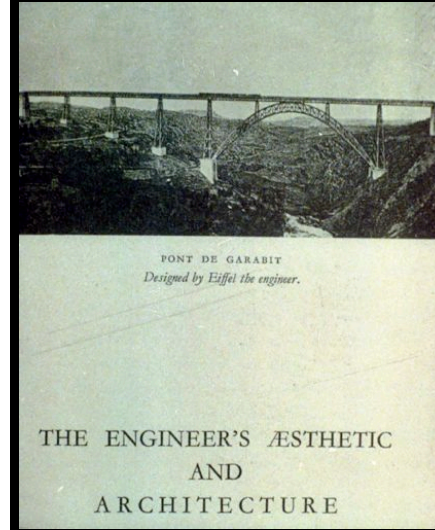


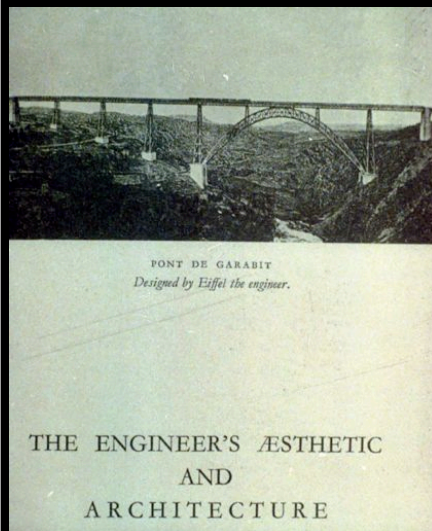
John A. Roebling and the Design of Suspension Bridges

1. Methods of stiffening suspension bridges
2. Evolution of form in Roebling's suspension bridges
3. Wind and dangerous oscillations in suspension bridges
4. Ambiguity of form vs. structural redundancy in suspension bridges
5. Artistic representations of the Brooklyn Bridge

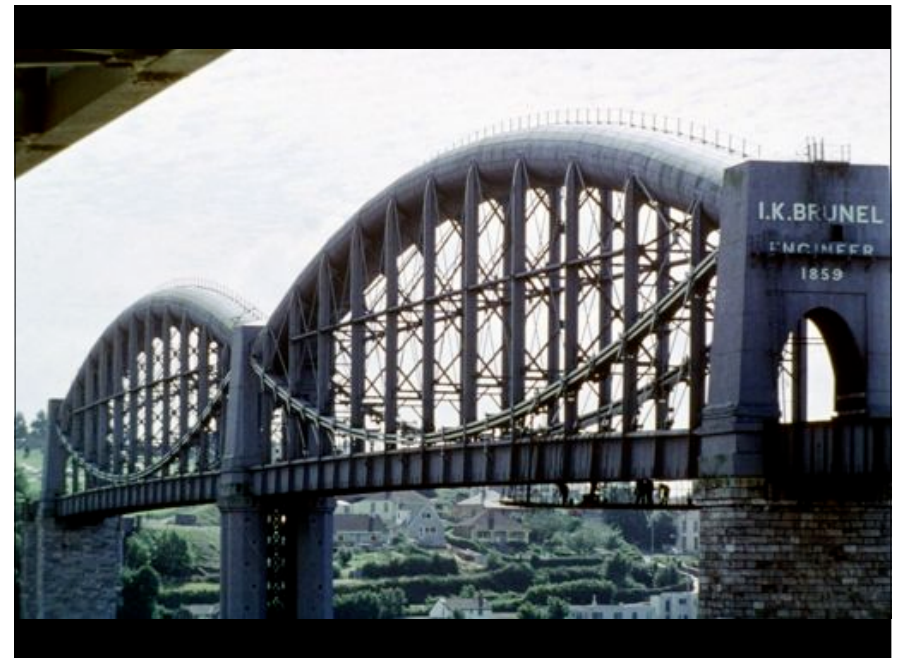
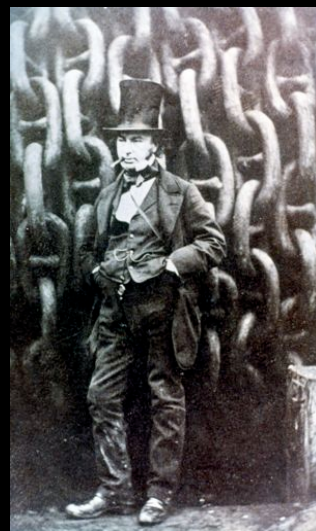
Eiffel



Eiffel

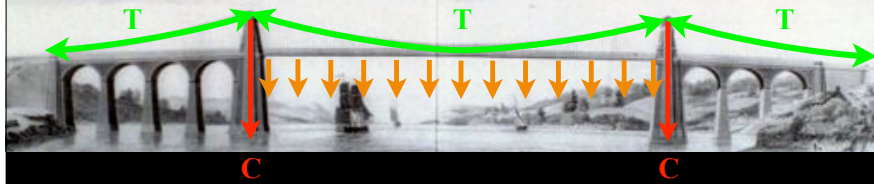


Brunel



Load Paths in Suspension Bridges

Weight of Bridge Deck

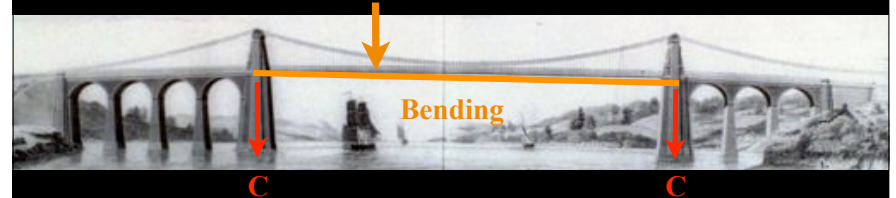
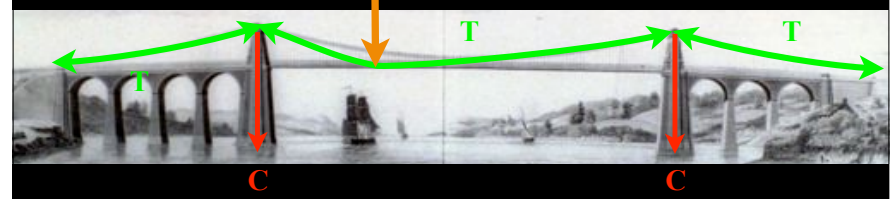


Shape of cable?

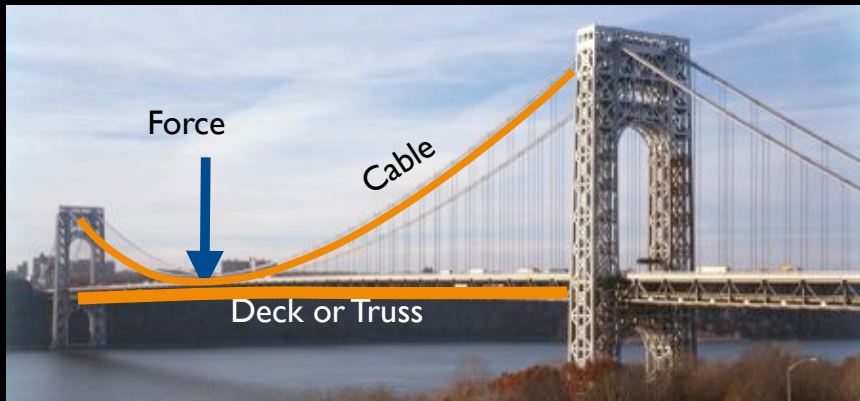
Parabola

Load Paths in Suspension Bridges

Vehicle on Bridge Deck



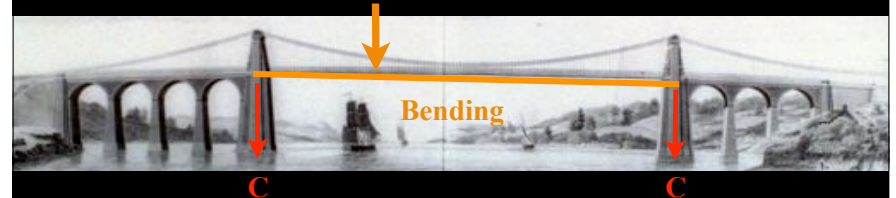
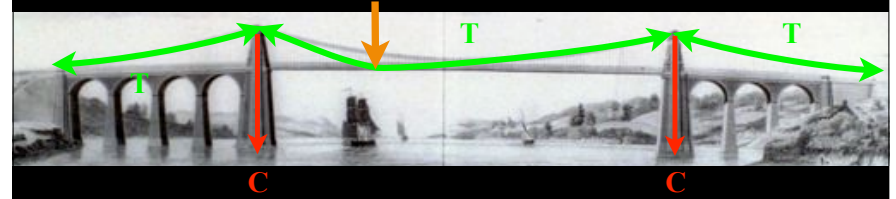
Stiffness
Resistance to Deformation



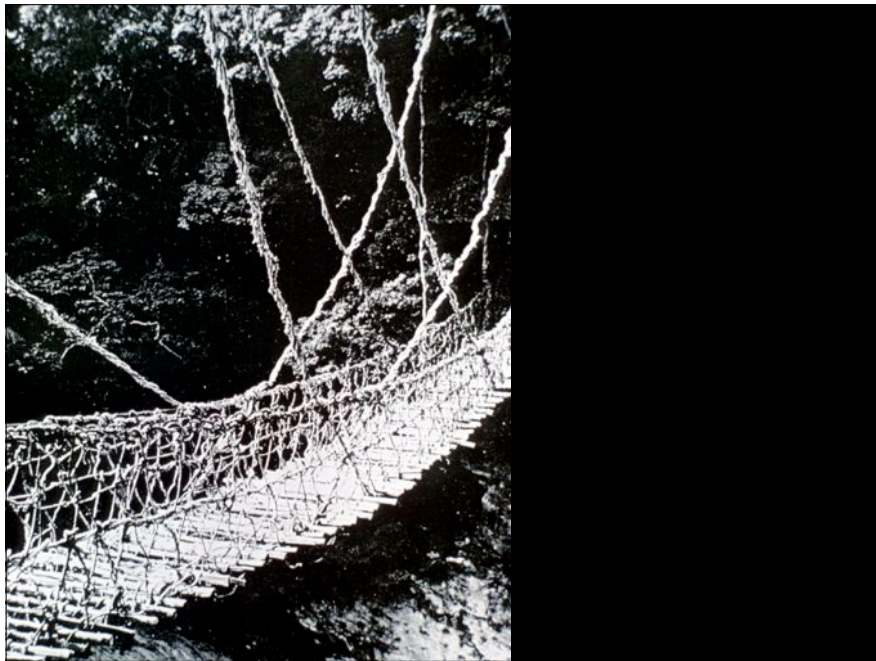
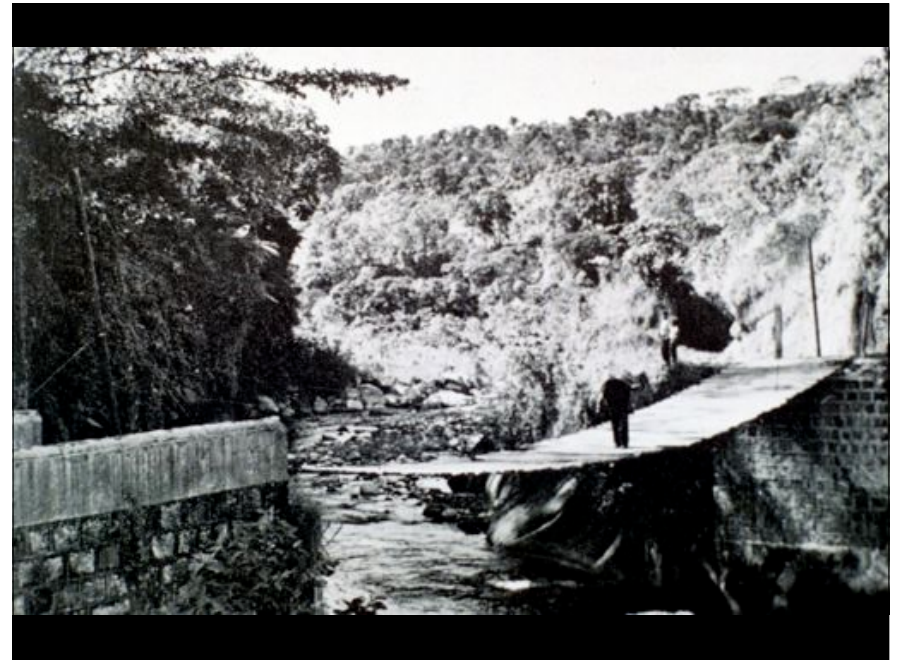
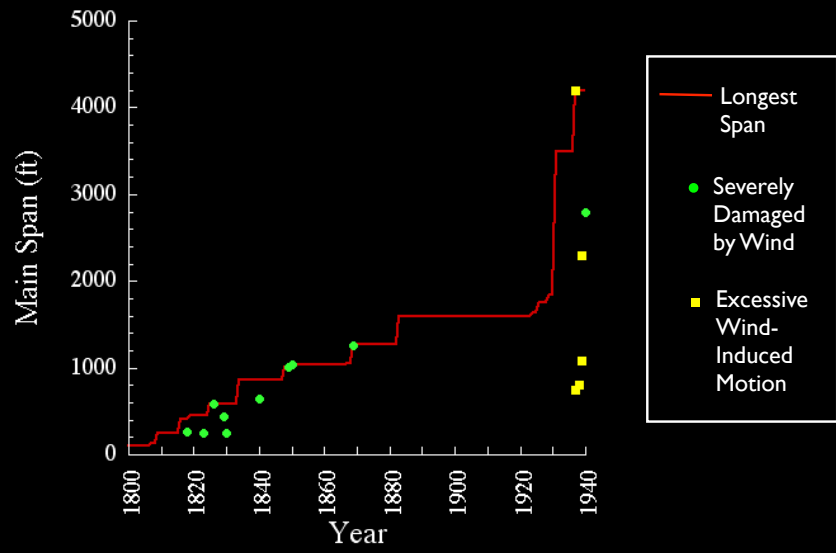
- 1. Cables have Stiffness
- 2. Force Follows Stiffness

Load Paths in Suspension Bridges

Vehicle on Bridge Deck



The Historical Record





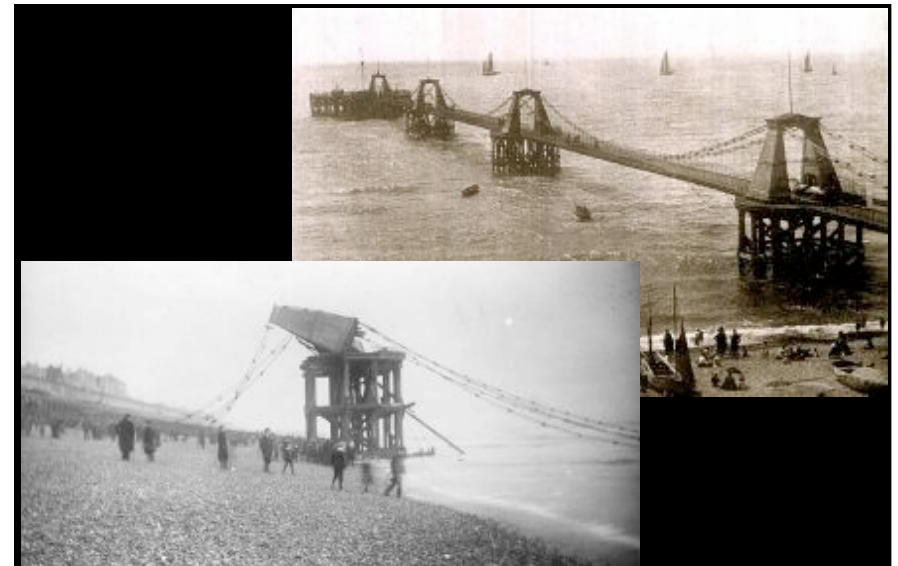
Buffalo Creek Bridge (1917)

113 ft span



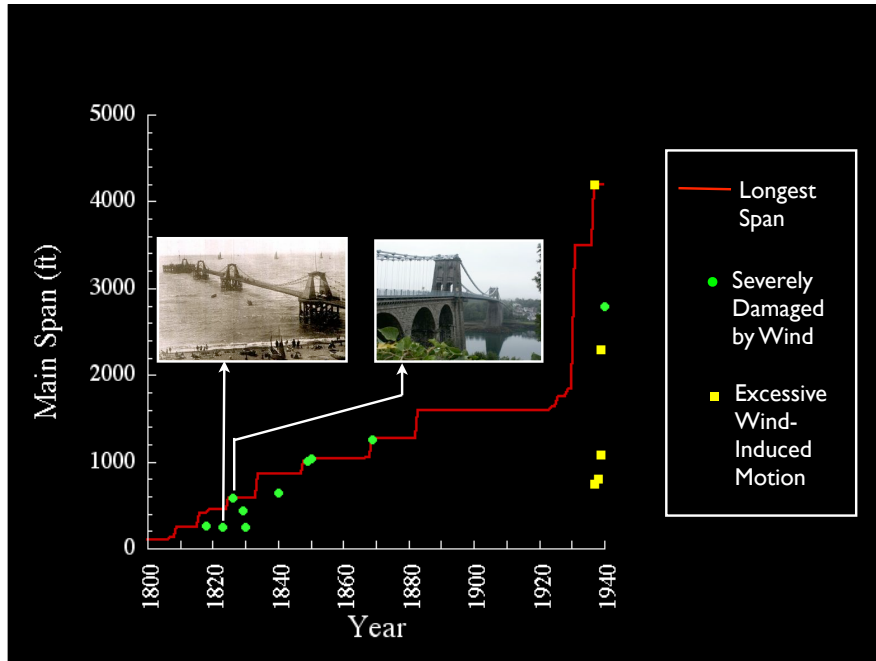
Union Bridge (1820)
Samuel Brown

449 ft span
England



Brighton Chain Pier (1823)
Samuel Brown

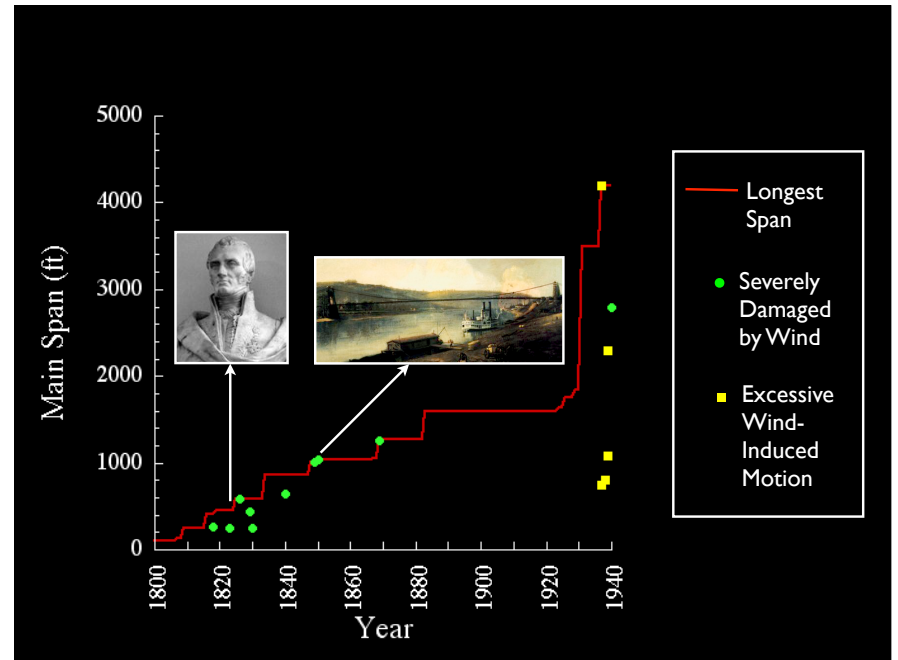
225 ft spans
England

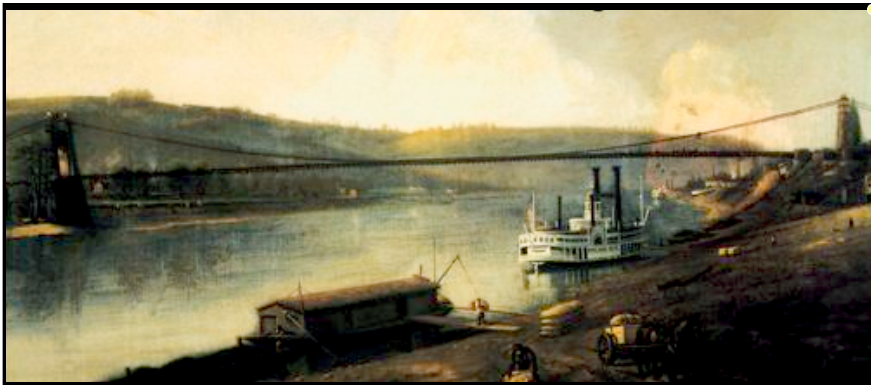


C.L.M.H. Navier

RAPPORT
A MONSIEUR BECQUEY,
CONSEILLER D'ÉTAT,
DIRECTEUR GÉNÉRAL DES PONTS ET CHAUSSEES ET DES MINES;
ET
MÉMOIRE
SUR LES PONTS SUSPENDUS;
PAR M. NAVIER,
INGÉNIEUR EN CHEF AU COMTE ROYAL DES PONTS ET CHAUSSEES.
A PARIS,
DE L'IMPRIMERIE ROYALE,
1823.

Cable Stiffness: Deformation $\propto \frac{1}{\text{Weight}}$





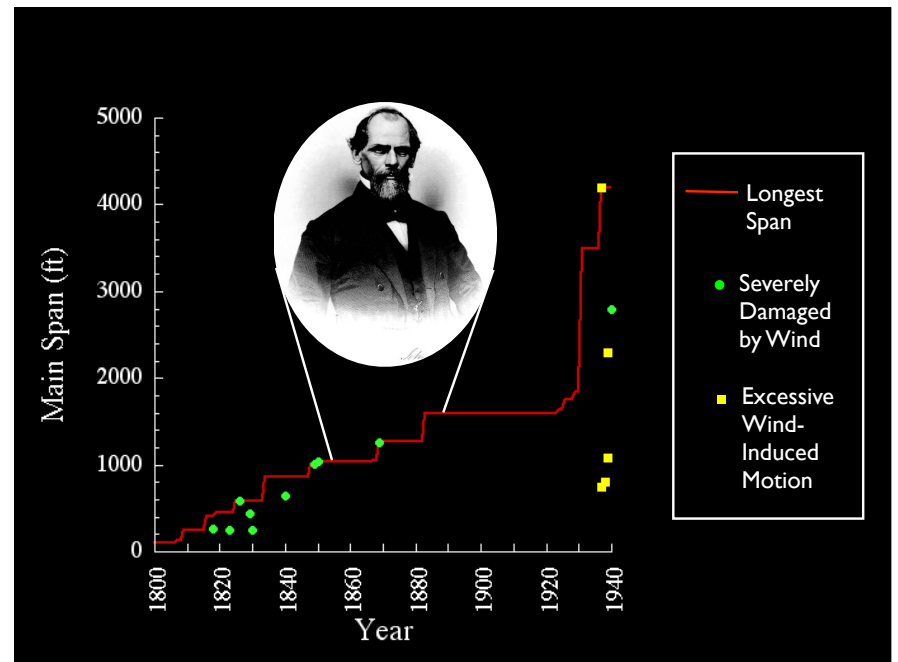
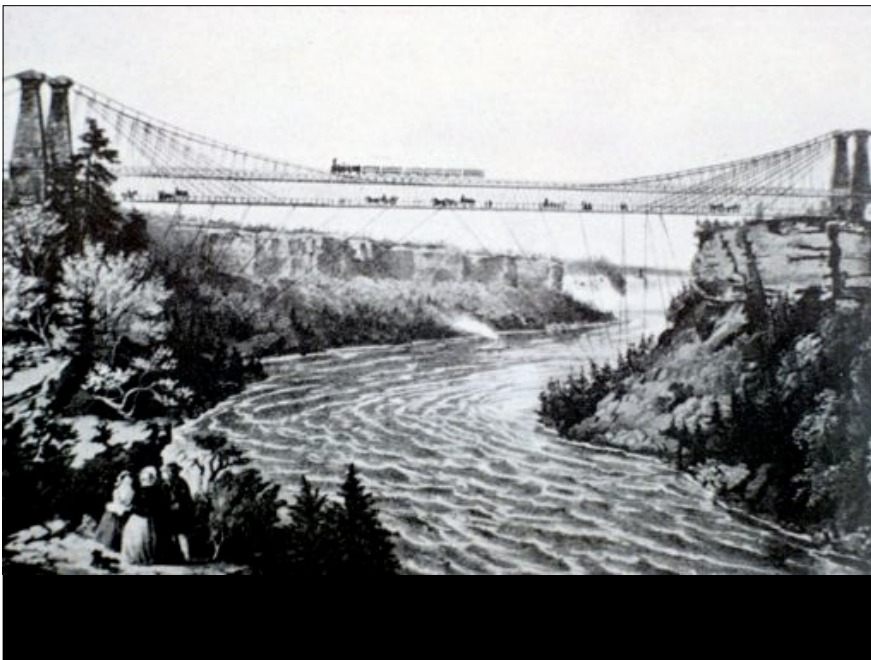
Wheeling Bridge (1849)
Charles Ellett

1010 ft span
West Virginia



Niagara Railroad Bridge (1849)
John A. Roebling

822 ft span
Niagara River





John Augustus Roebling
1806-1869

“The means employed are:
Weight, Girders, Trusses, and Stays.
With these any degree of stiffness can be insured, to resist either the action of trains or the violence of storm . . .”

J.A. Roebling, *Final Report, Niagara Bridge*

Niagara Railroad Bridge (1849)
John A. Roebling

822 ft span
Niagara River

Load Paths in Suspension Bridges

Vehicle on Bridge Deck

1. Suspension Cables
- 2.
- 3.

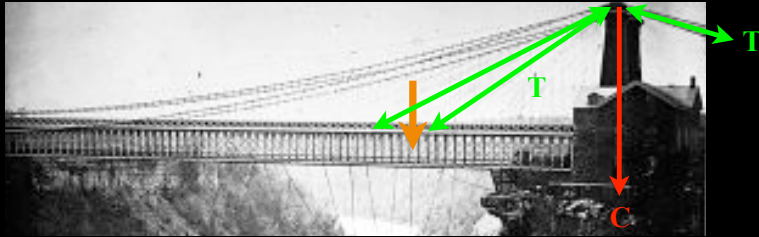
Load Paths in Suspension Bridges

Vehicle on Bridge Deck

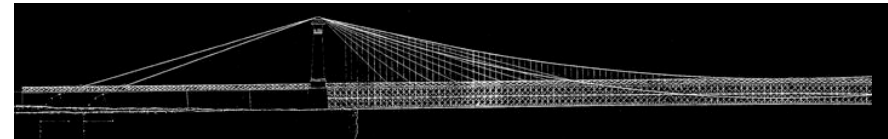
1. Suspension Cables
2. Bridge Deck
- 3.

Load Paths in Suspension Bridges

Vehicle on Bridge Deck



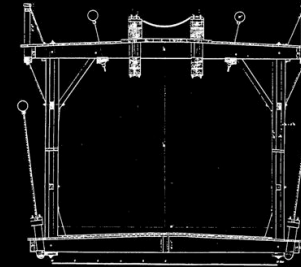
1. Suspension Cables
2. Bridge Deck
3. Diagonal Stays



“The means employed are:

Weight, Girders, Trusses, and Stays.

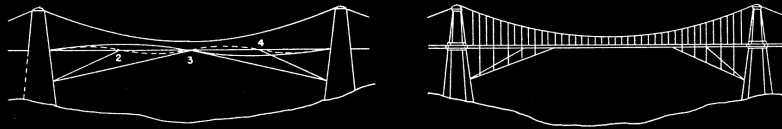
With these any degree of stiffness can be insured, to resist either the action of trains or the violence of storm . . .”



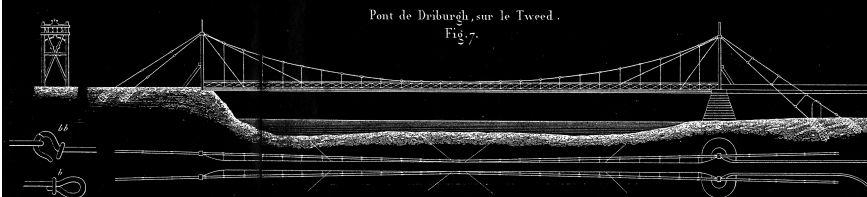
J.A. Roebling, *Final Report, Niagara Bridge*

Niagara Railroad Bridge (1849)
John A. Roebling

822 ft span
Niagara River



John Scott Russell (1839)



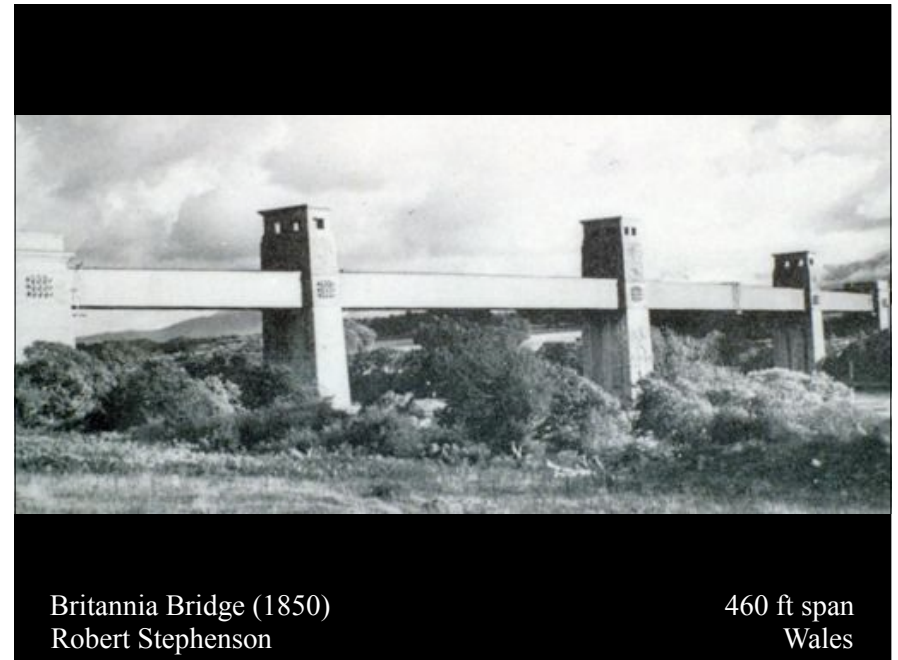
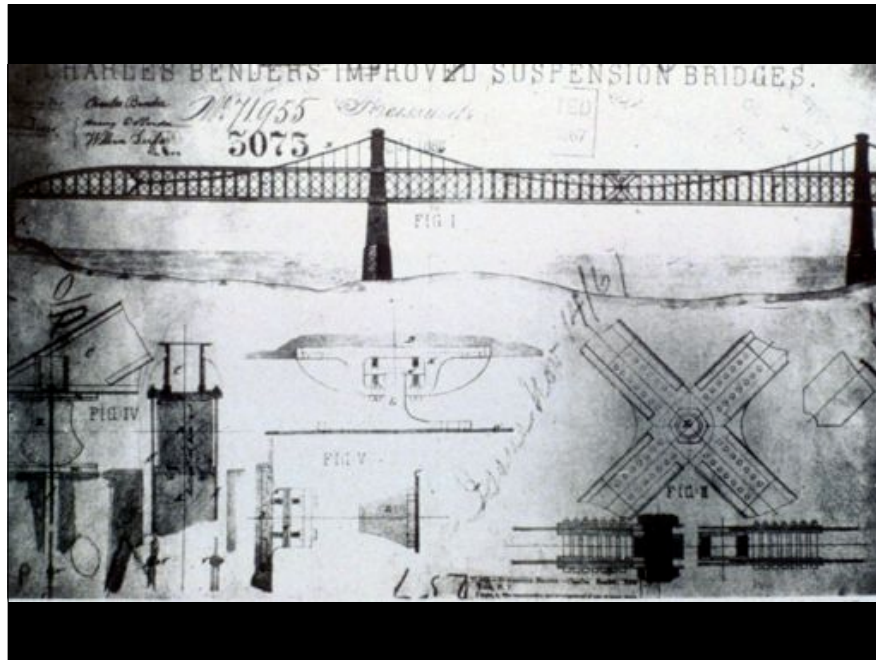
2nd Dryburgh Abbey Bridge (1818)

260 ft span



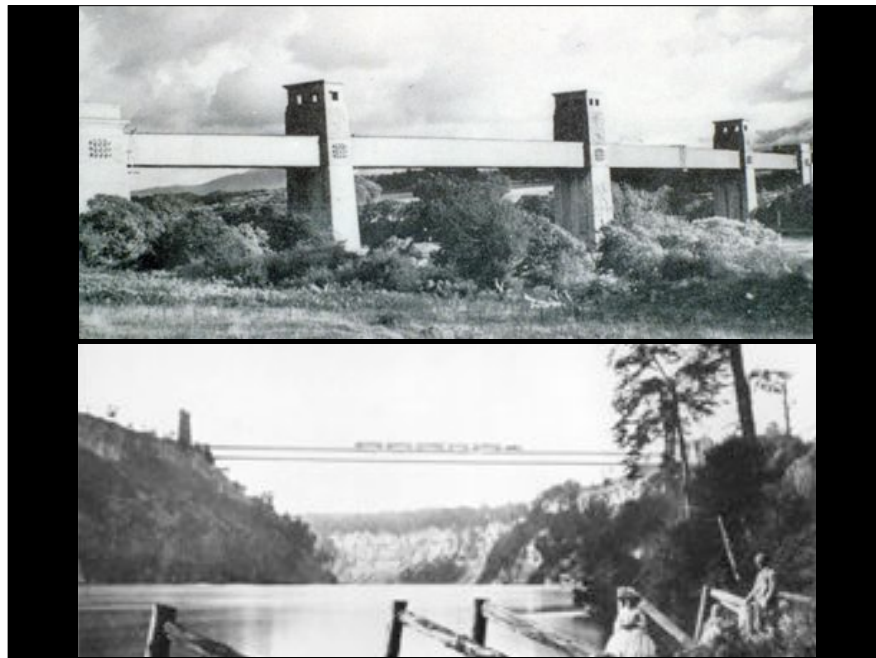
Second Montrose Bridge (1840)

432 ft span

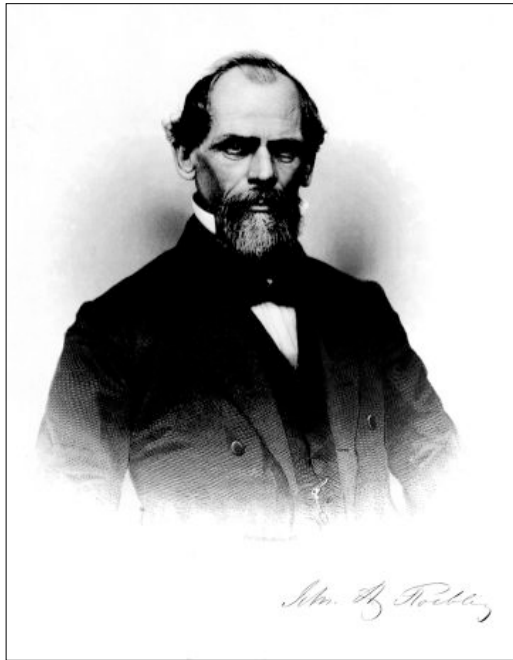


Britannia Bridge (1850)
Robert Stephenson

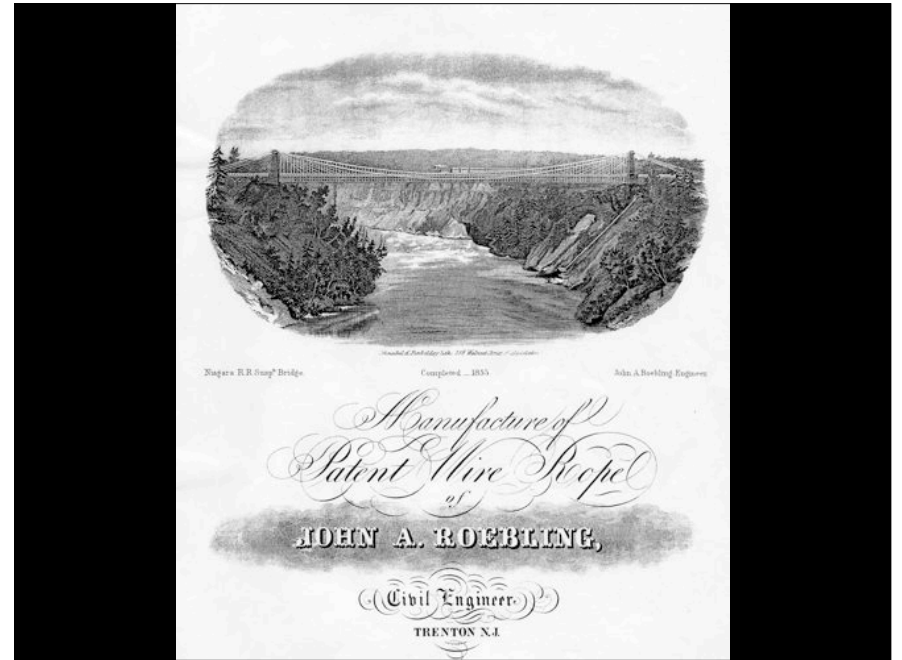
460 ft span
Wales



	Niagara	Britannia
Span Length	821 ft	460 ft
Total Length	821 ft	2 @ 1400 ft
Weight	2400 lb/ft	7000 lb/ft
Cost	£ 100 /ft	£ 215 /ft

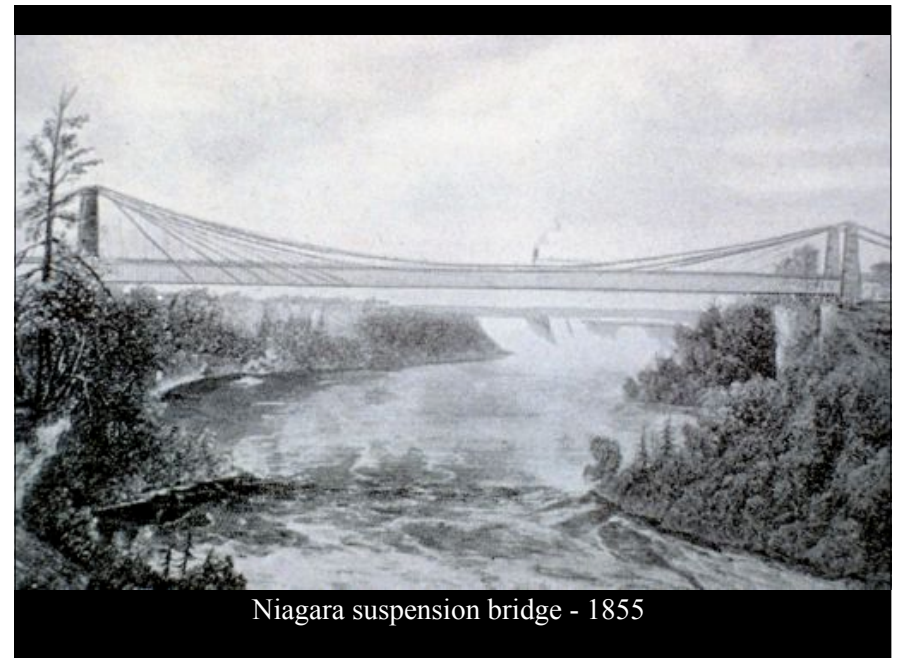


John Augustus Roebling
1806-1869

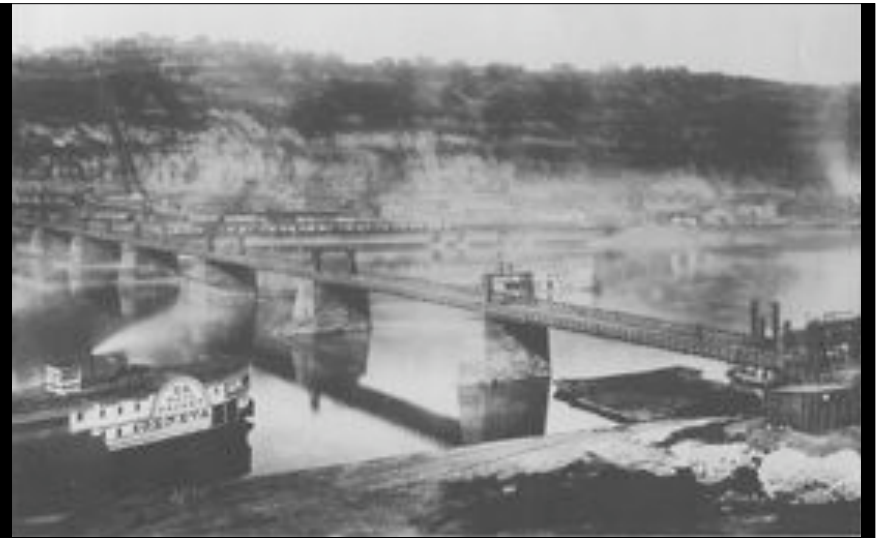
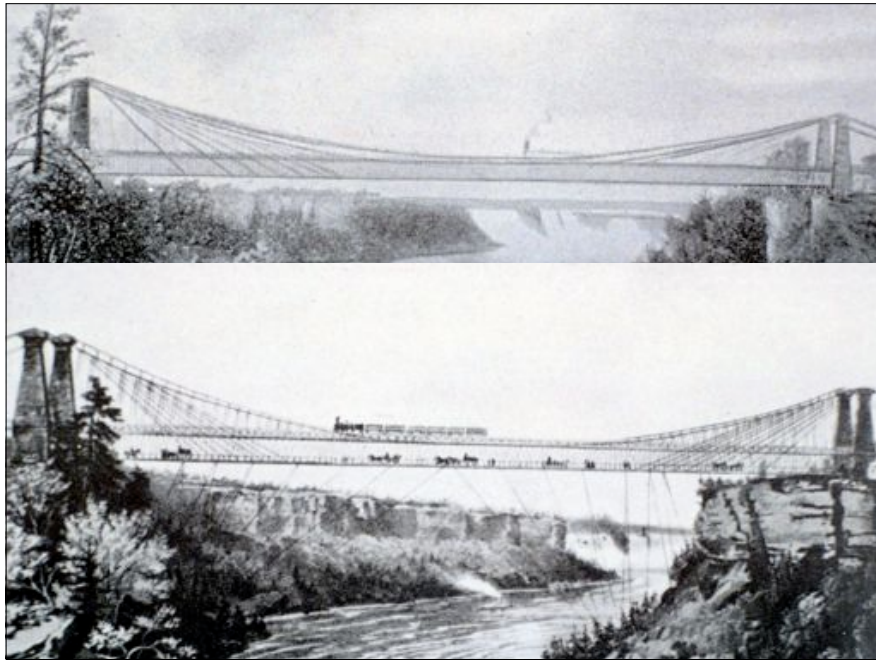


John Roebling's Suspension Bridges

- 1844 Allegheny aqueduct at Pittsburgh
- 1845 Smithfield Street Bridge
- 1849 Delaware and Hudson aqueducts
- 1855 Niagara suspension bridge
- 1856 Ohio river bridge at Cincinnati
- 1860 Sixth Street Bridge
- 1883 Brooklyn Bridge



Niagara suspension bridge - 1855



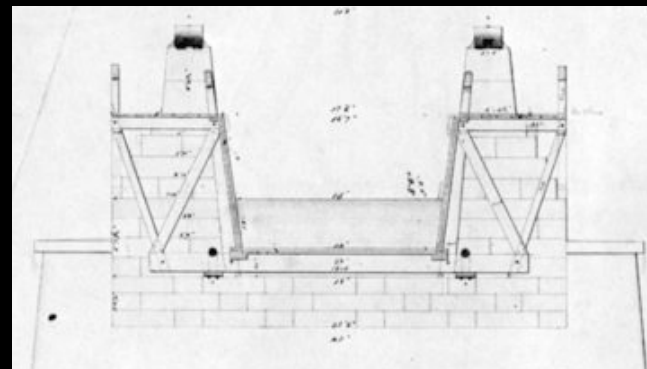
Smithfield Street Bridge (1846)
John A. Roebling

188 ft spans
Pittsburgh



Sixth Street Bridge (1860)
John A. Roebling

344 ft spans
Pittsburgh



p- The original idea upon which the plan has been perfected, was to form a wooden trunk, strong enough to support its own weight, and stiff enough for an aqueduct or bridge, and to combine this structure with wire cables of a sufficient strength to bear safely the great weight of water.

Allegheny River Aqueduct (18xx)
John A. Roebling

188 ft spans
Pittsburgh

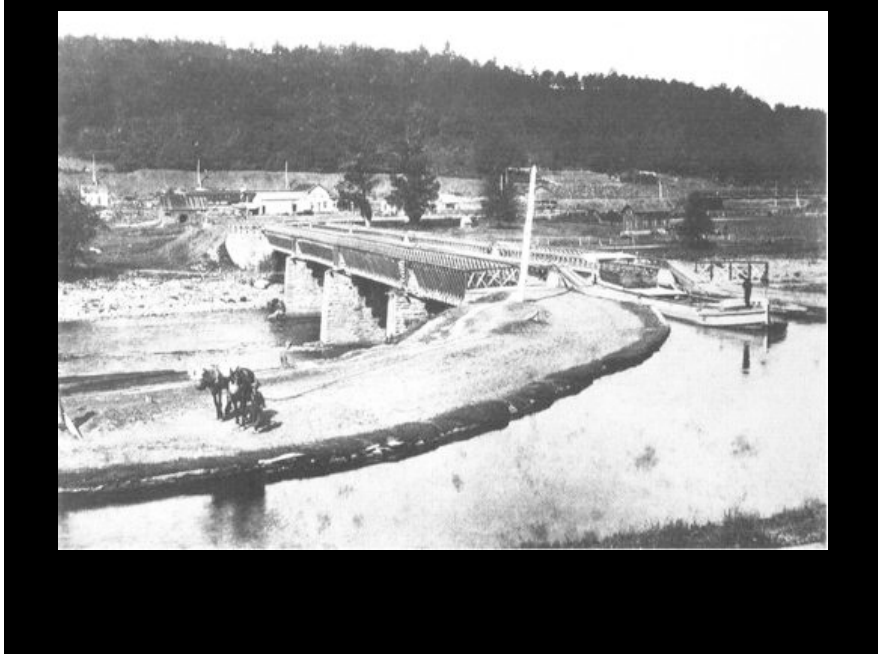


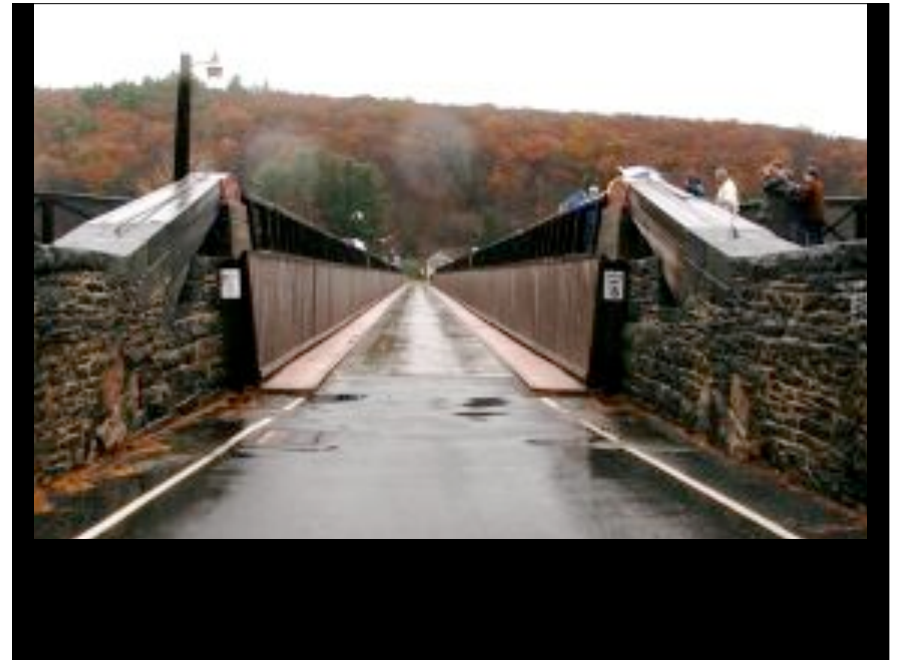
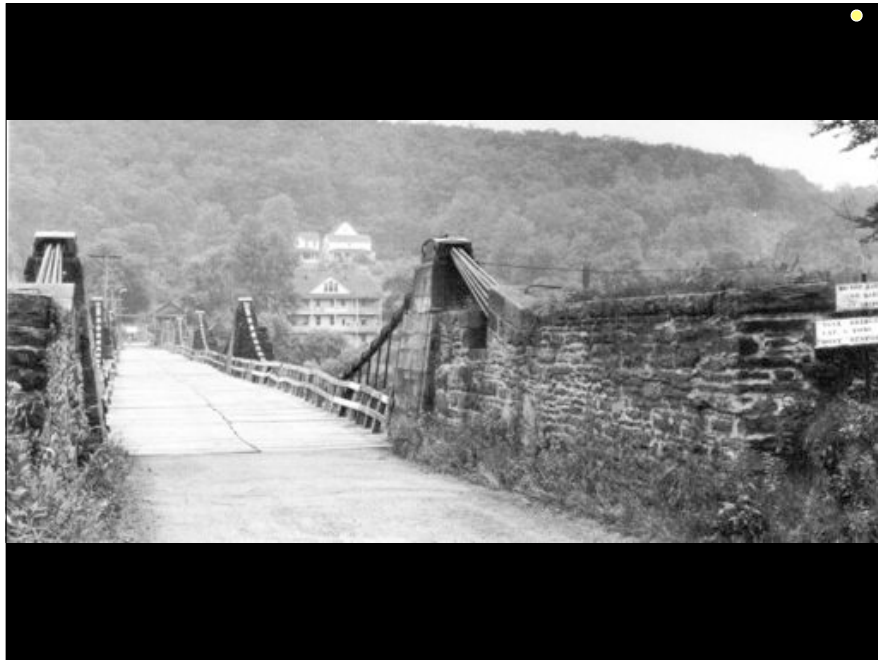
THE DELAWARE AND HUDSON CANAL AND GRAVITY RAILROAD, 1865

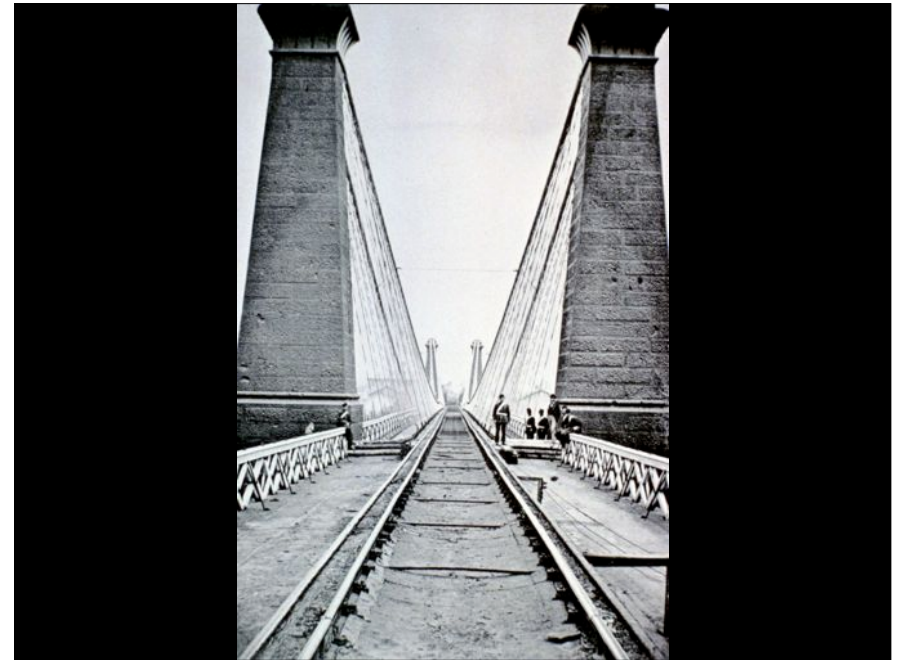
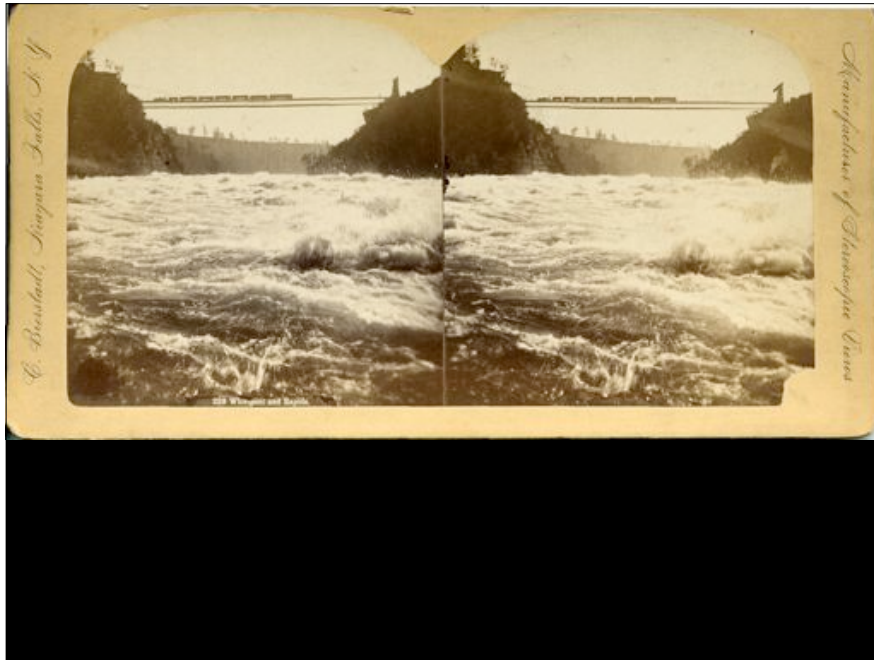
Delaware and Hudson Canal Aqueducts (1847-1850)
 114 ft to 170 ft spans
 Pennsylvania & New York



HACE L.S. PA-1-37



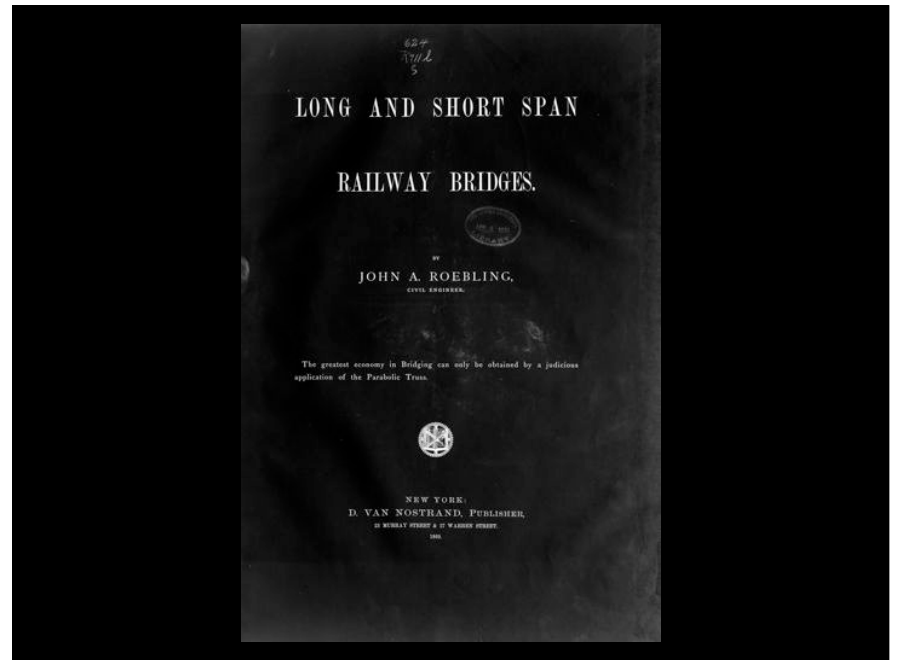
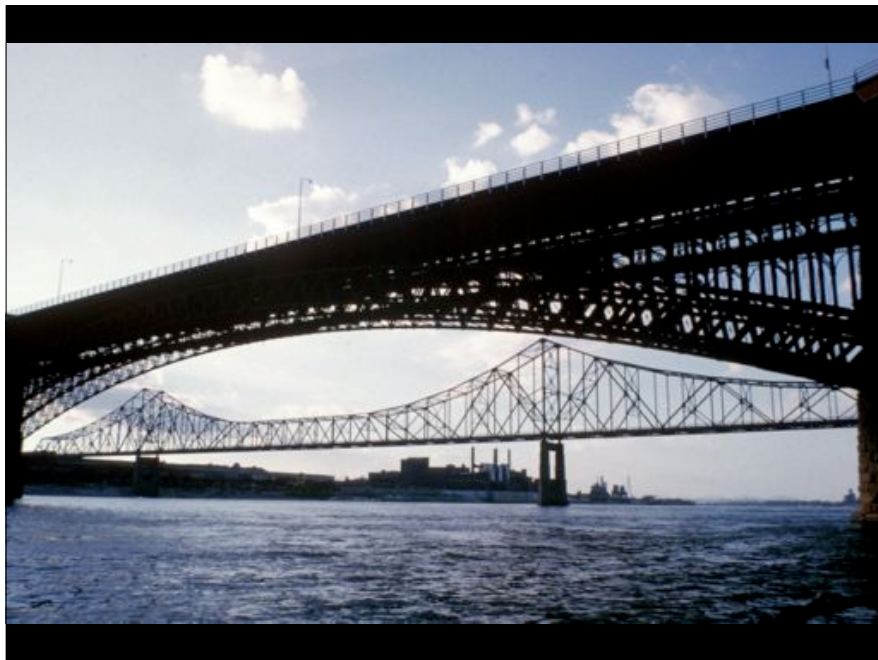
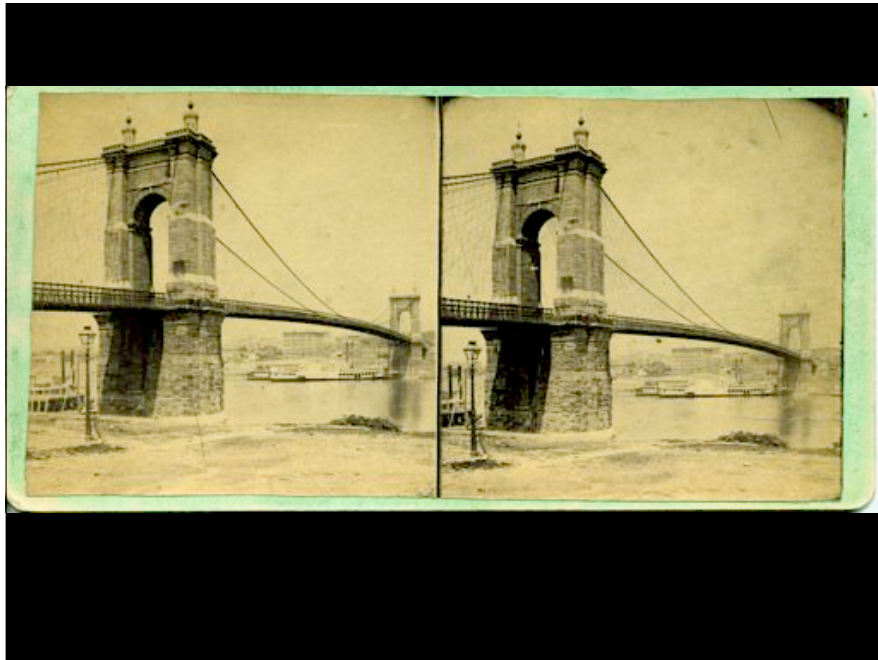


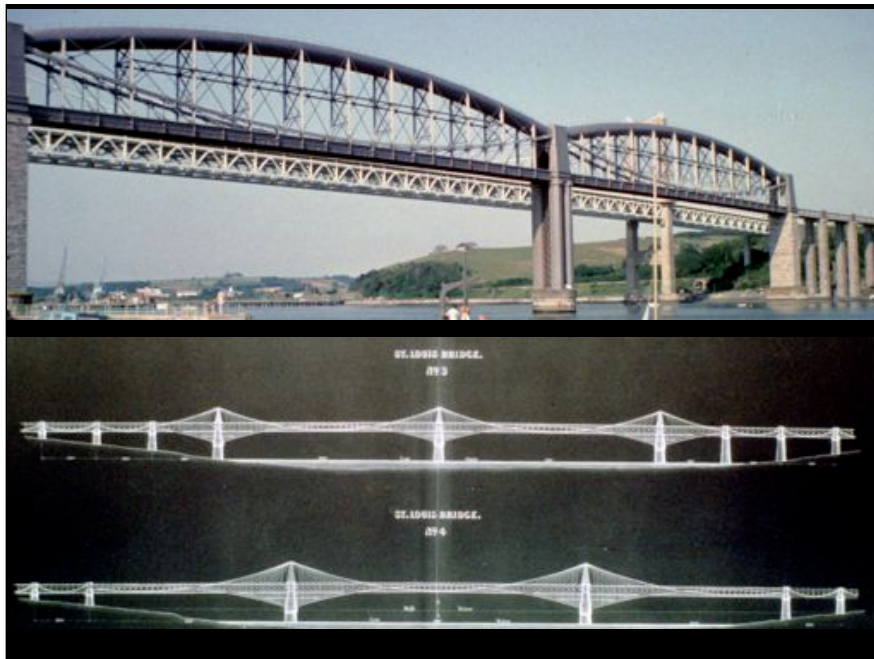
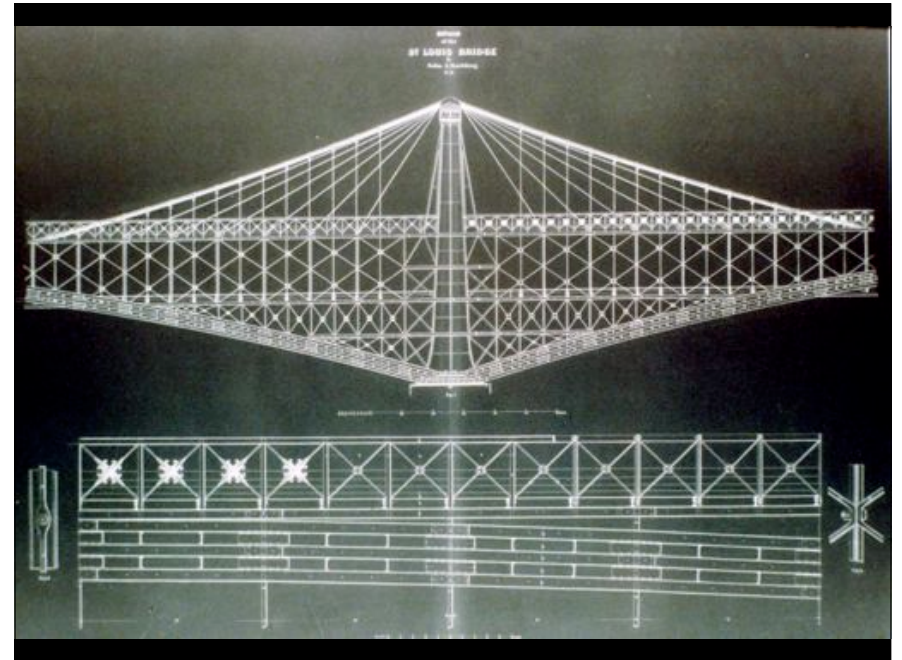
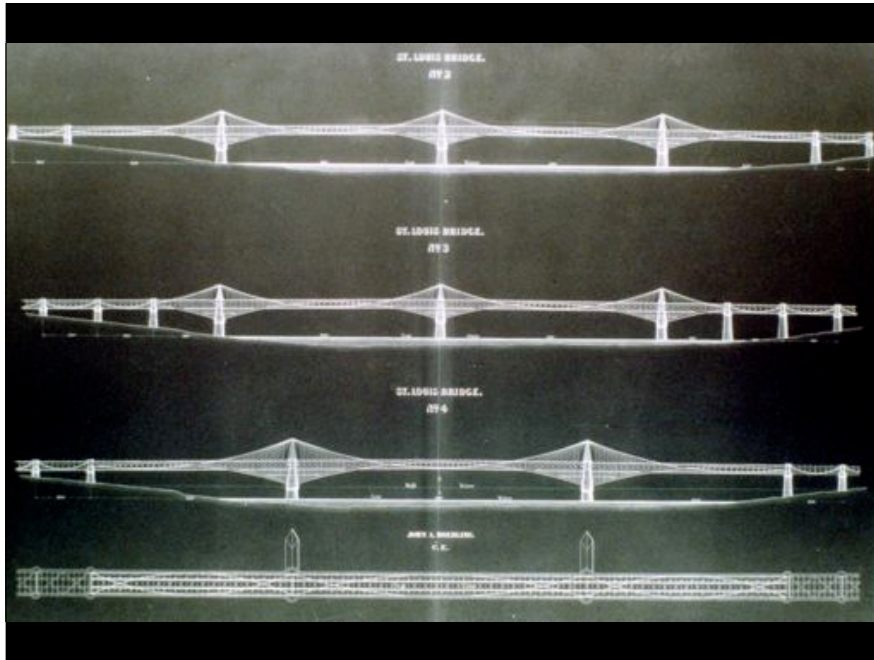


Ohio River Bridge (1856)
John A. Roebling

1057 ft span
Cincinnati



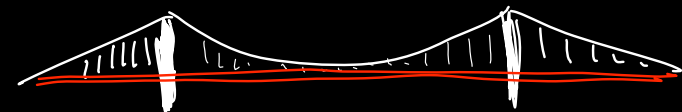




What is one method for imparting stiffness to a suspension bridge?

What are the aesthetic implications of this method?

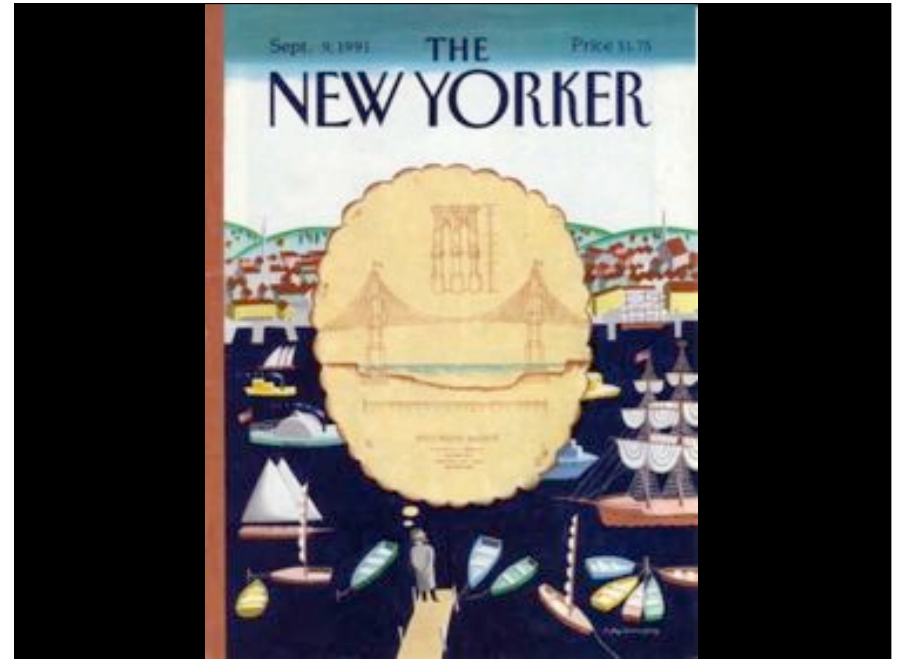
Draw a quick sketch of such a proposal



Flood tide below me! I see you face to face!
Clouds of the west – sun there half an hour high –
I see you also face to face

Crowds of men and women attired in the usual costumes,
how curious you are to me!
On the ferry-boats the hundreds and hundreds that cross, returning home,
are more curious to me than you suppose,
And you that shall cross from shore to shore years hence are more to me,
and more in my meditations, than you might suppose

-Crossing Brooklyn Ferry
Walt Whitman (1856)



The contemplated work, when constructed in accordance with my designs, will not only be the greatest Bridge in existence, but it will be the great engineering work of this continent, and of the age. Its most conspicuous features, the great towers, will serve as landmarks to the adjoining cities, and they will be entitled to be ranked as national monuments. As a great work of art, and as a successful specimen of advanced Bridge engineering, this structure will forever testify to the energy, enterprise and wealth of that community, which shall secure its erection.

Respectfully submitted,

JOHN A. ROEBLING.

TRENTON, N. J., Sept. 1st, 1867.

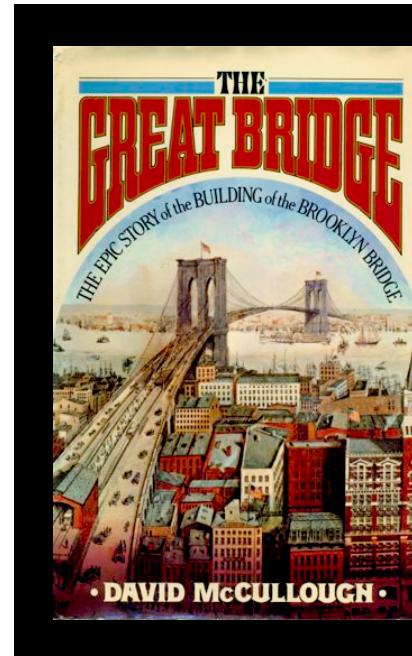
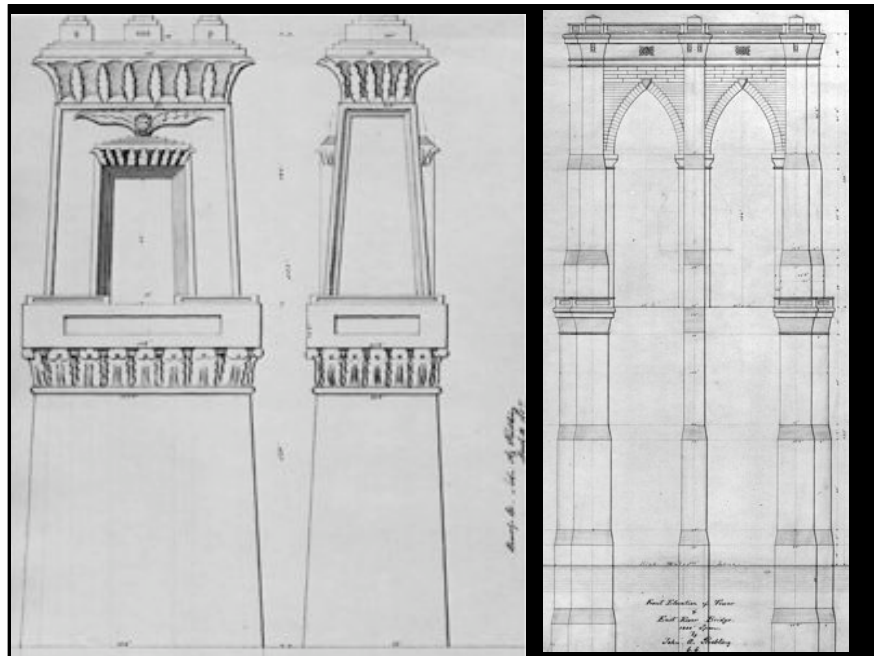
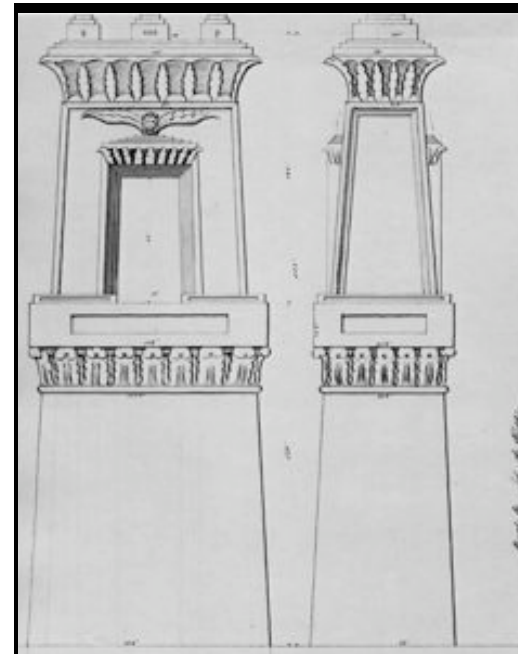
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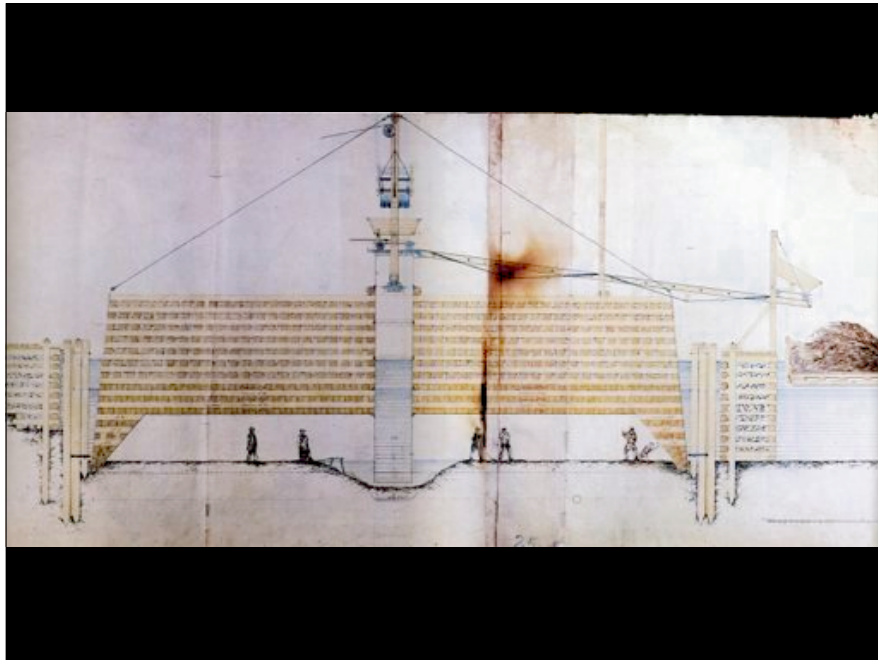
JOHN A. ROEBLING.

TRENTON, N. J., Sept. 1st, 1867.

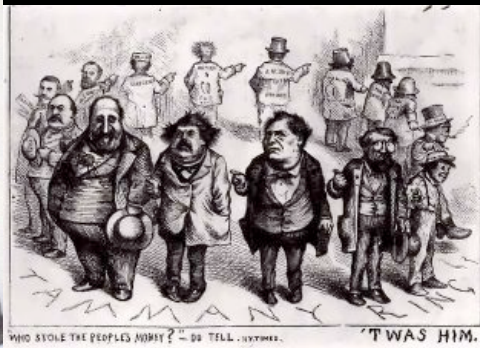
Identify the presence of the 3 S's in this Roebing passage



Washington Roebling

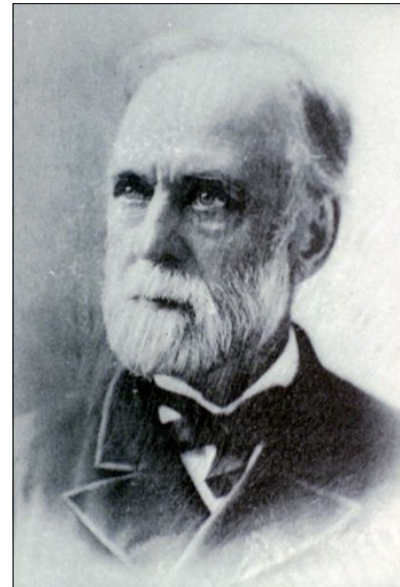


Boss Tweed



Tammany Hall





Abraham Hewitt

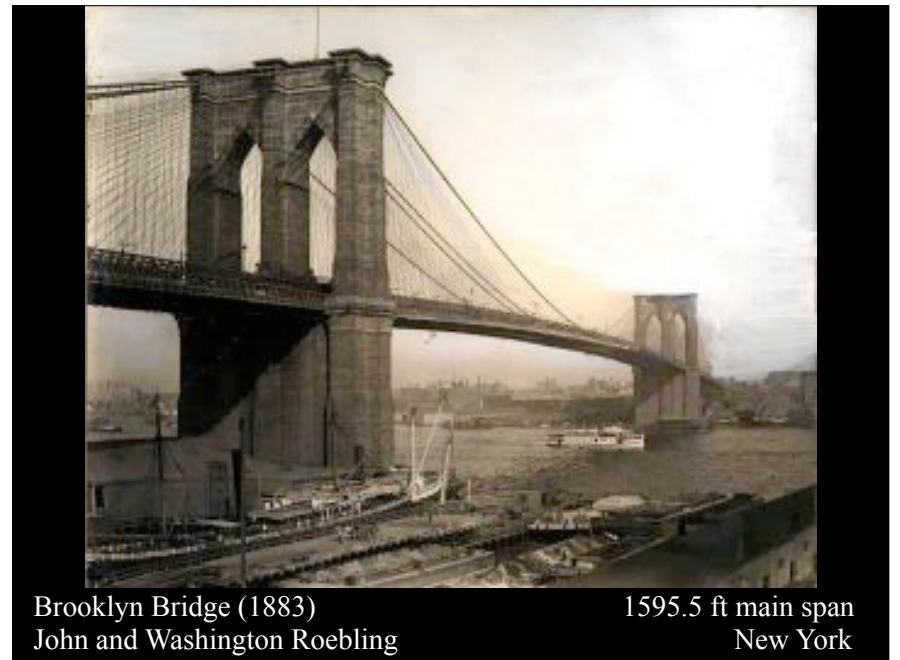
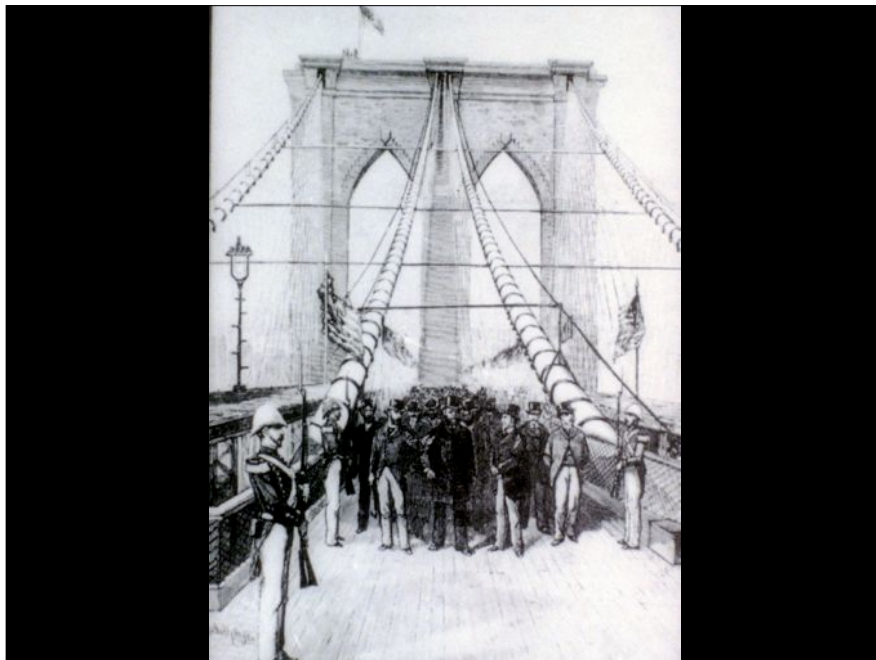


Emily Roebling



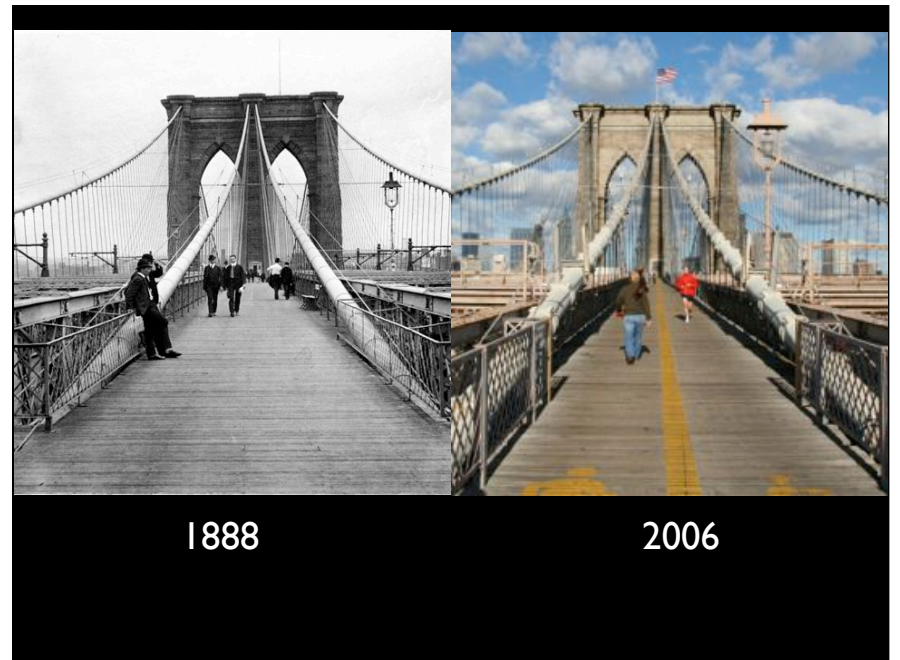
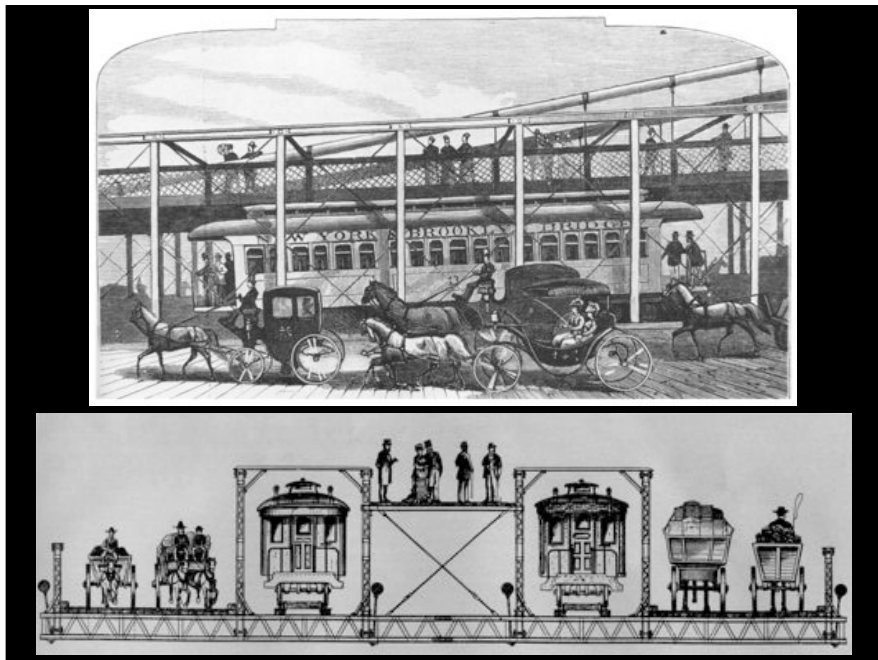
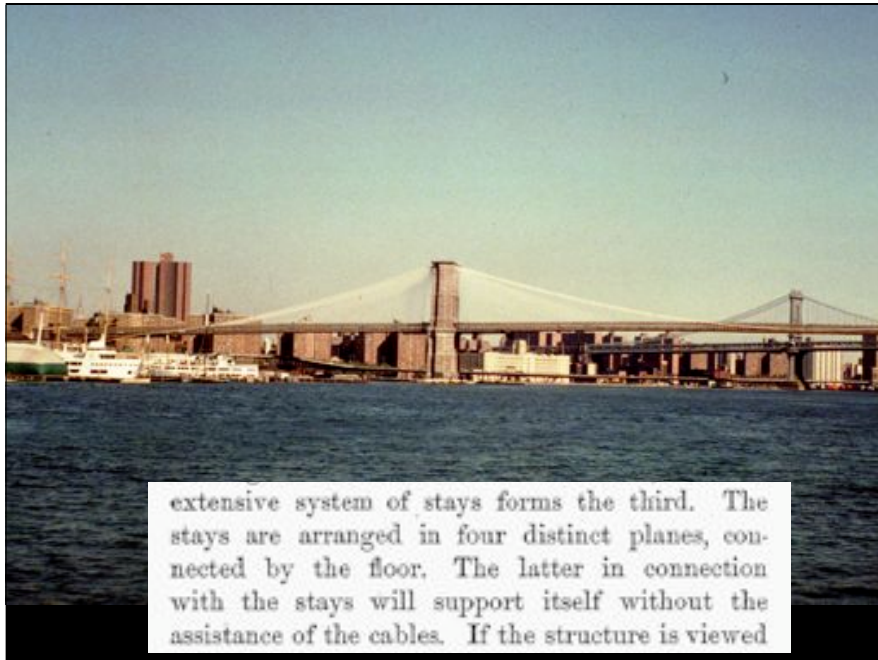


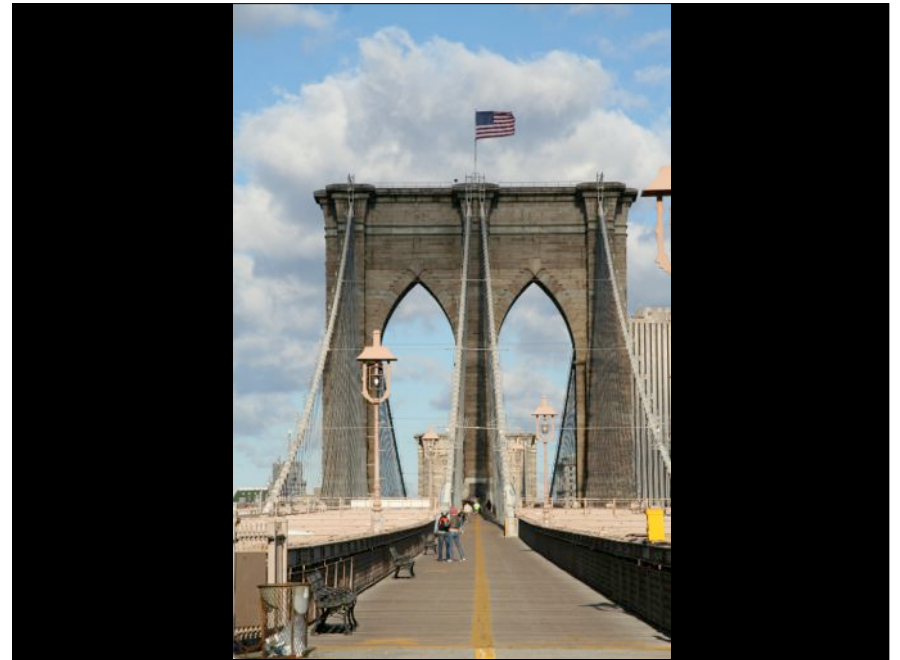
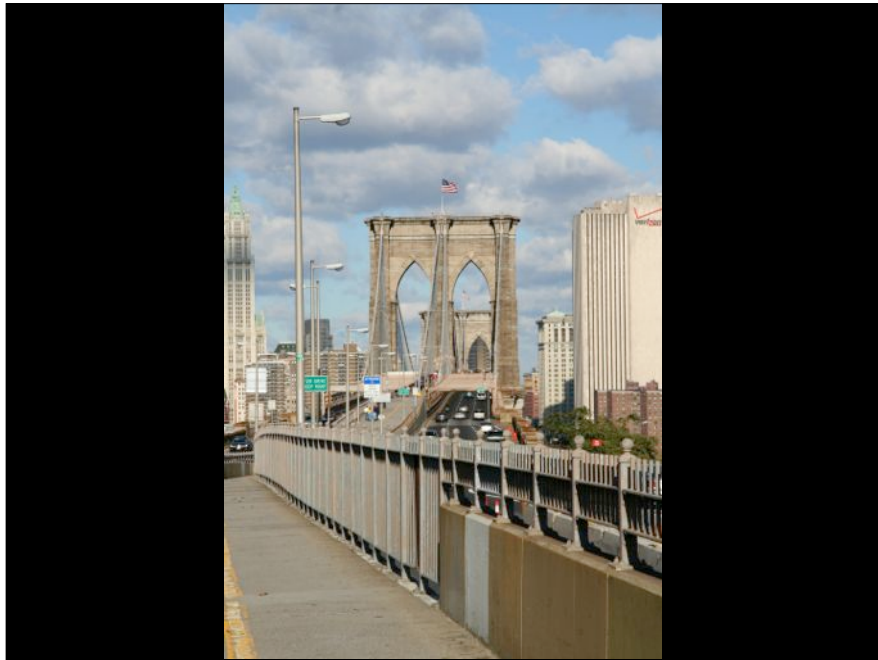
Emily Roebling

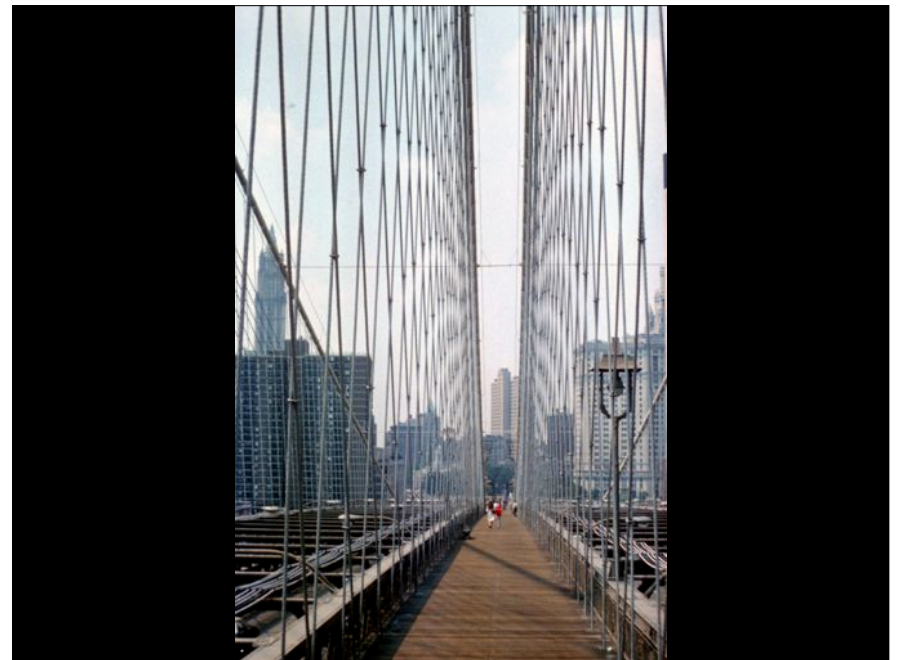
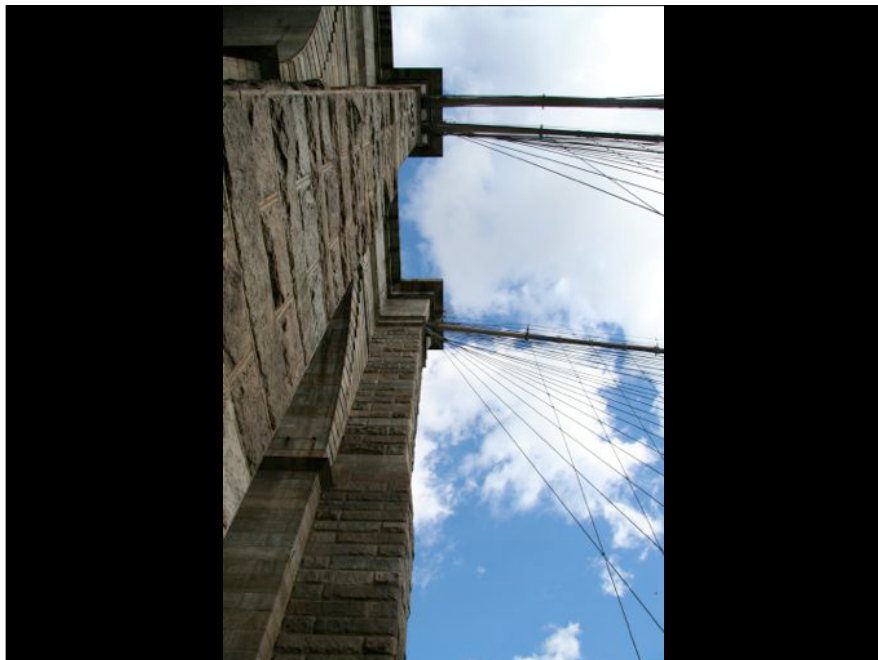
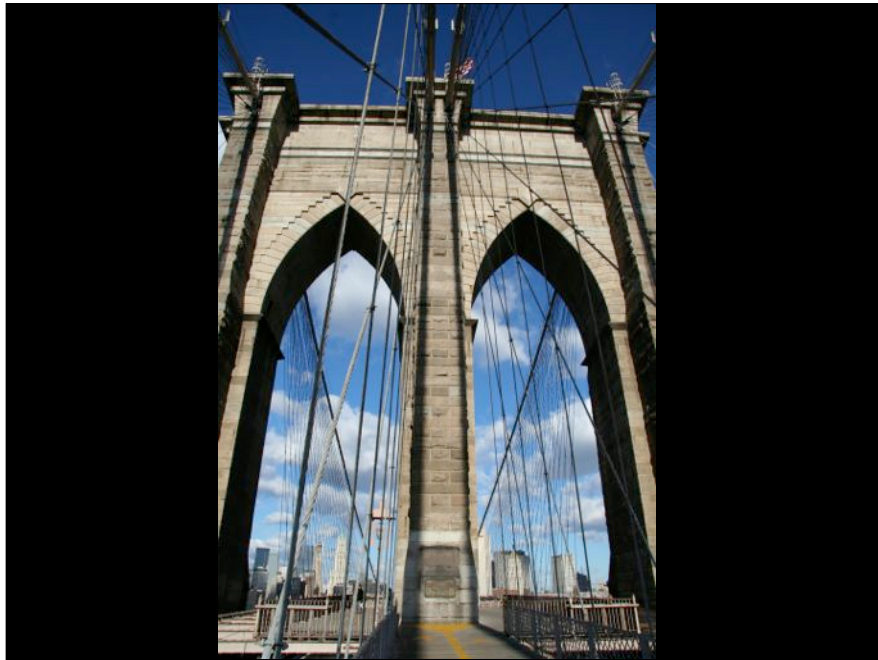


Brooklyn Bridge (1883)
John and Washington Roebling

1595.5 ft main span
New York







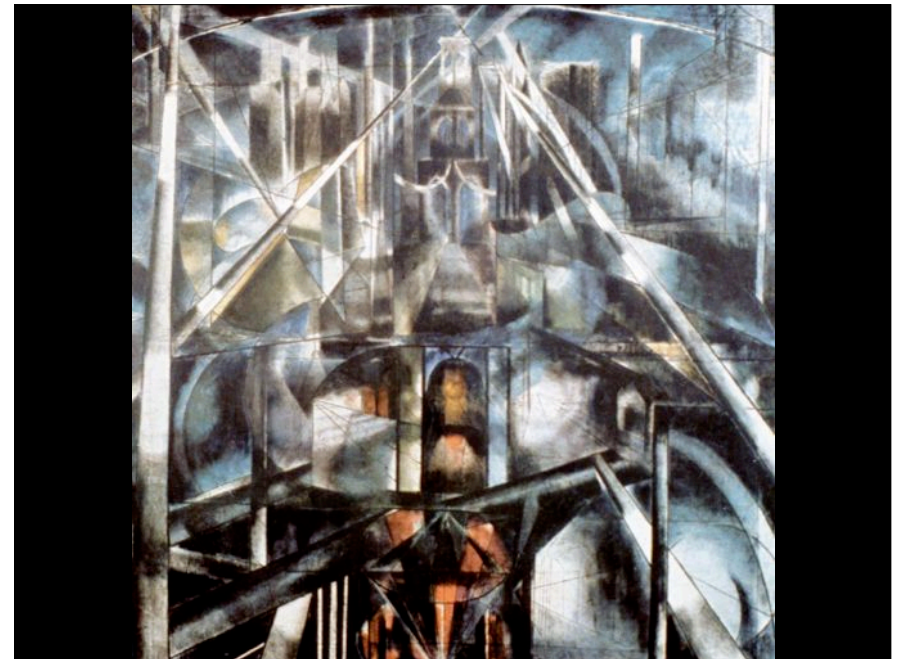


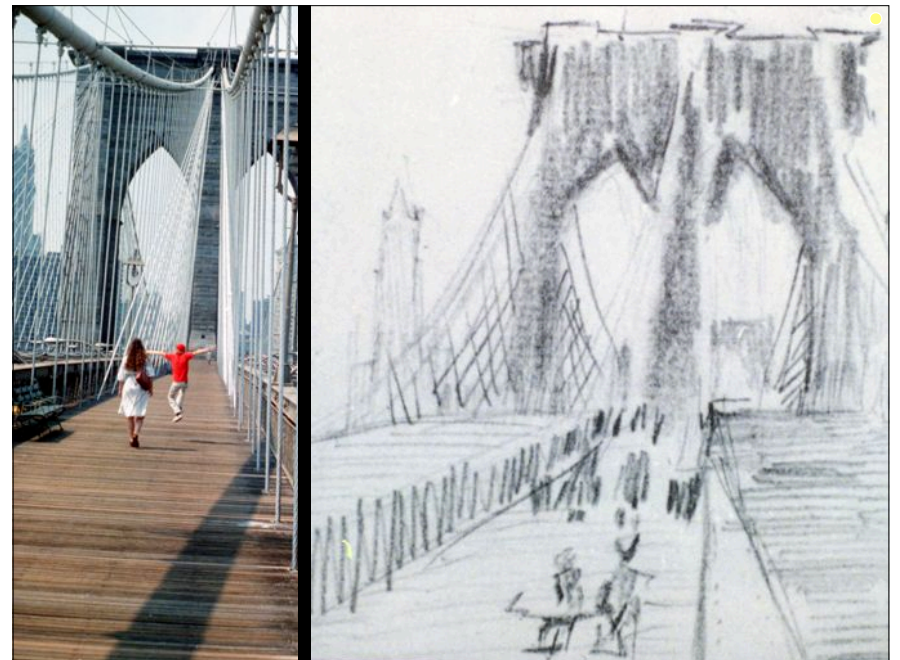
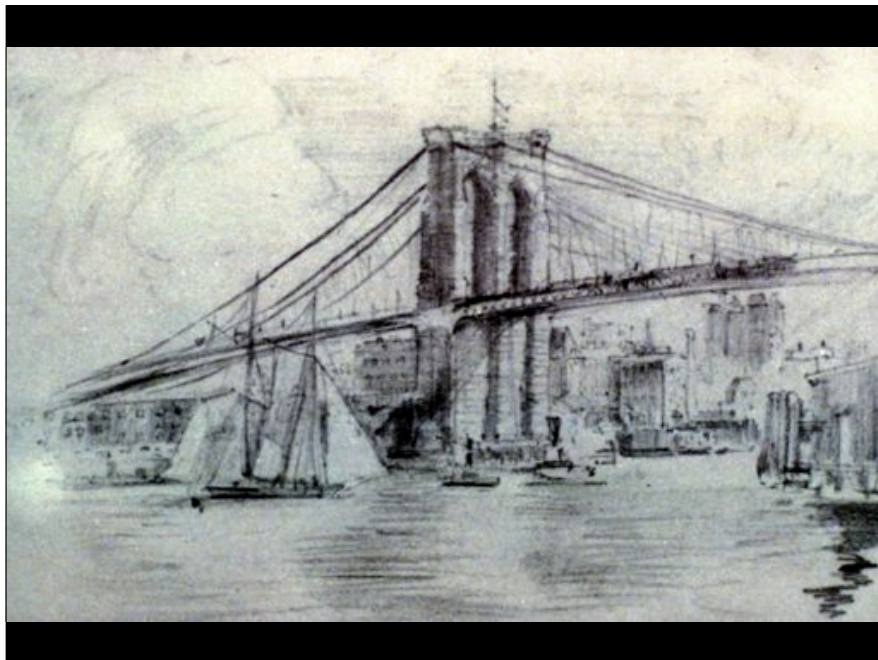
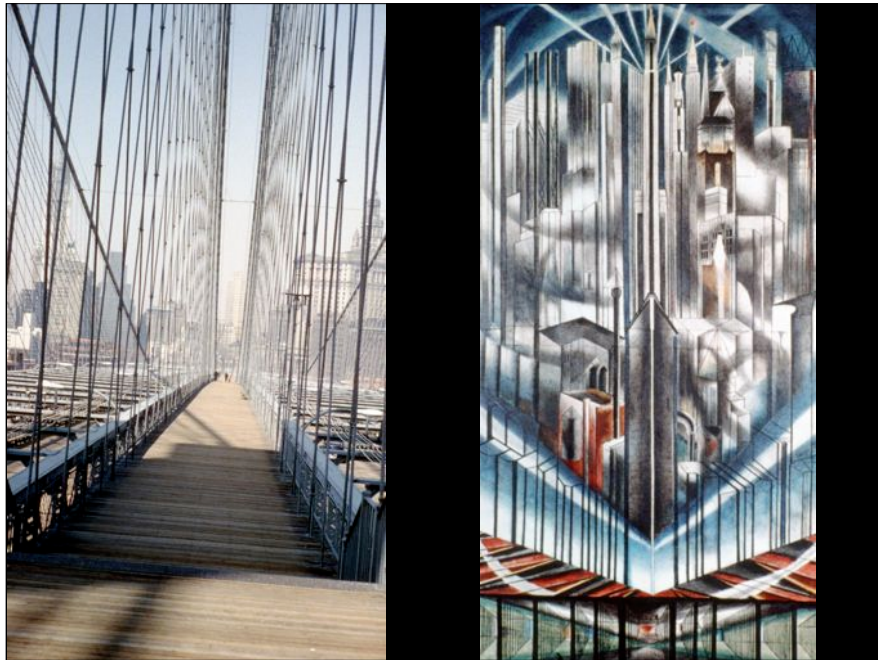
The Brooklyn Bridge was politically and economically significant because it joined the cities of New York and Brooklyn.

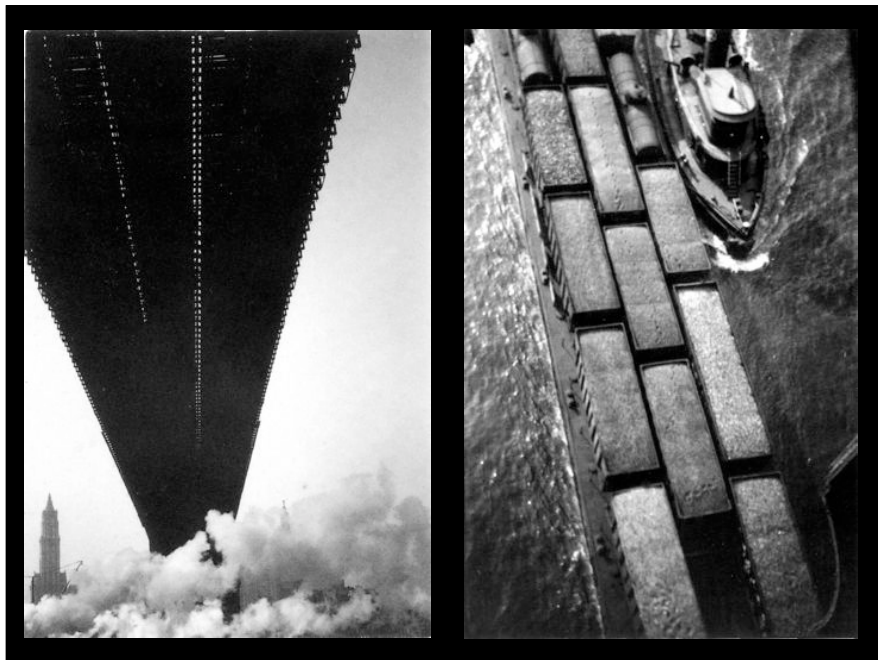
Can you think of other civil works that have had similar political and economic meanings?

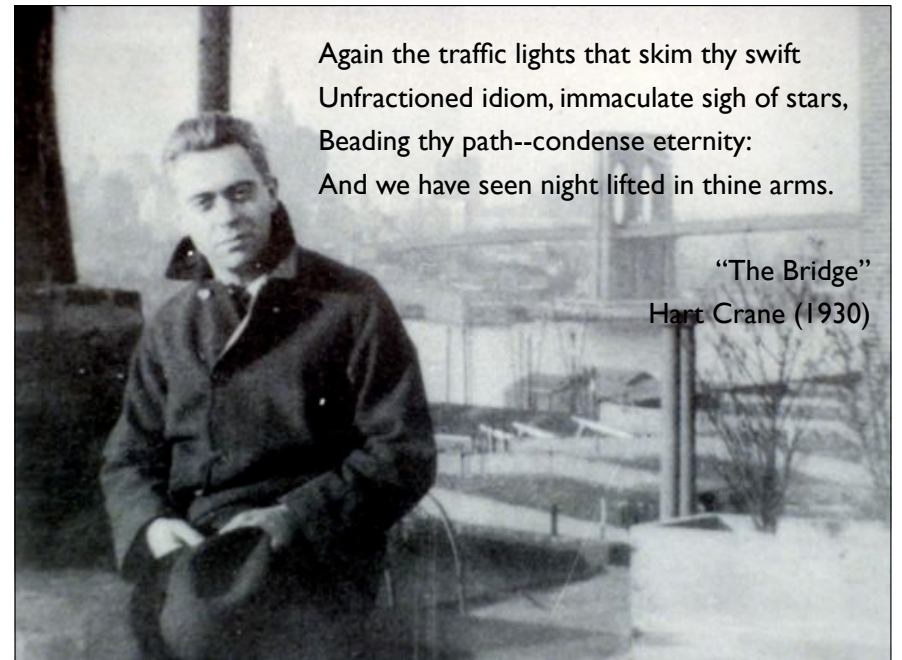
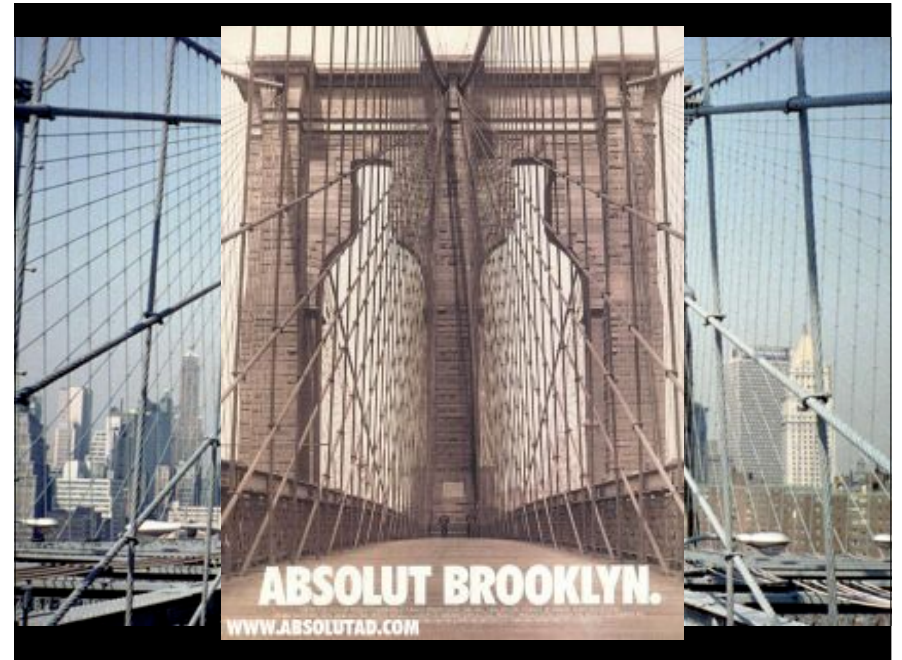
Are there places you would propose such a construction?

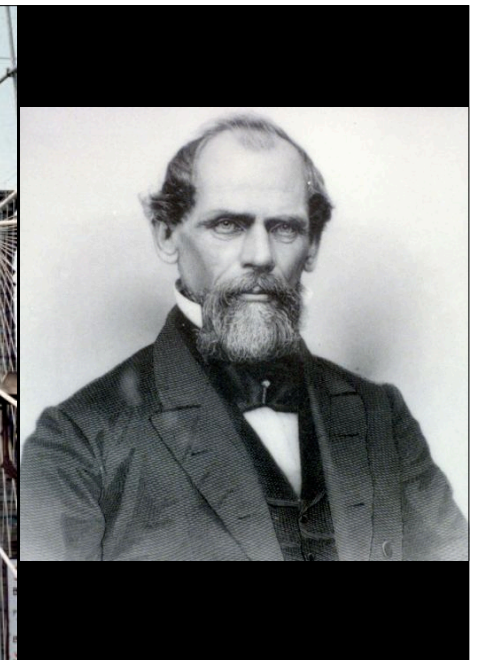
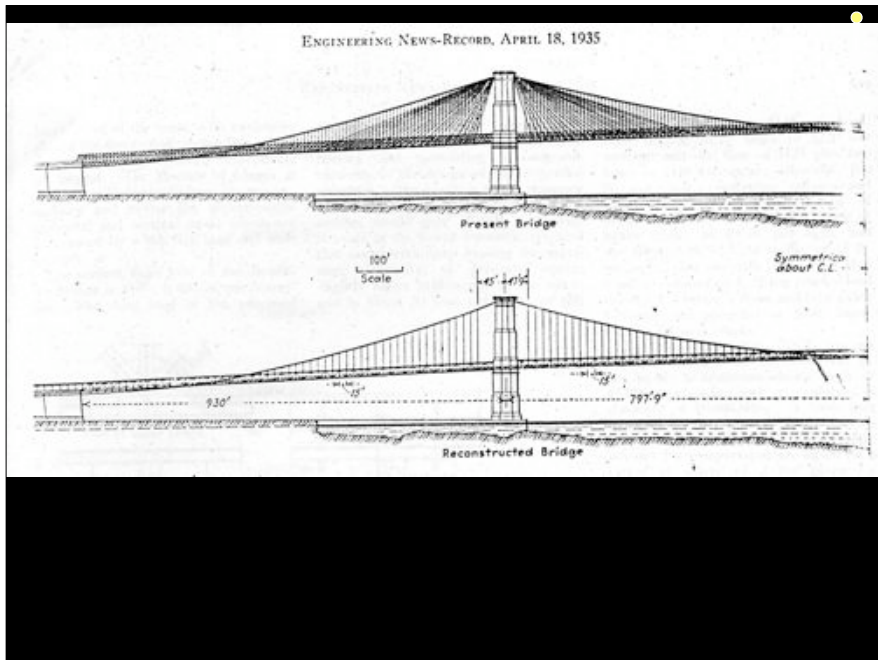
Were the results positive, negative, mixed?



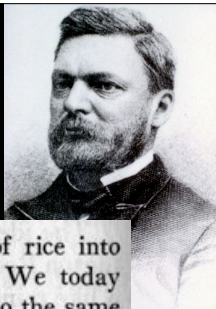








Washington Roebling's reponse to the corrupt Mr. Hewitt. In response to Hewitt's request for discussing the Brooklyn Bridge as a symbol of man's progress. (McCulloch, *The Great Bridge*, p. 522)



To build his pyramid Cheops packed some pounds of rice into the stomachs of innumerable Egyptians and Israelites. We today would pack some pounds of coal inside steam boilers to do the same thing, and this might be cited as an instance of the superiority of modern civilization over ancient brute force. But when referred to the sun, our true standard of reference, the comparison is naught, because to produce these few pounds of coal required a thousand times more solar energy than to produce the few pounds of rice. We are simply taking advantage of an accidental circumstance.

It took Cheops twenty years to build his pyramid, but if he had had a lot of Trustees, contractors, and newspaper reporters to worry him, he might not have finished it by that time. The advantages of modern engineering are in many ways over balanced by the disadvantages of modern civilization.

Brooklyn Bridge

- Scientific Innovative structural system of cables, stays and truss
Longest span in the world
- Social Construction amidst political corruption
Transforms city of New York (connects the city)
Bridge itself is a unique experience
- Symbolic Inspires numerous works of art
The image of New York City



10 Days in Switzerland

CE-ENGIN / ARCH-DES 538 (3 credits)
May 19-29, 2014

A unique opportunity to travel to Switzerland with University of Massachusetts Engineering and Architecture faculty to study the famous bridges of Swiss structural engineer Robert Maillart as well as works by renowned architects such as Le Corbusier

Prof. Sanjay Arwade - Structural Engineering arwade@umass.edu
Prof. Sigrid Miller Pollin - Architecture smiller@art.umass.edu

Program fee: \$2800
Travel, meals, supplies (estimate): \$1900

Priority to UMass students, but open to interested students from any college or university

http://people.umass.edu/arwade/maillart_course

UMassAmherst

UMass Announcements

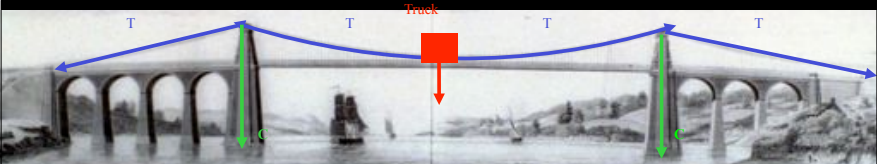
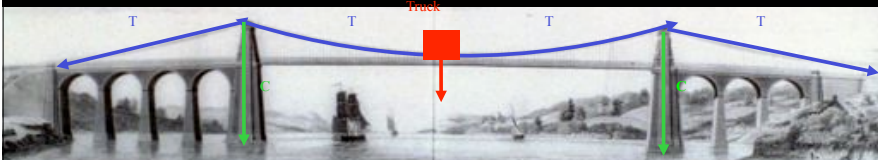
HW 3 (GWB) Due Wed. Feb 19, 5PM Prof. Arwade's office.

Help session Next Tuesday 4PM - 5PM

Suspension Bridge Statics

Load Path

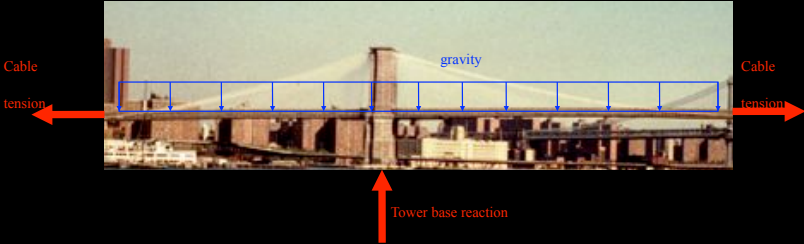
All forces or loads must eventually get to the ground.
Can we trace the path of tension or compression?

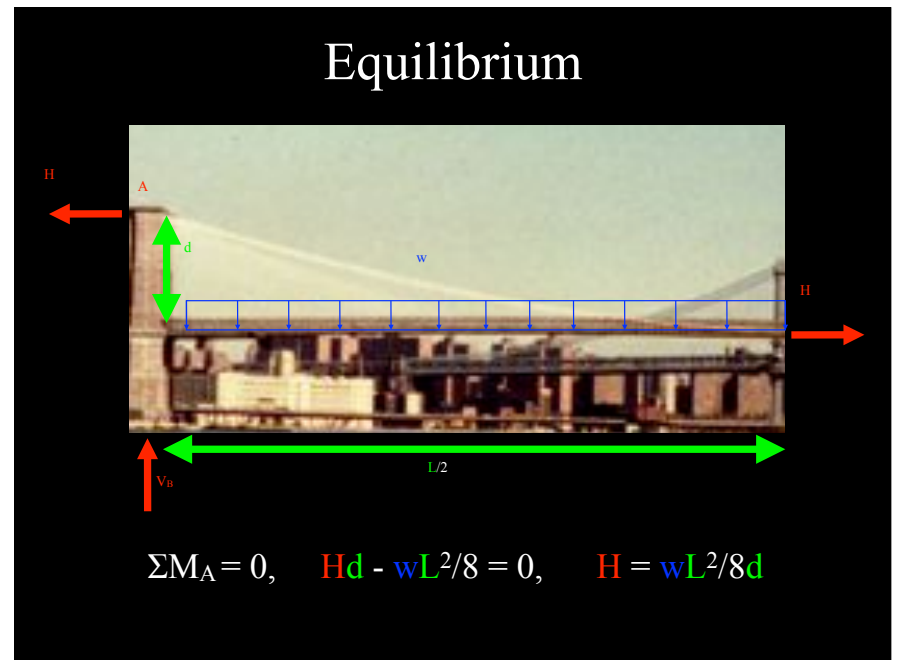
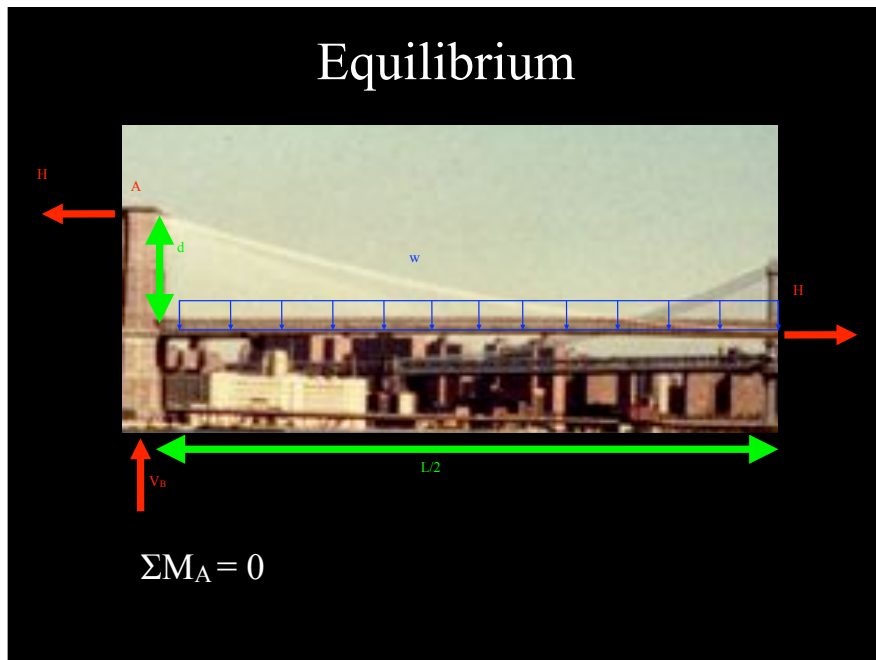
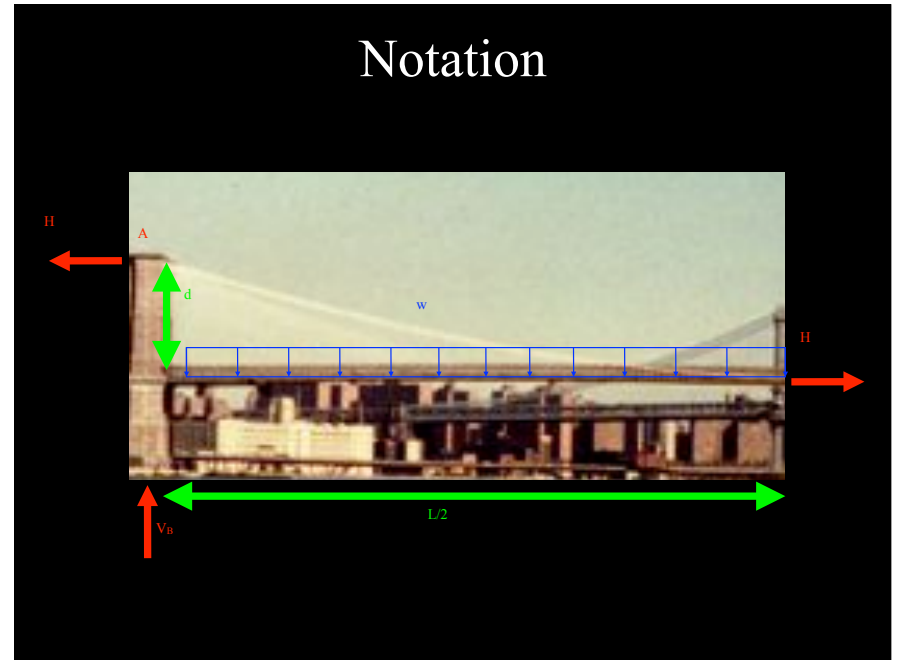
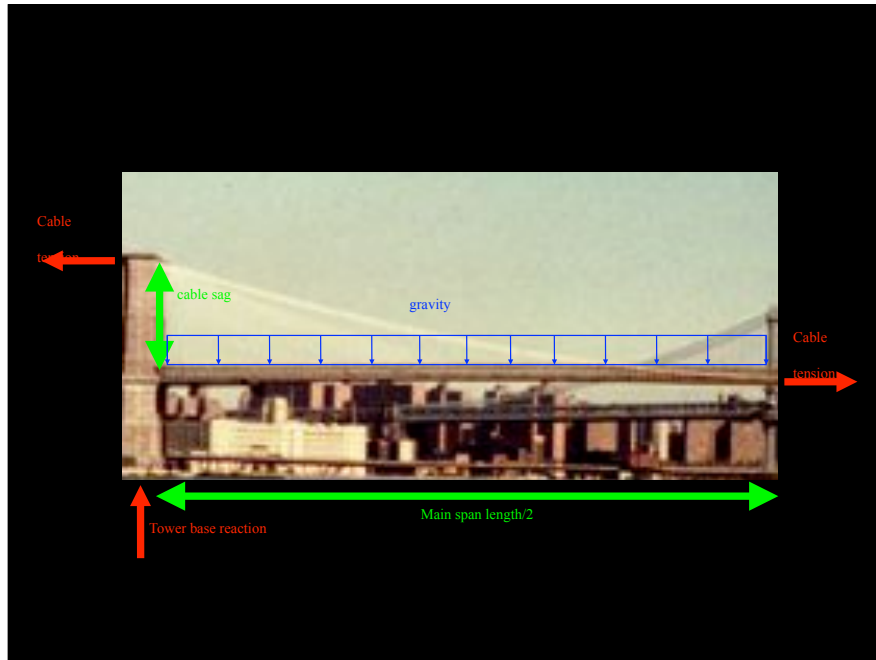


How does Roebling's introduction of diagonal stays introduce ambiguity to the load path?

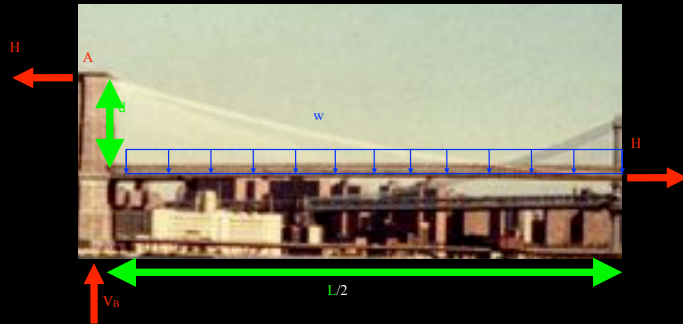
Free Body Diagrams

A sketch of all or part of a structure, detached from its support





Cable tension



$$H = \frac{wL^2}{8d}$$

$$\downarrow R = L/d$$

$$H = \frac{wLR}{8}$$

R, L transform w into H

w = load

L = size

R = form

H = function

