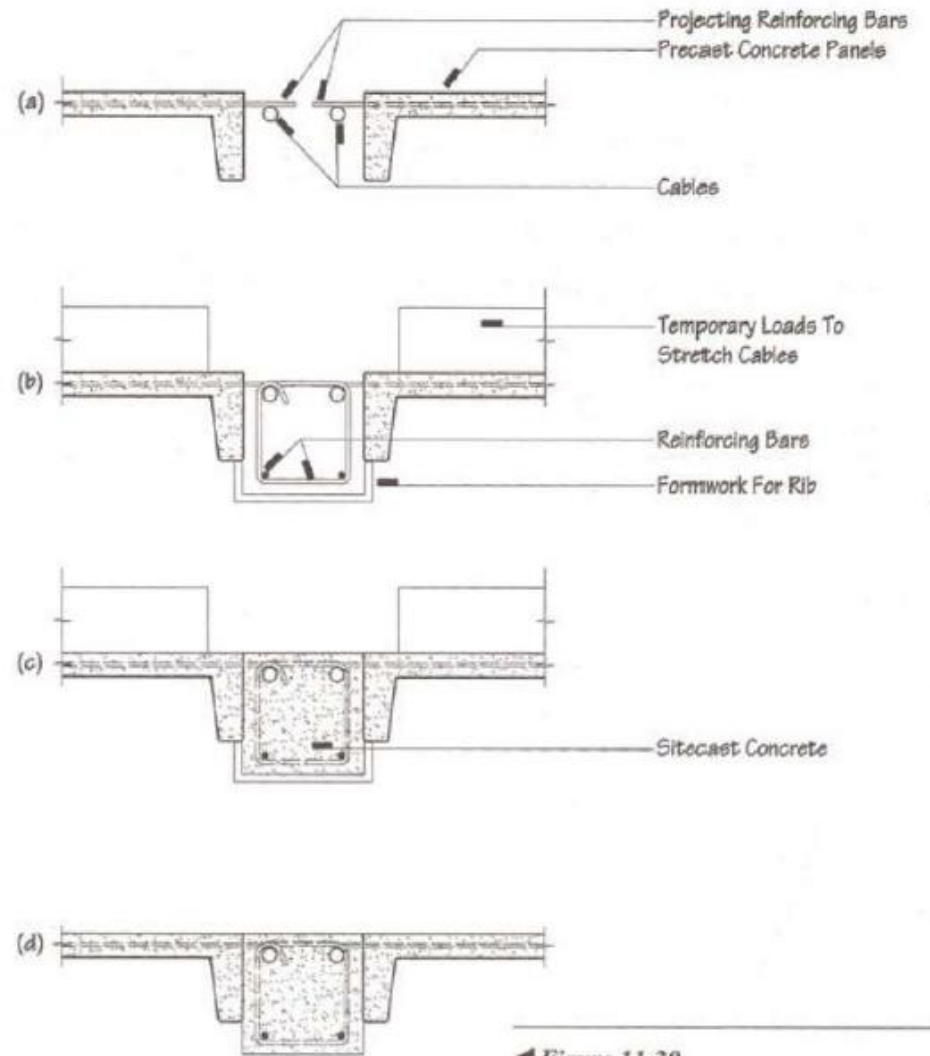
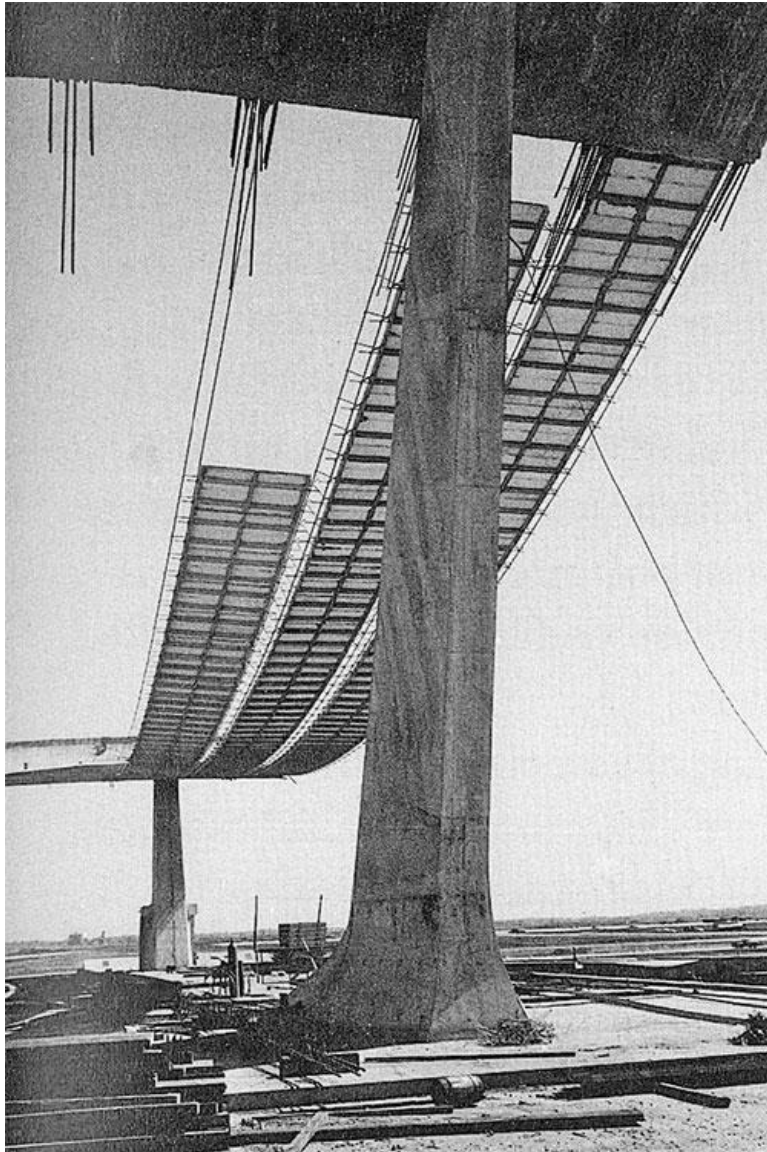


Aeroporto Dulles, Washington (1958) *Atual "Ronald Reagan Washington National Airport"*





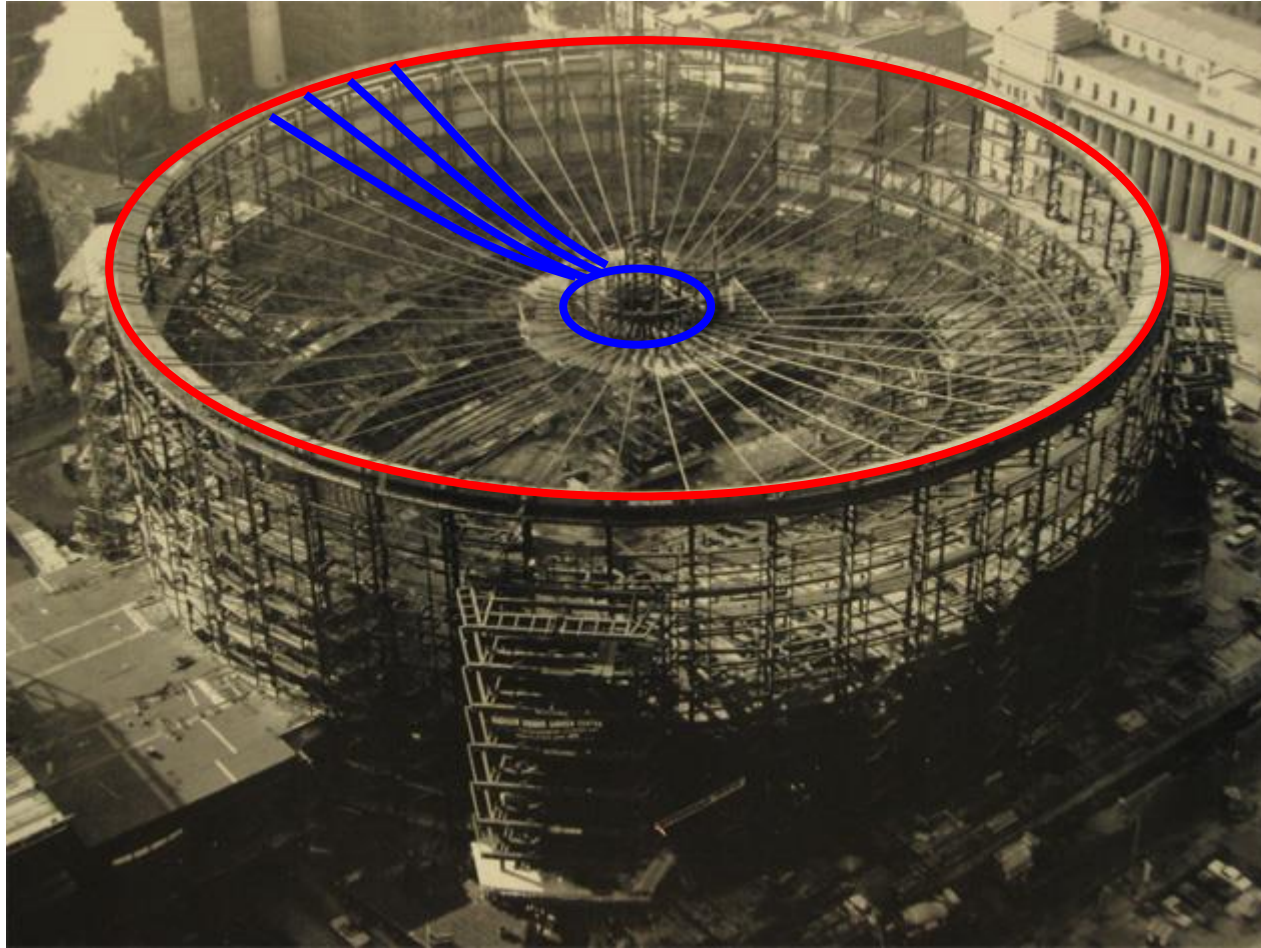




◀ *Figure 11.30*
How the deck was attached to the Dulles roof.



Madison Square Garden's, New York (1968)



'Cilindro Municipal', Montevideo, Uruguai (1956)



*Arq. Leonel Viera e Luis A. Mondino (1956). Incendiado em 2010, demolido em 2014.
Diâmetro do anel externo: 95 m, diâmetro do anel interno 5,5m. Capacidade 18.000 espectadores*

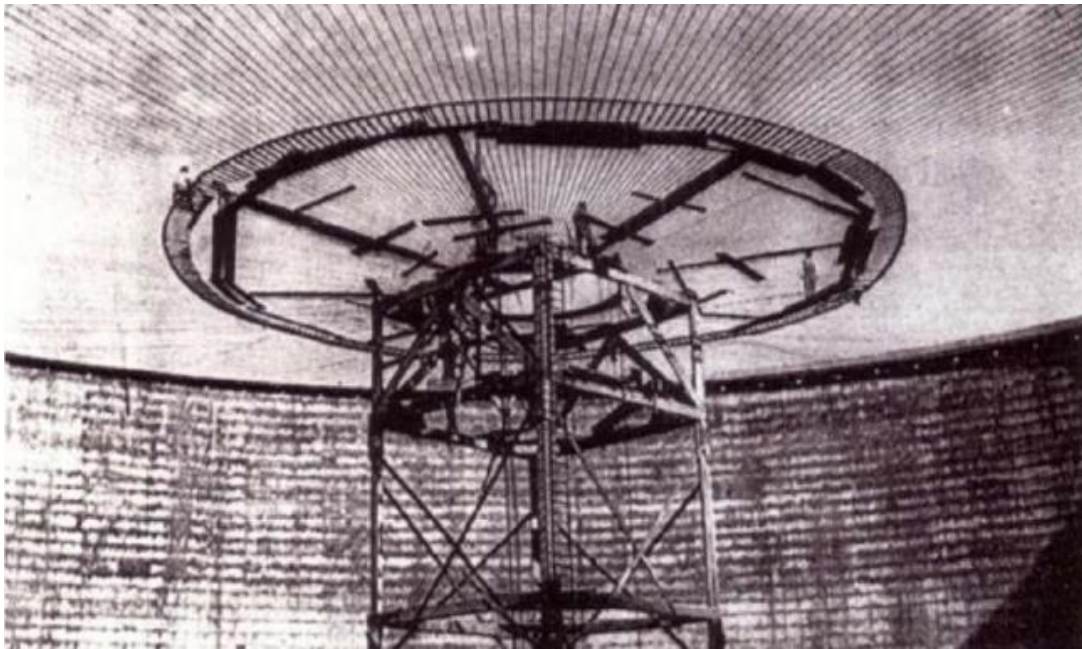
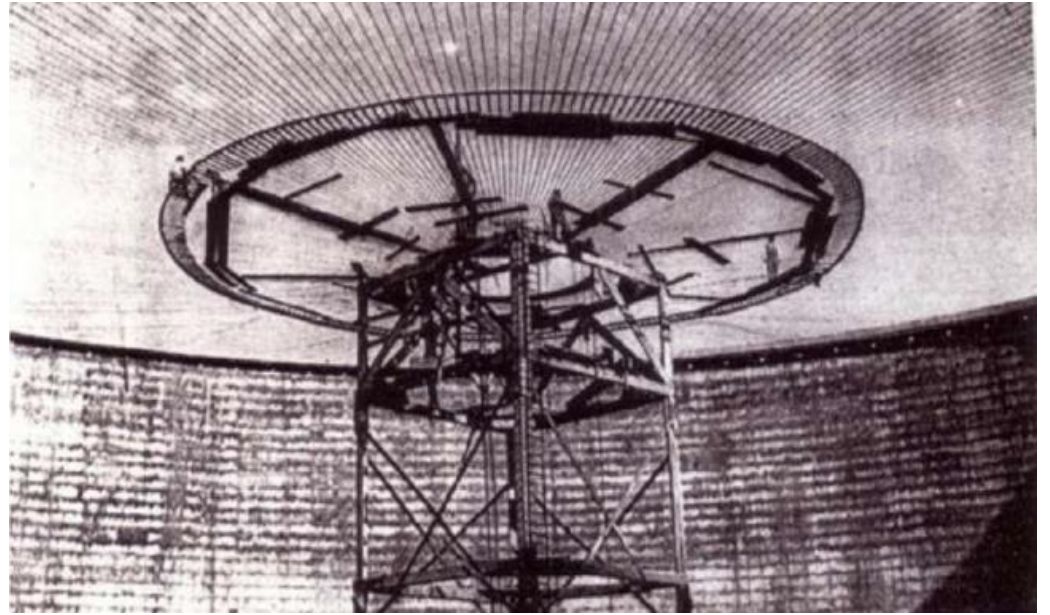
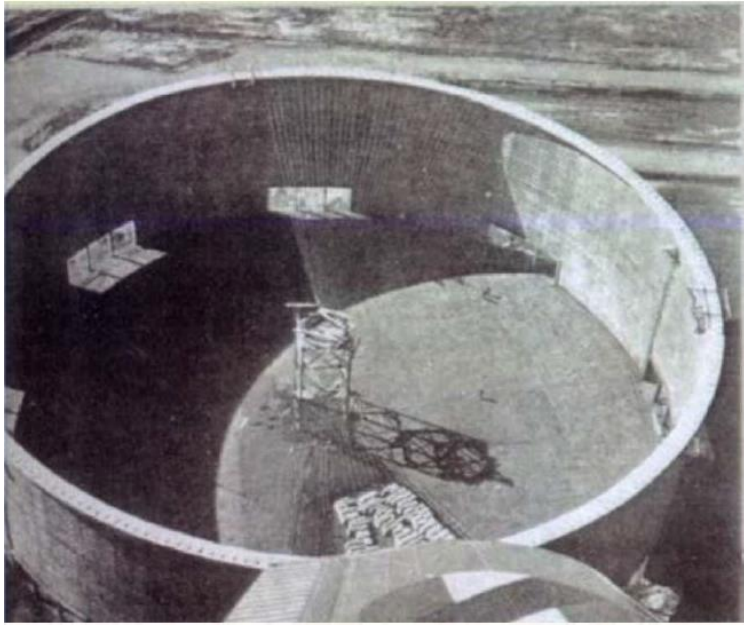


'Cilindro Municipal', Montevideo, Uruguay



Danificado por um incendio em 21/10/2010, demolido em 12/05/2014







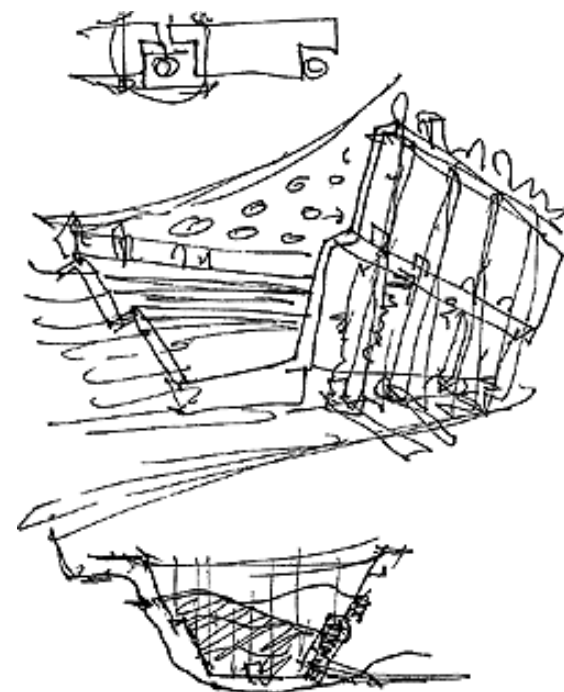
*Pavilhão de Portugal para EXPO 98 (Lisboa)
Arq. Eduardo Souto de Moura*





*Pavilhão de Portugal para EXPO 98 (Lisboa)
Arq. Eduardo Souto de Moura*

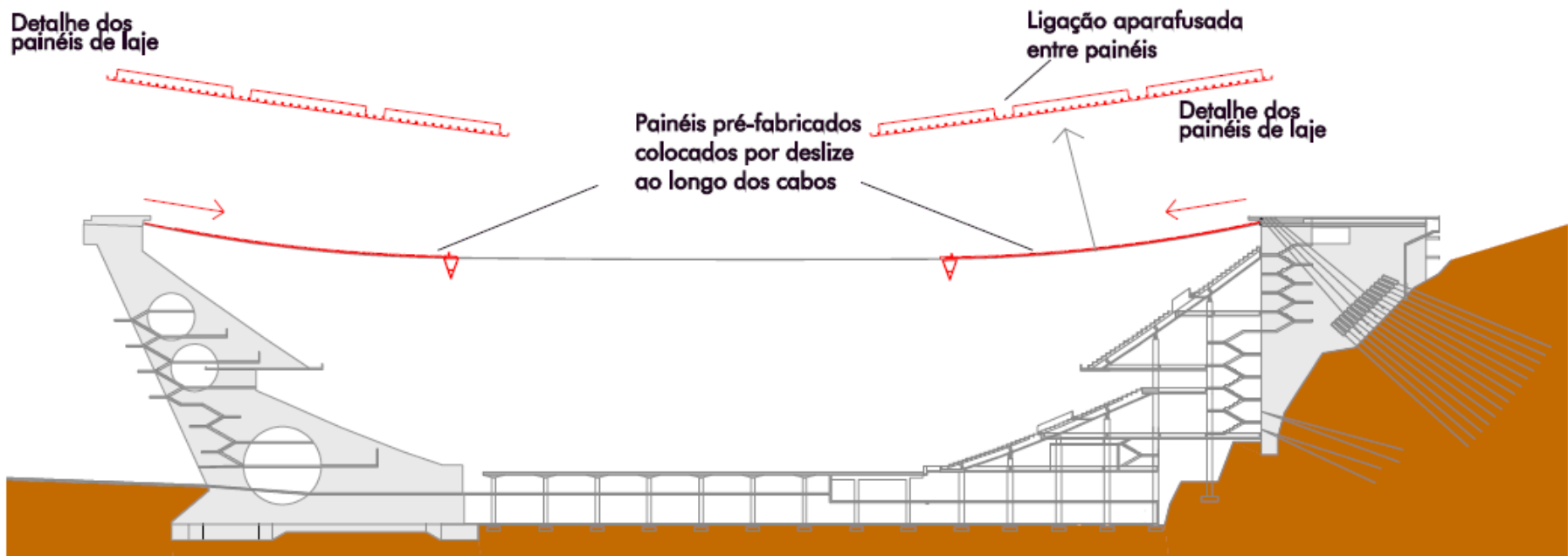




*Estádio Municipal de Braga – Braga, Portugal, 2004
Arq. Eduardo Souto de Moura & Eng. Rui Furtado*



Detalhe dos painéis de laje

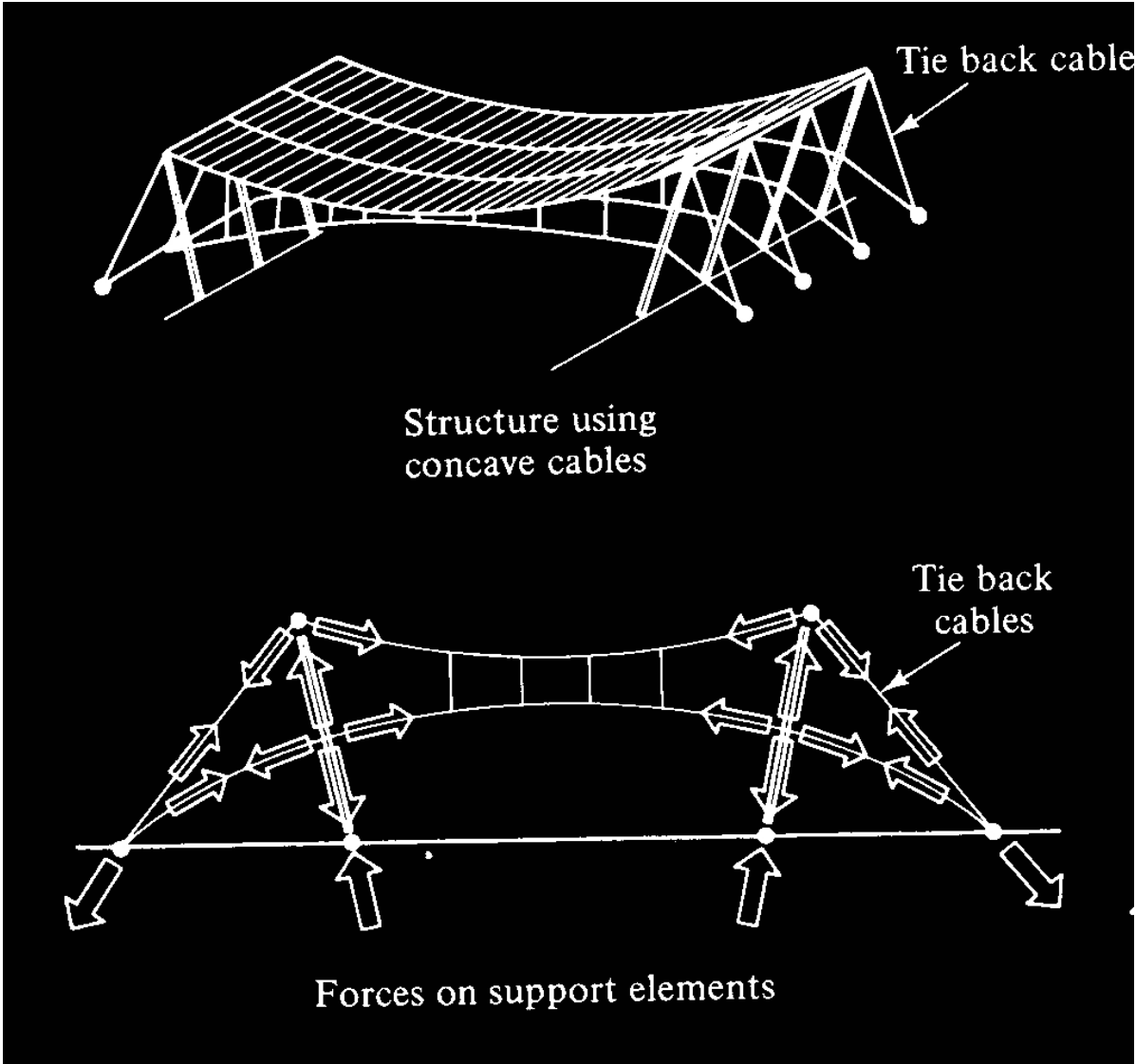


Ligação aparafusada entre painéis

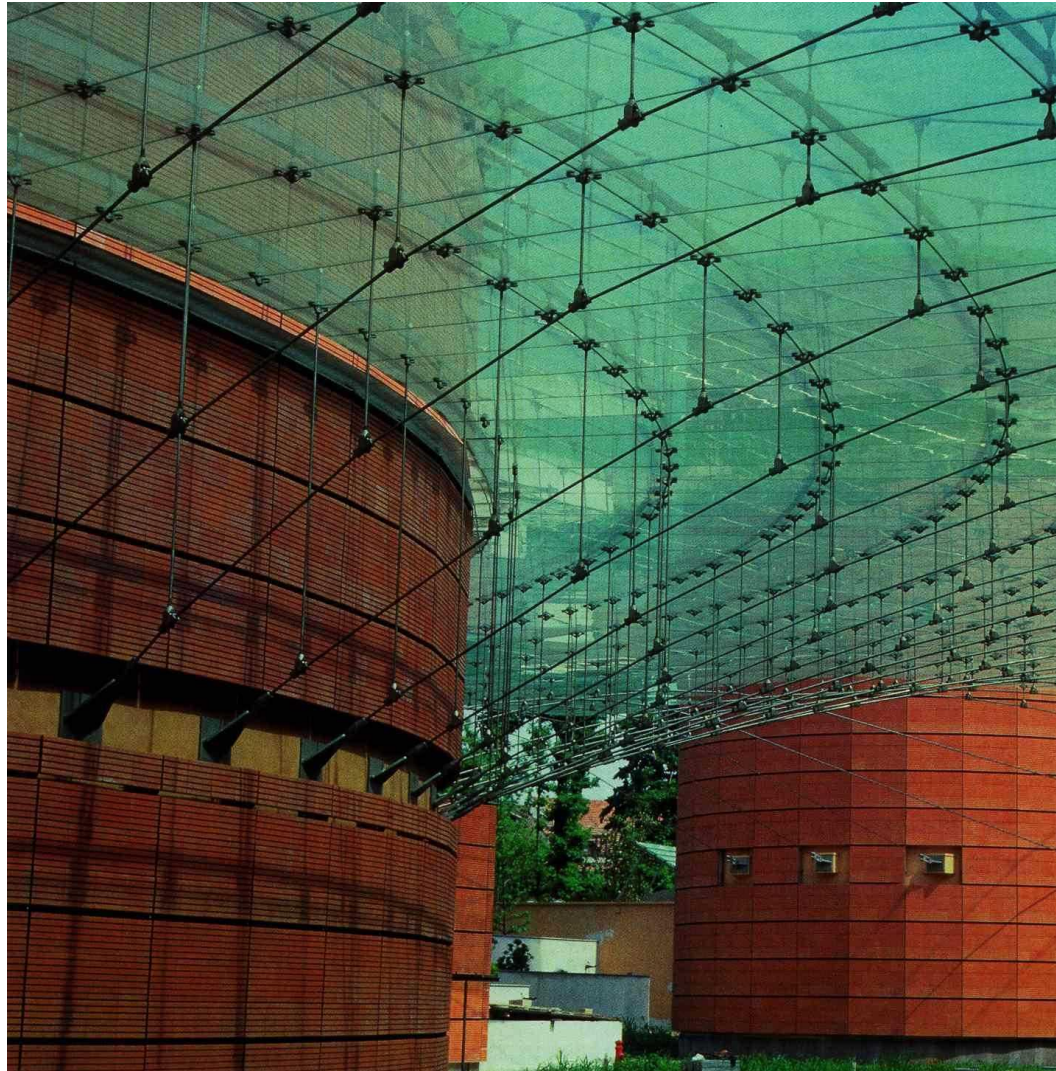
Painéis pré-fabricados colocados por deslize ao longo dos cabos

Detalhe dos painéis de laje





Cobertura de vidro em Lodi (1999)



Cobertura de vidro em Lodi (1999)





Federal Reserve Building, Minnesota



Arcos:

Rainbow Bridge, Utah (vão
71m, altura 88m)





'Portões de Deus' (Nineveth, Assíria).

Construídos pelo rei Sennacherib no séc. VII AC, destruído pelo ISIS em 2016. Nineveth foi um dos primeiros insediamentos da Mesopotâmia, desde 6000 AC.



Porta de Istar, em Babilônia (construída em 575 AC, por ordem de Nabucodonosor II; reconstruída no Pergamon Museum, Berlim)





Concepção artística de Babilônia no séc. VII AC





*Ponte de Vulci, Itália
(originalmente etrusca, séc. VI AC, reconstruída pelos romanos, vão 20m).*



*Ponte Fabricio, a mais antiga ponte
de Roma (62 AC)*



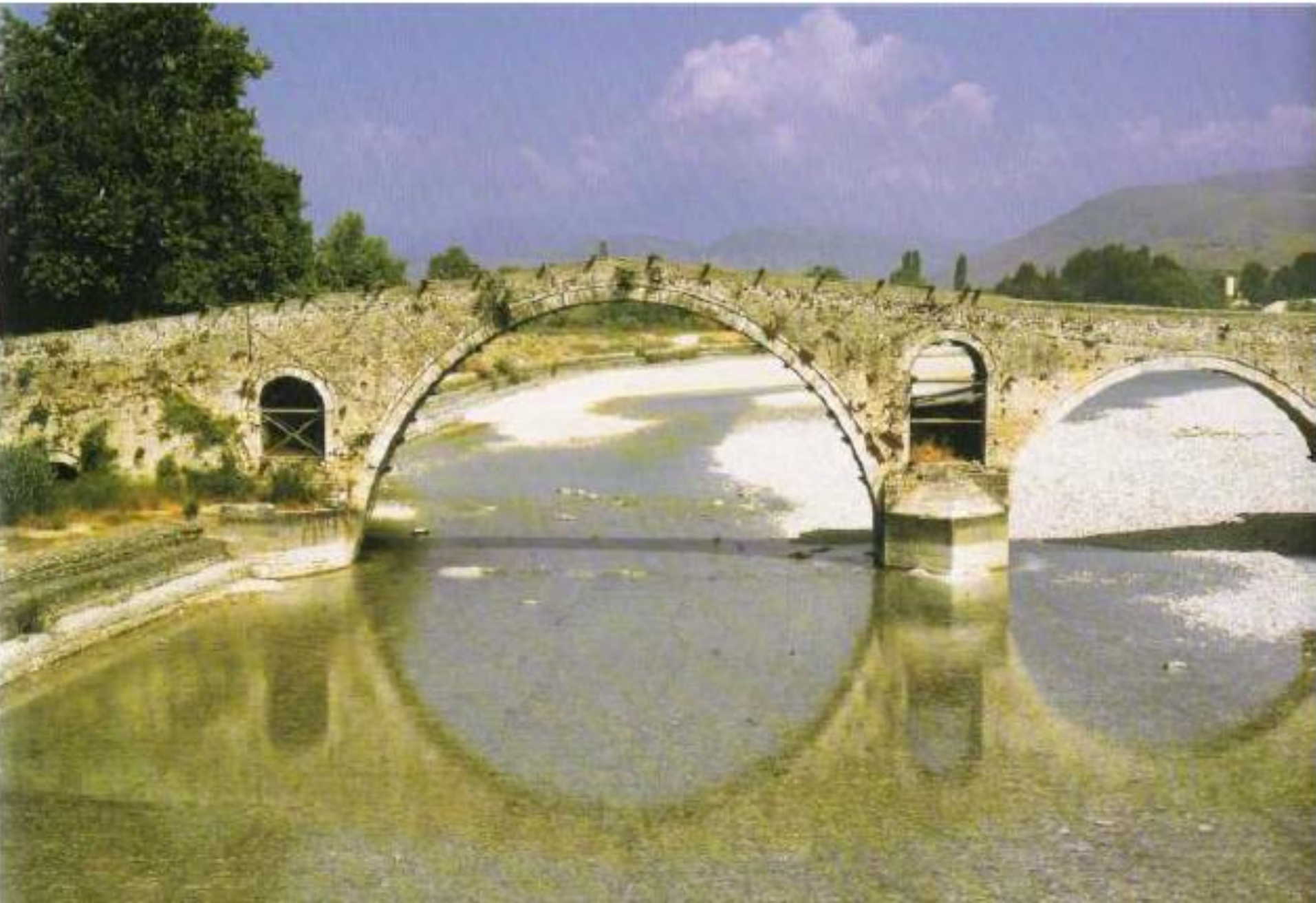
Ponte de Arta, Grécia, construída pelos romanos século XIII, reconstruída em 1603.



Danos 14



Ponte de Arta, Grécia, construída pelos romanos século XIII, reconstruída em 1603.





Pont du Gard, porção de um aqueduto romano próximo a Nîmes, ~séc. I AC



'Ponte Vecchio', Florença, (última reconstrução em 1345)



No mesmo local, existiram outras pontes, desde os tempos romanos. Inicialmente de madeira, depois de pedra. 1o registro documental data de 996 DC.



***'Ponte de Rialto, Veneza,
(1a construção 1181, ultima em 1591)***



*Miracolo della Croce a Rialto,
Vittore Carpaccio, c. 1496.*



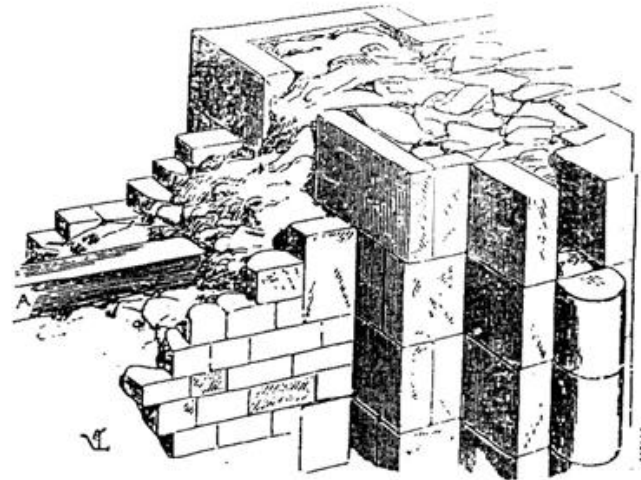
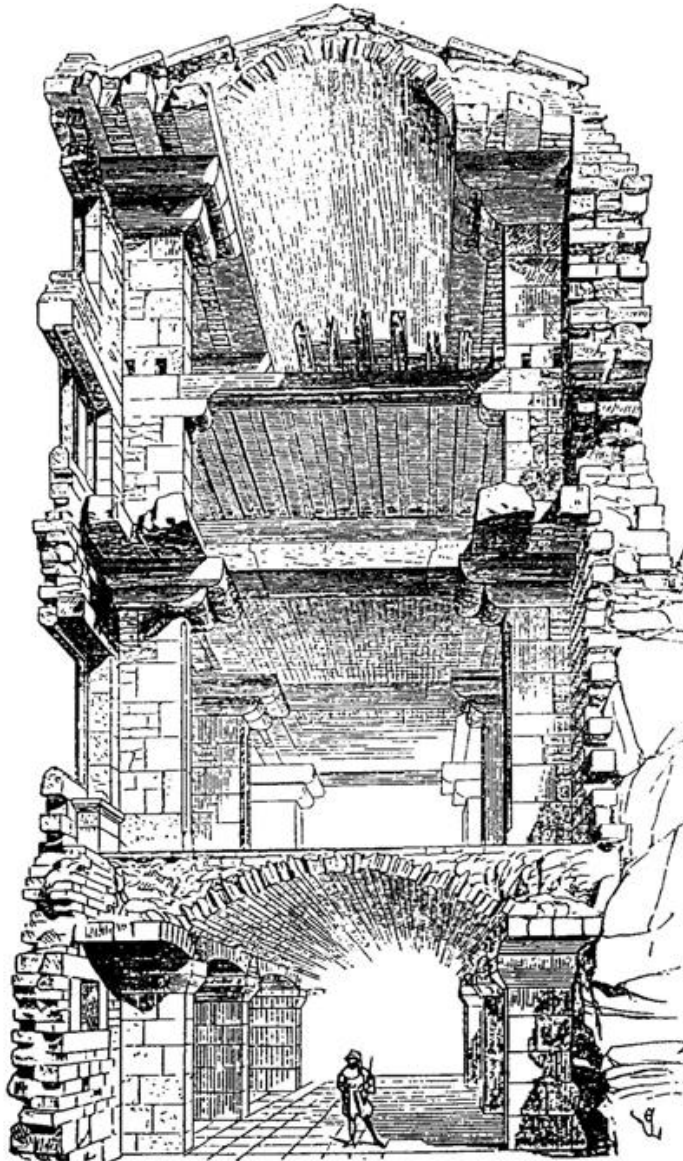


Figure 1 : Constructive section through a medieval building. Details of the construction of roman and medieval walls (Viollet-le-Duc 1858)

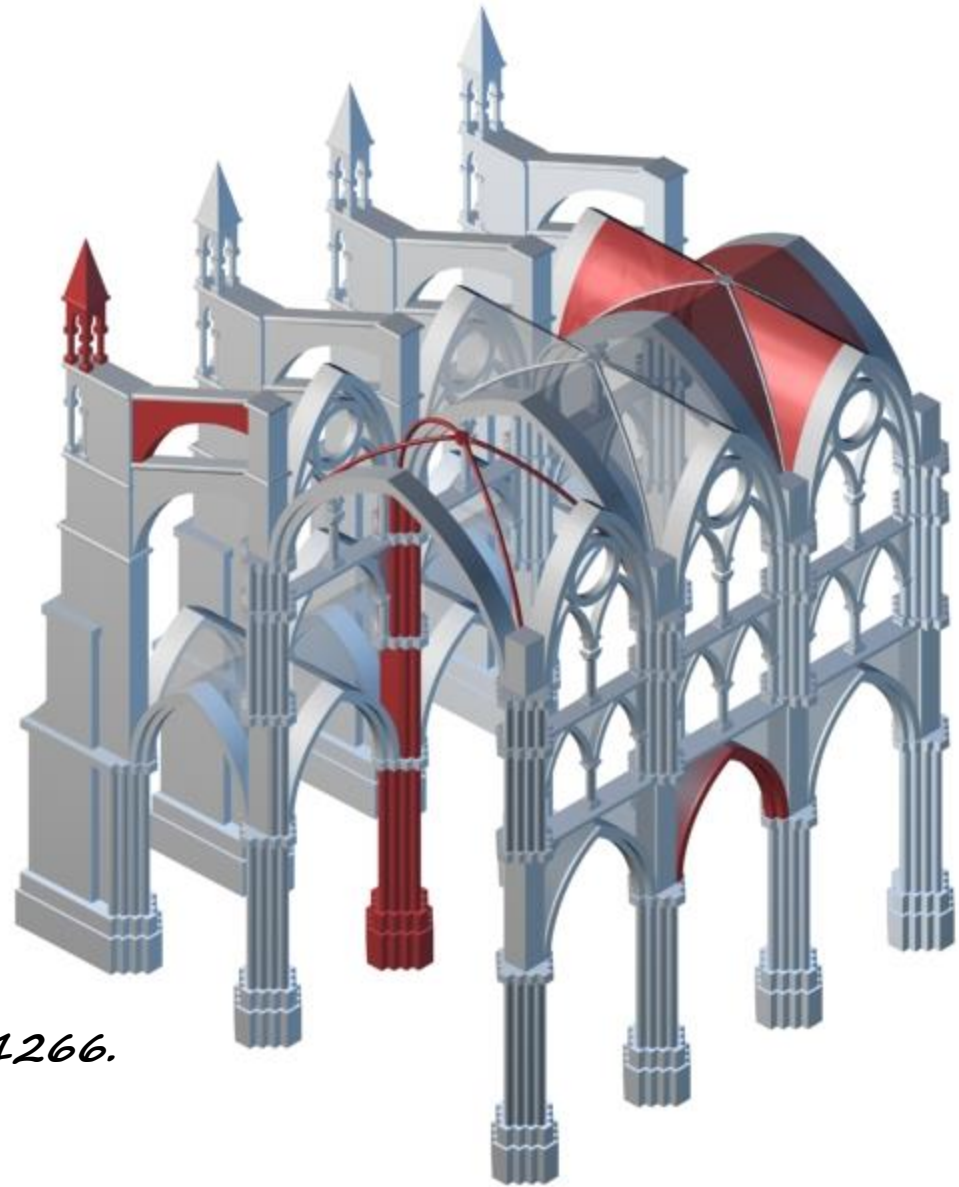




Catedral de Notre Dame, Paris, 1160 – 1345.







Catedral de Amiens, 1220 - 1266.







King's College Chapel, Cambridge, 1446-1515





King's College Chapel, Cambridge, 1446-1515





Landwasser Viaduct, Suíça, 1902. Restaurada em 2009.





*Ponte Salginatobel, Suíça
Robert Maillart, 1929
(total length 133 metres, longest span 90 metres)*



Altstadt, Berna, Suíça





Viaducto del Ulla, 2011. 630 metros de comprimento, altura máxima 117m, vão principal 168m.





Viaducto del Ulla, 2011



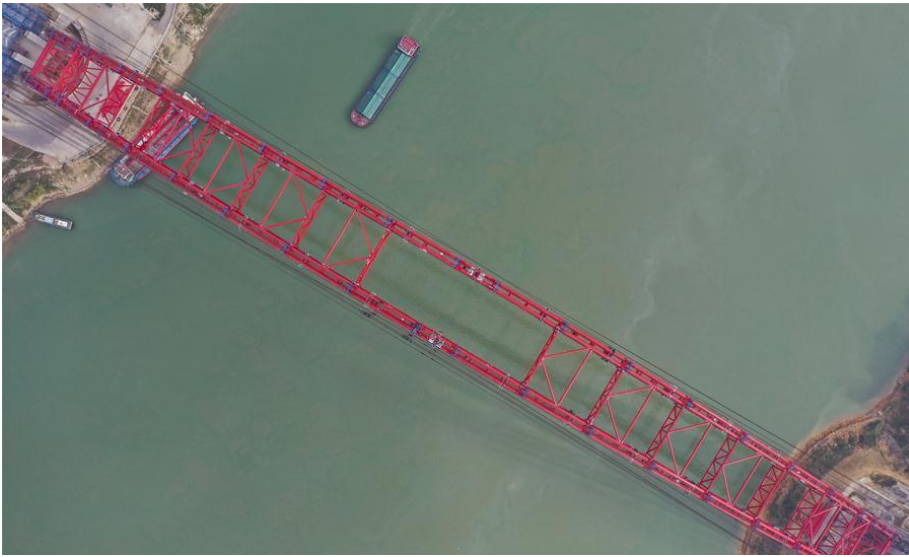
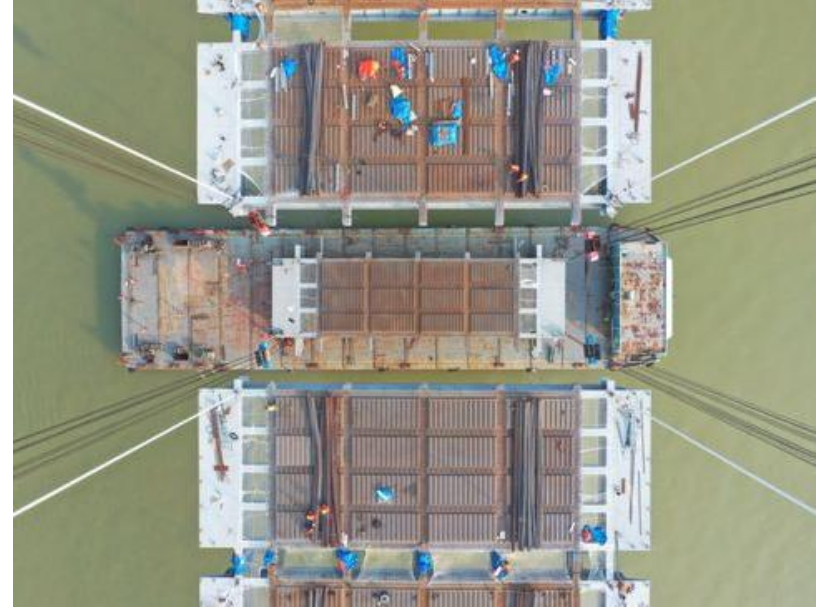


Viaducto del Ulla, 2011



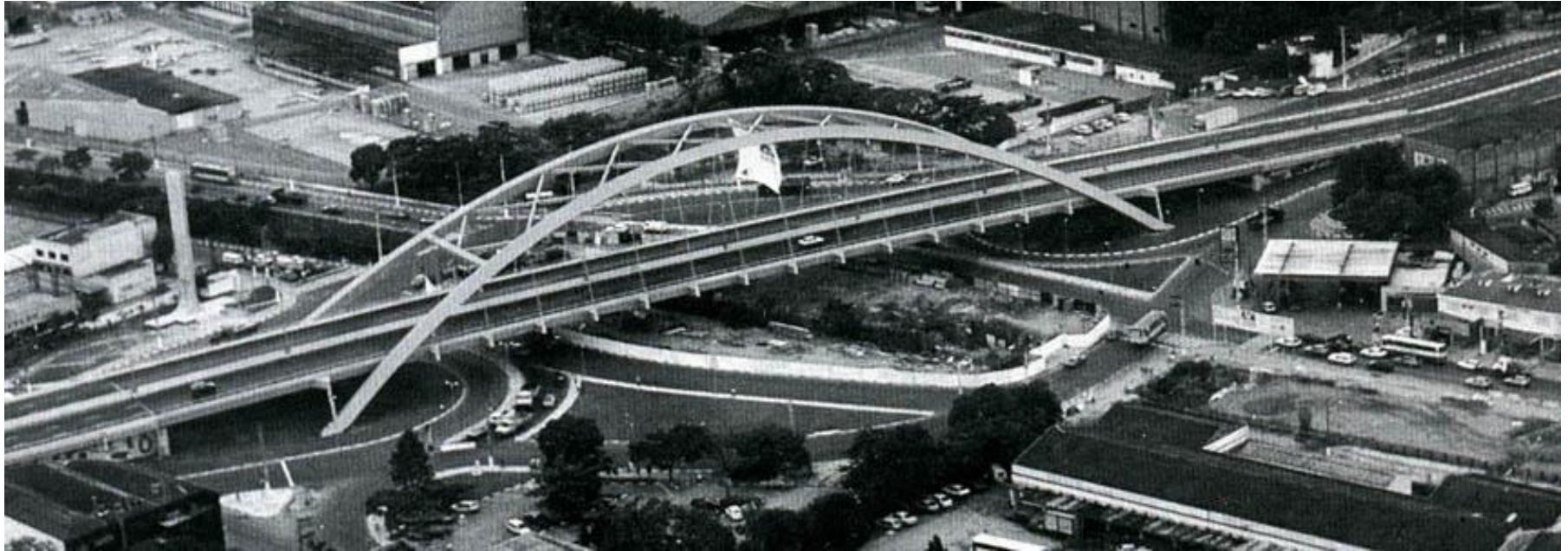
*Pingnan No. 3 Bridge (Sept. 2020),
Guangxi Road and Bridge Engineering Group*

*Total length 1035 meters, main span 575 meters, deck width 36.5 meters.
The bridge is equipped with four two-way lanes, two non-motorized lanes and two sidewalks. The world's largest span arch bridge by 2022.*









Ponte de Osasco

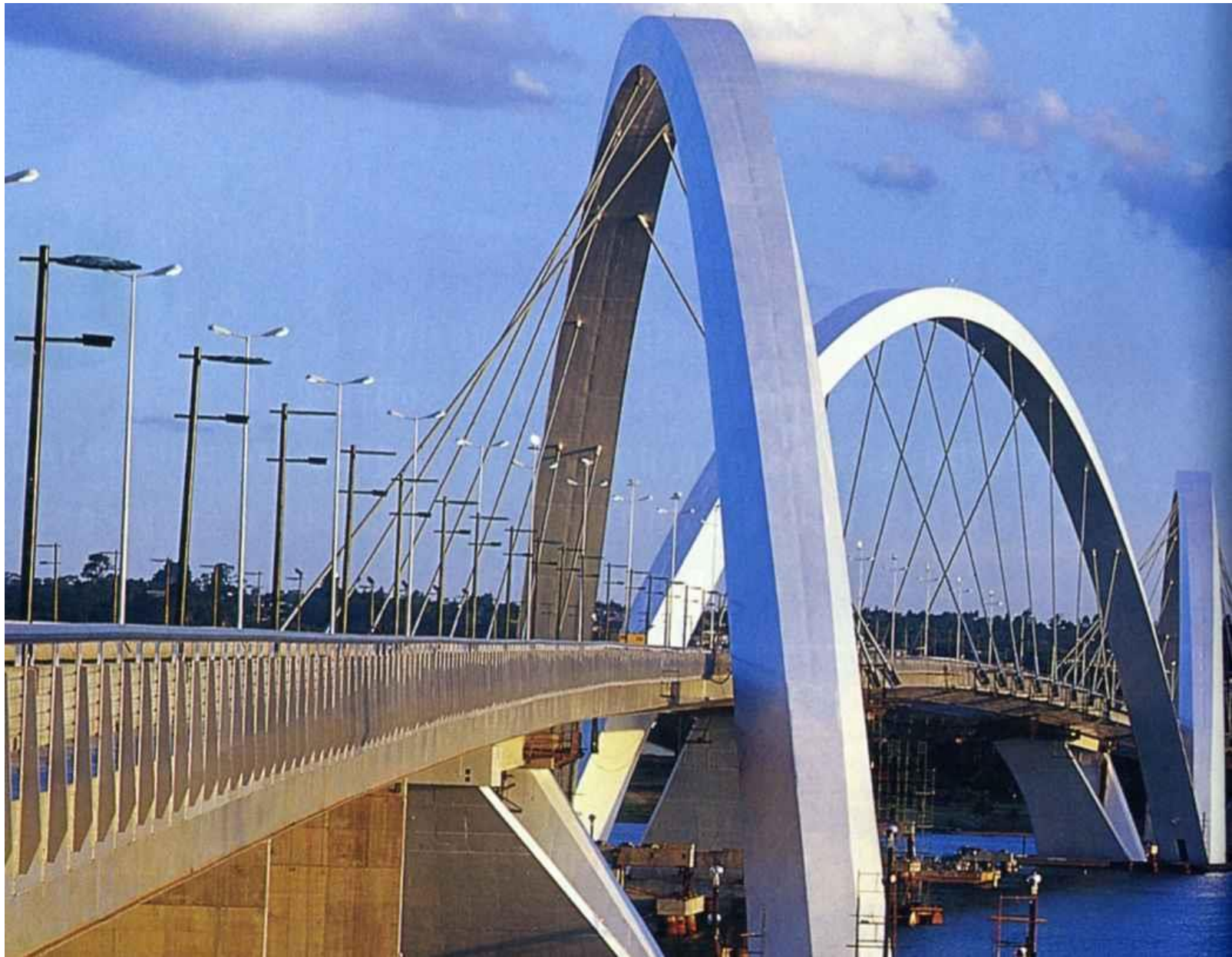
Autoria - Usiminas Mecânica e Escritório de Engenharia

RMG - Belo Horizonte

Concepção estrutural - Tabuleiro de aço com 150m de vão livre suspenso por tirantes em dois arcos metálicos







Broadgate Exchange House, Liverpool, Londres, S.O.M., 1990



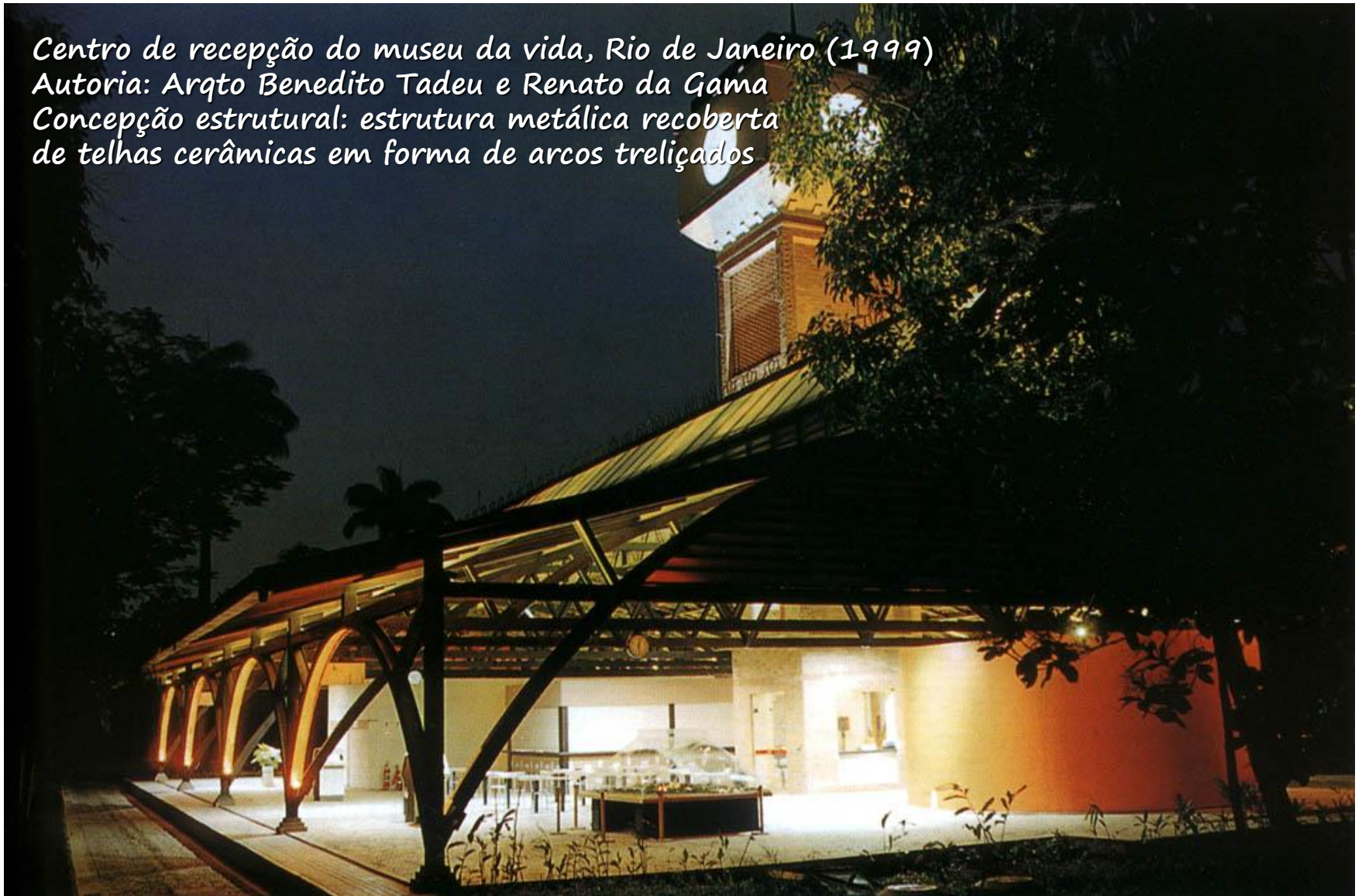
Broadgate Exchange House, Liverpool, Londres, S.O.M., 1990

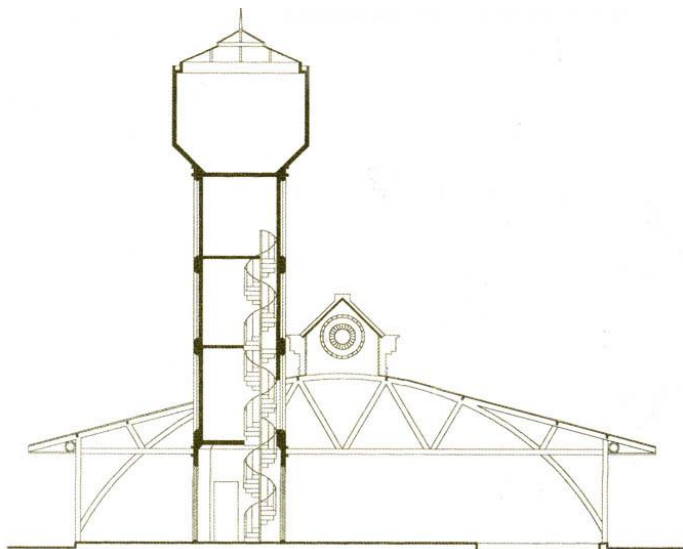




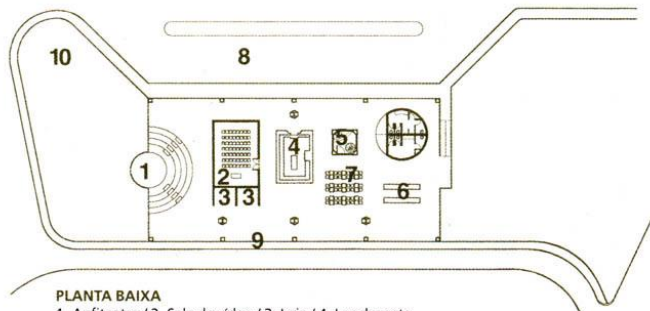


*Centro de recepção do museu da vida, Rio de Janeiro (1999)
Autoria: Arqto Benedito Tadeu e Renato da Gama
Concepção estrutural: estrutura metálica recoberta
de telhas cerâmicas em forma de arcos treliçados*



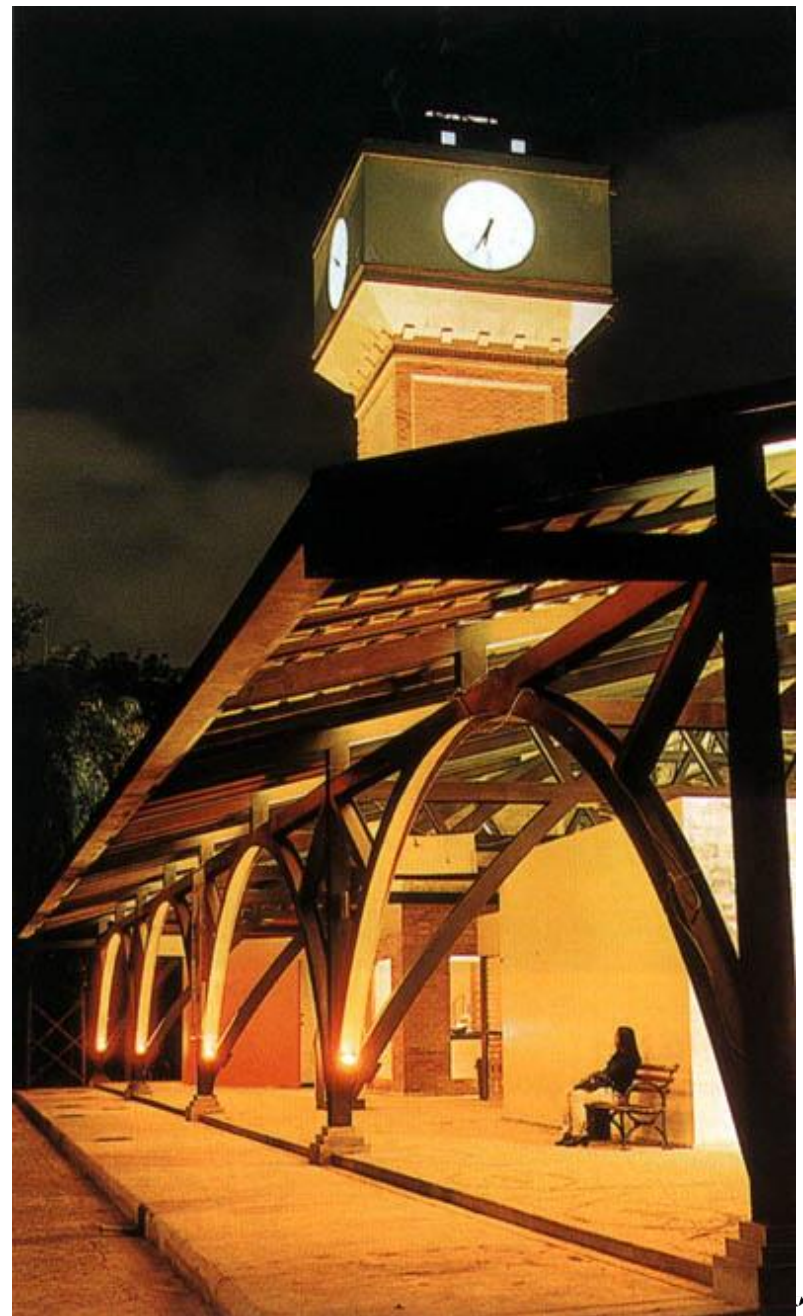


CORTE TRANSVERSAL



PLANTA BAIXA

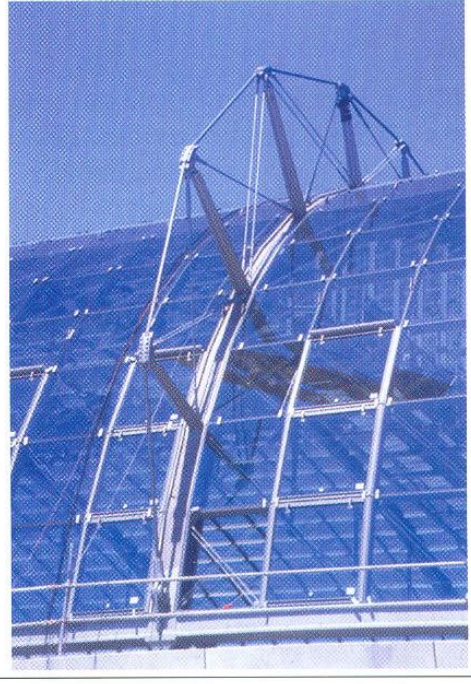
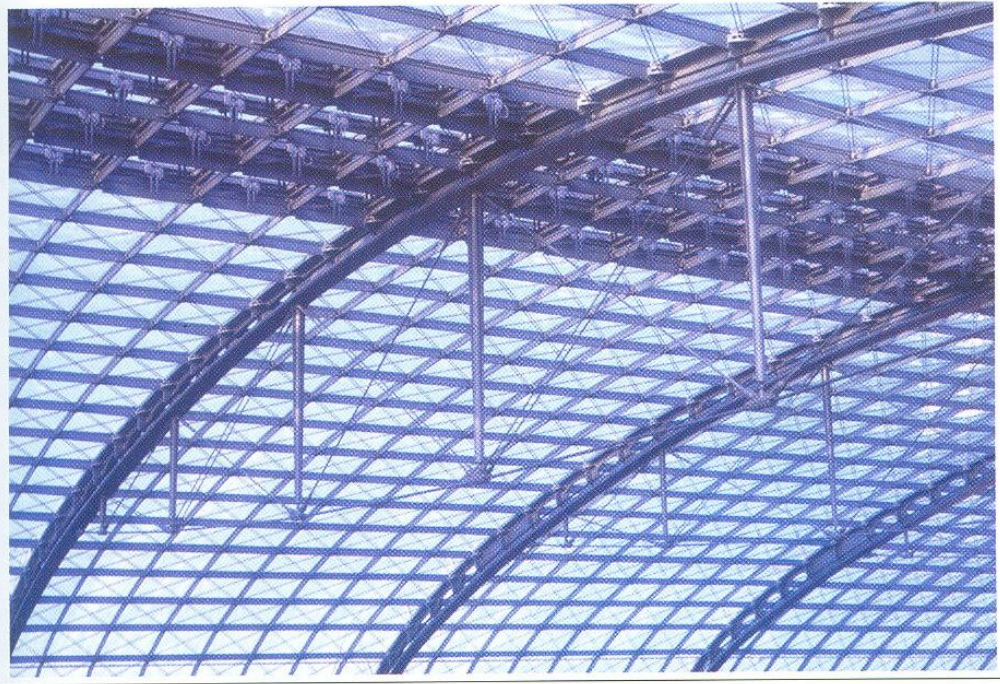
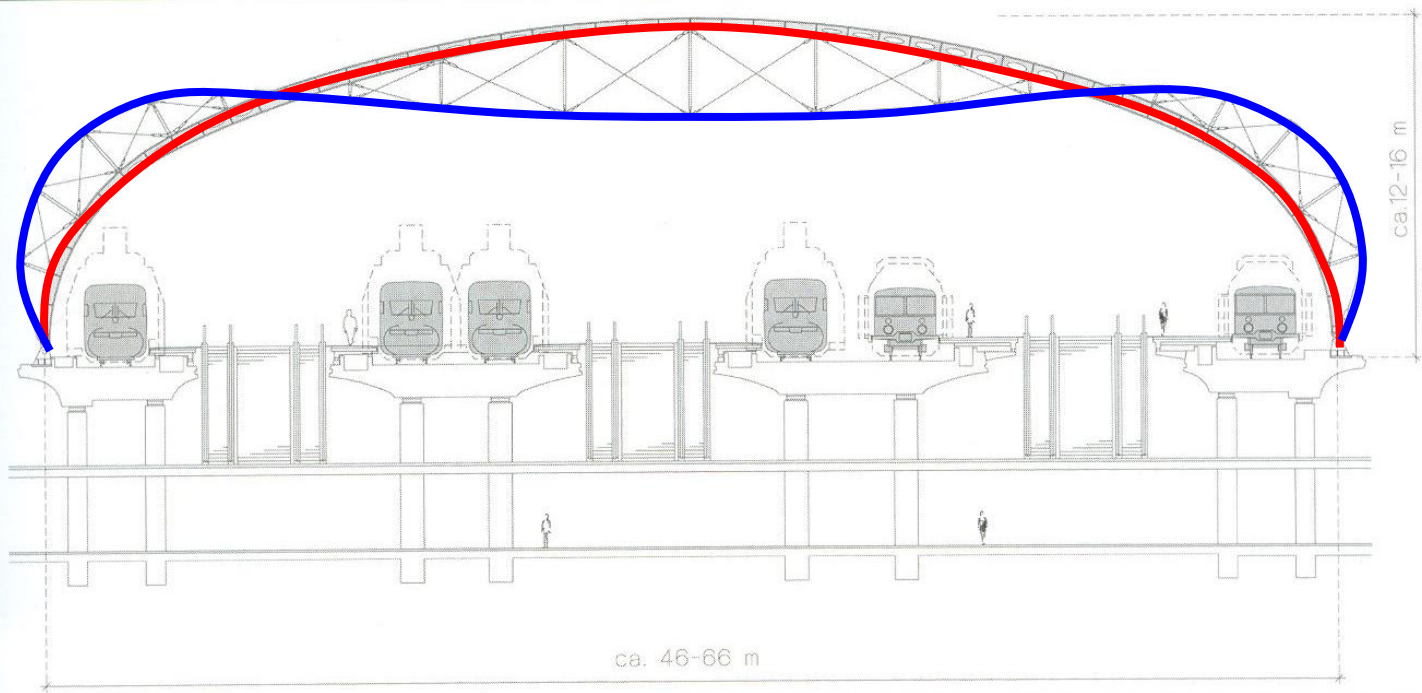
1. Anfiteatro / 2. Sala de vídeo / 3. Loja / 4. Lanchonete
 5. Informações/administração / 6. Espera / 7. Multimídia
 8. Acesso de ônibus / 9. Acesso de trem / 10. Jardim





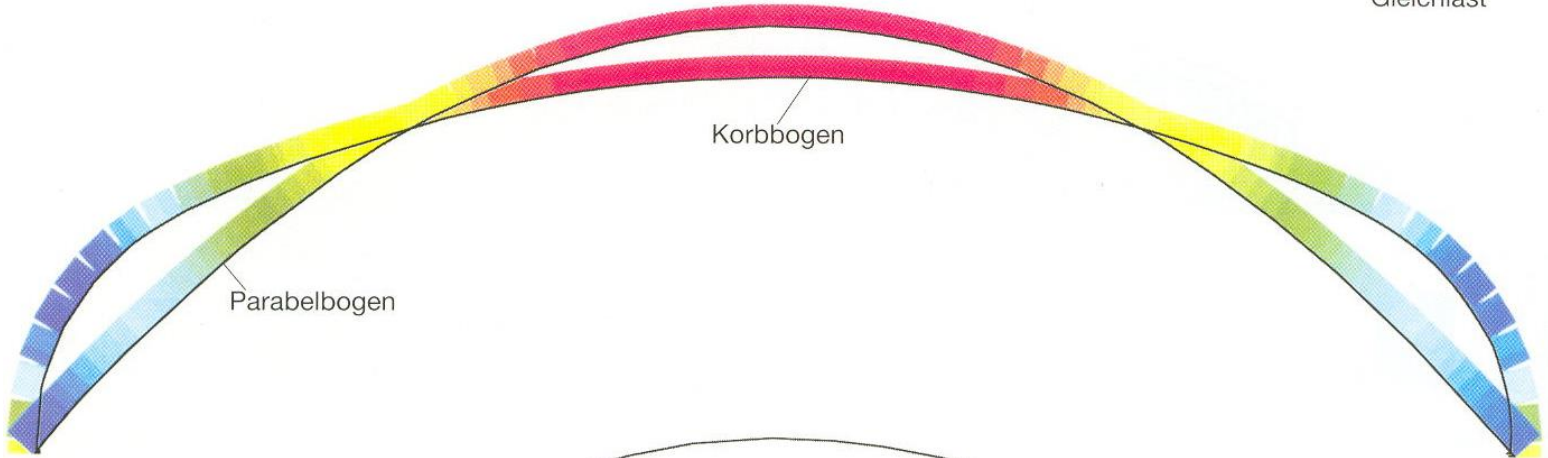
Estação de Trens Lehrter, Berlim



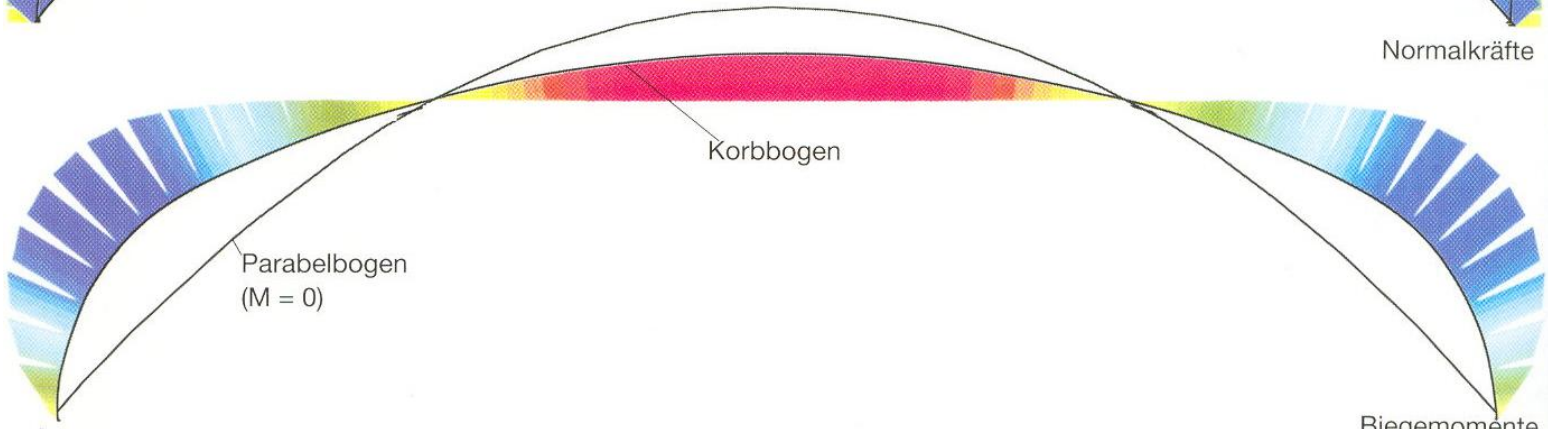




Gleichlast



Normalkräfte



Biegemomente







