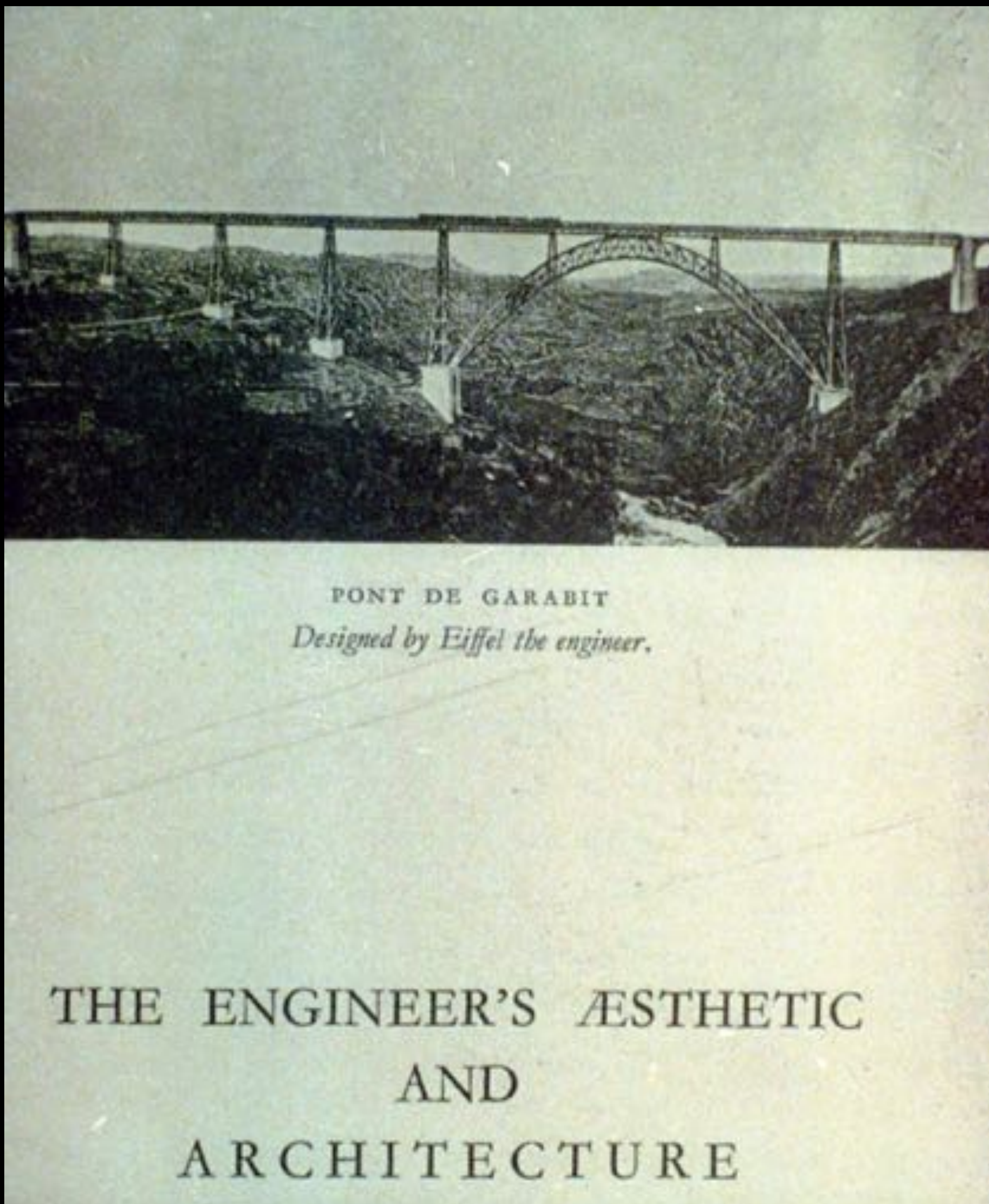
John A. Roebling and the Design of Suspension Bridges

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



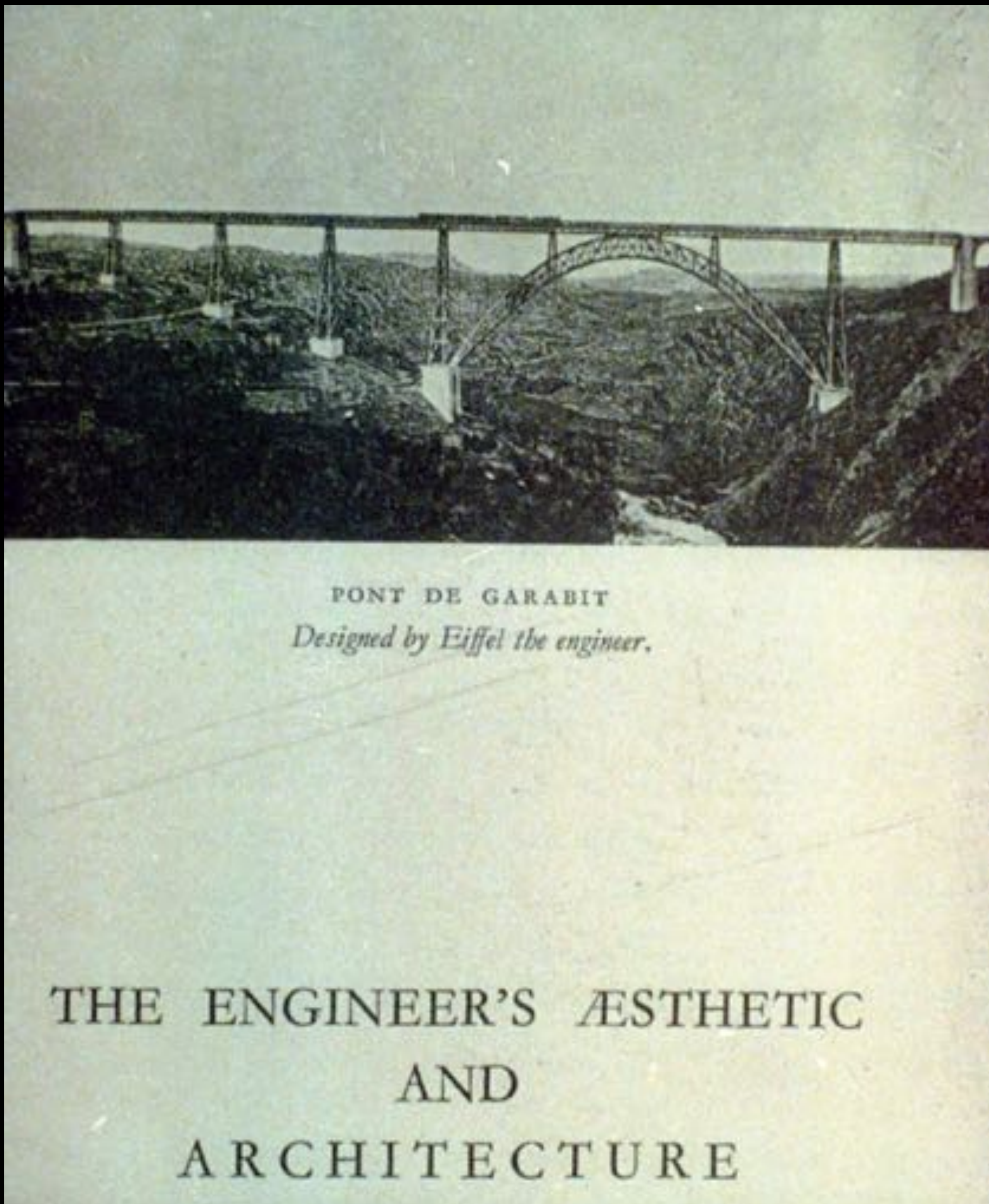
PONT DE GARABIT

Designed by Eiffel the engineer.

THE ENGINEER'S ÆSTHETIC
AND
ARCHITECTURE

Eiffel

Brunel


PONT DE GARABIT

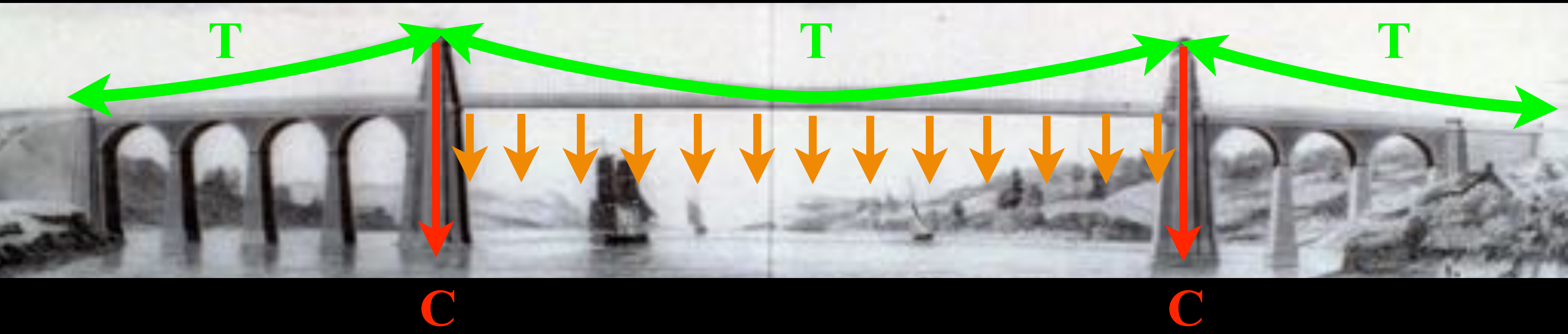
Designed by Eiffel the engineer.

THE ENGINEER'S ÆSTHETIC
AND
ARCHITECTURE


I.K.BRUNEL
ENGINEER
1859

Load Paths in Suspension Bridges

Weight of Bridge Deck

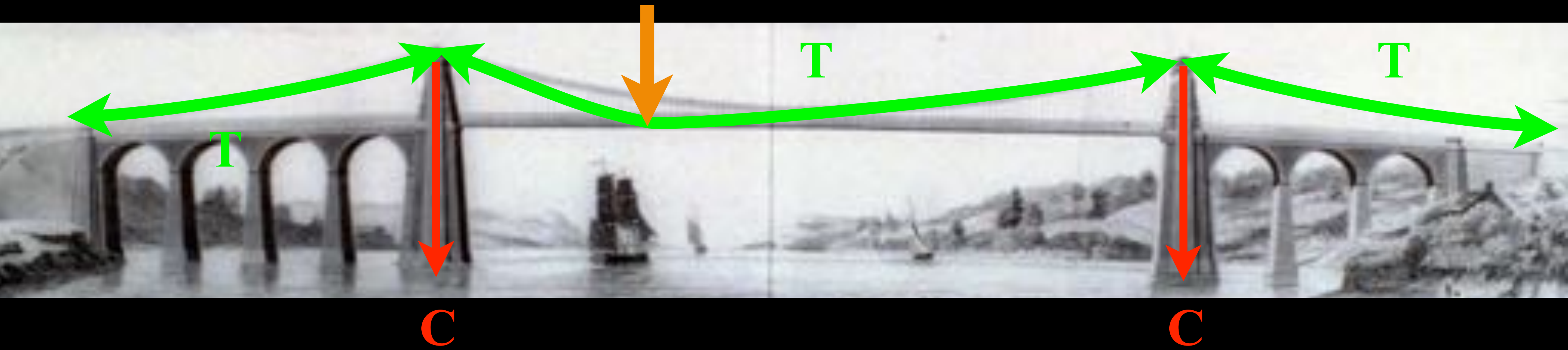


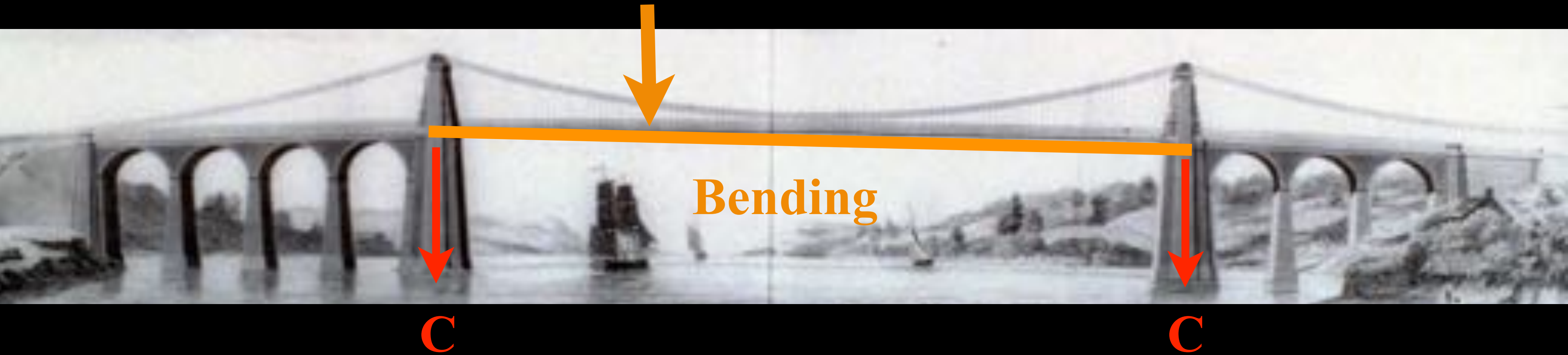
Shape of cable?

Parabola

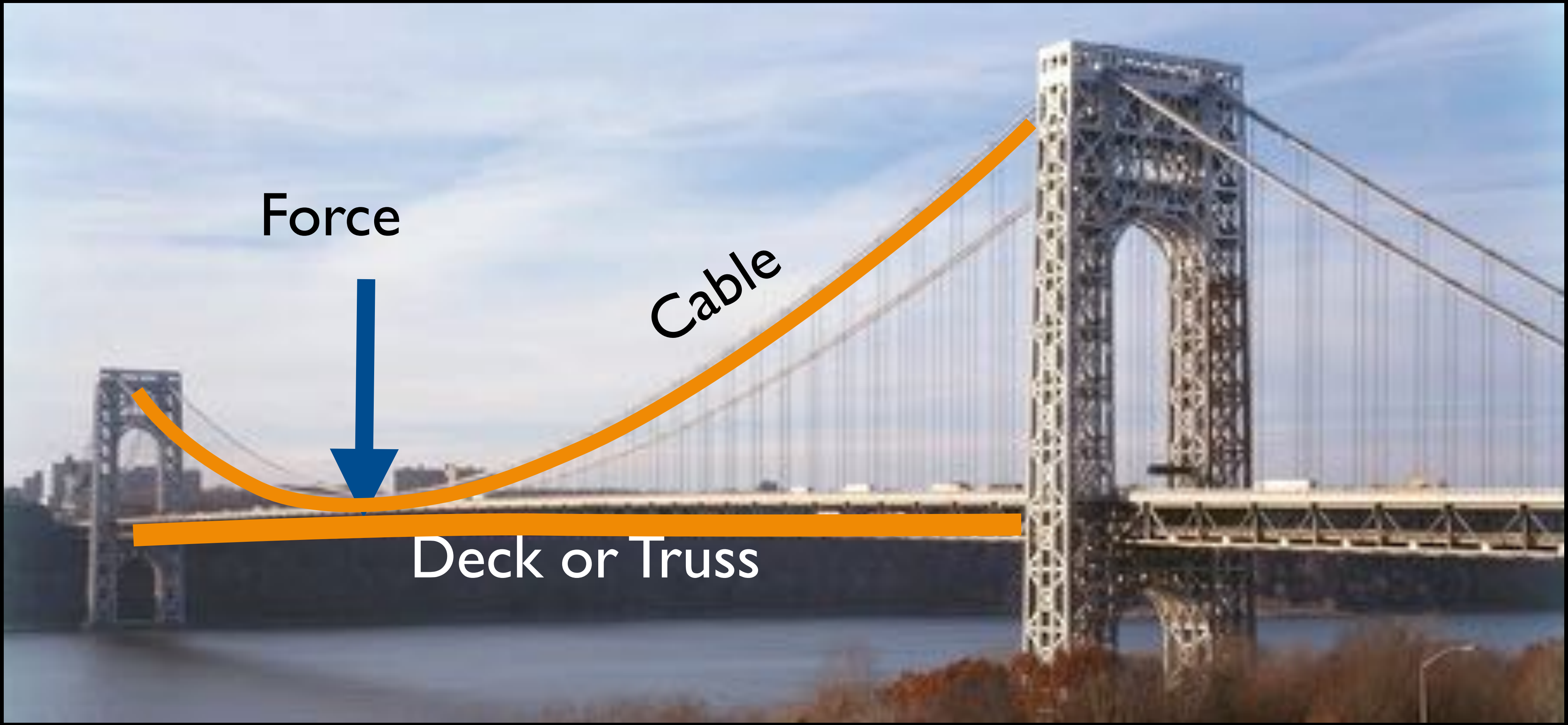
Load Paths in Suspension Bridges

Vehicle on Bridge Deck





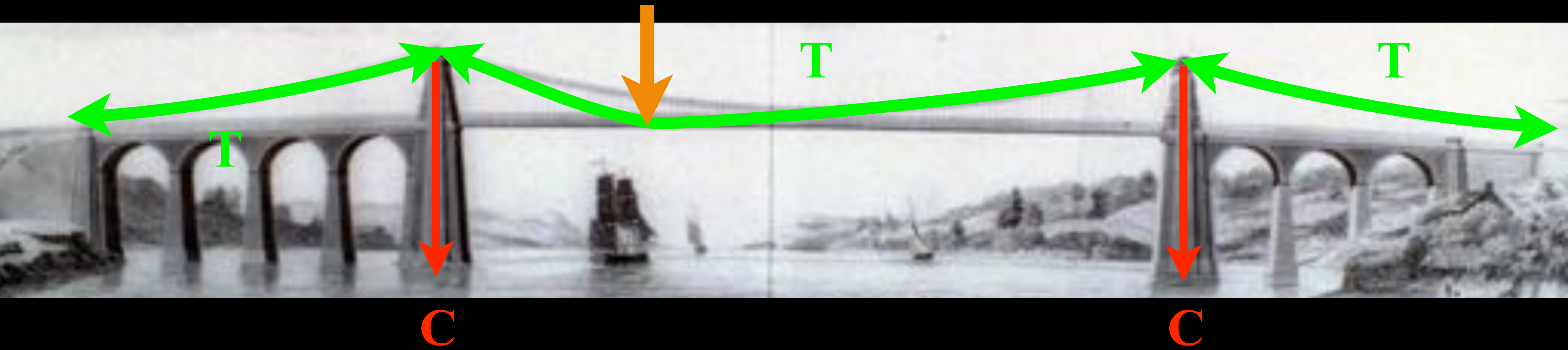
Stiffness
Resistance to Deformation

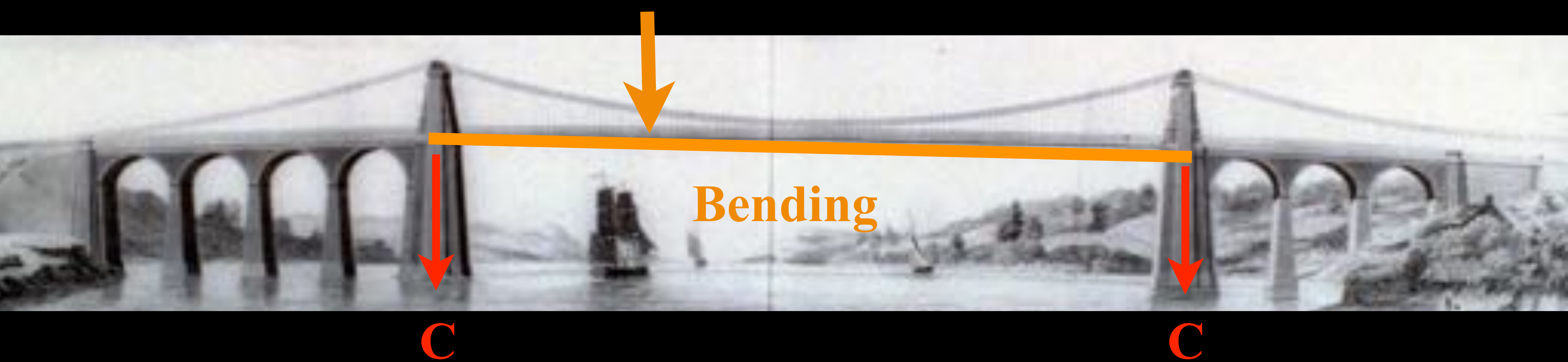


1. Cables have Stiffness
2. Force Follows Stiffness

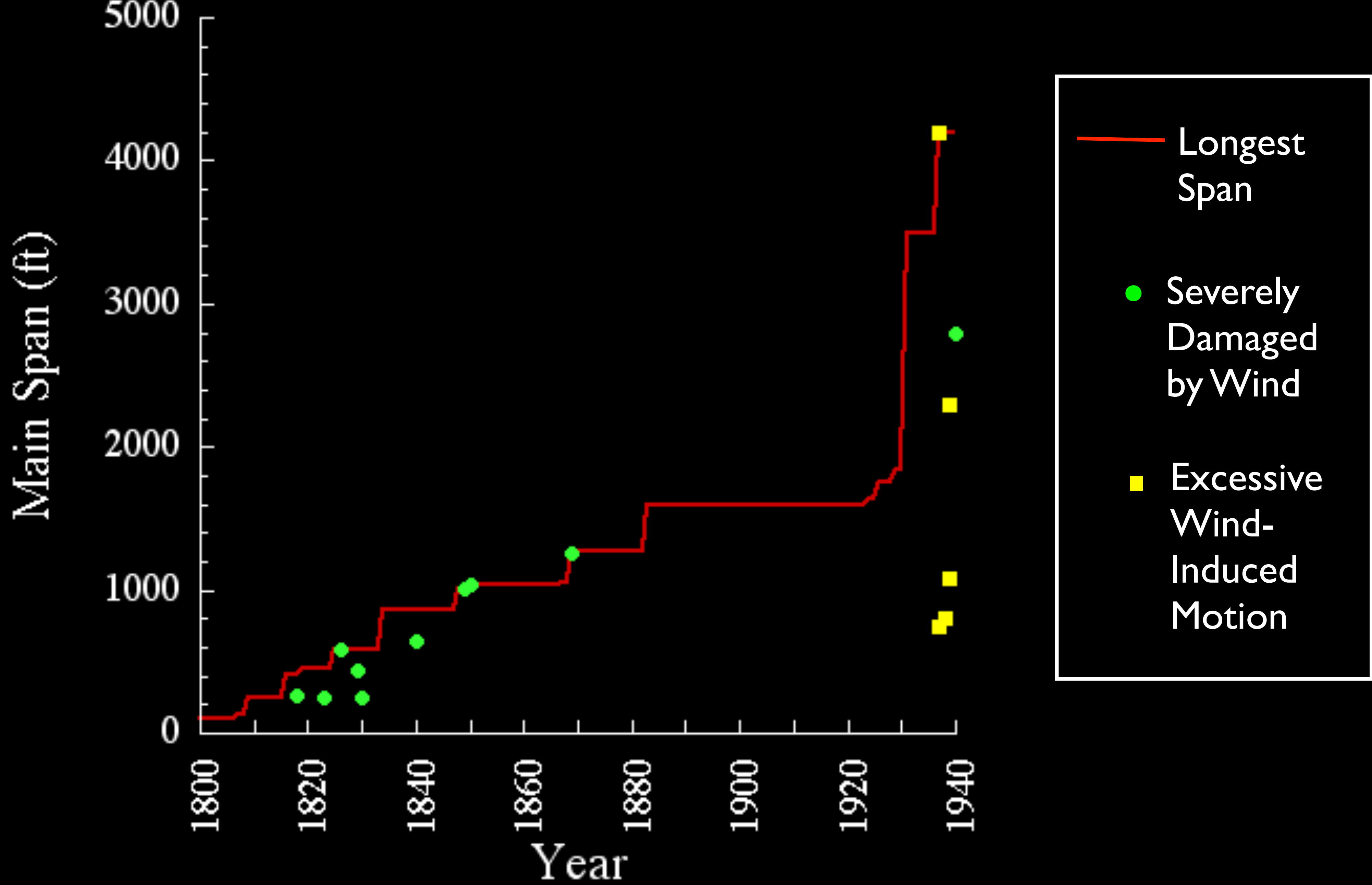
Load Paths in Suspension Bridges

Vehicle on Bridge Deck

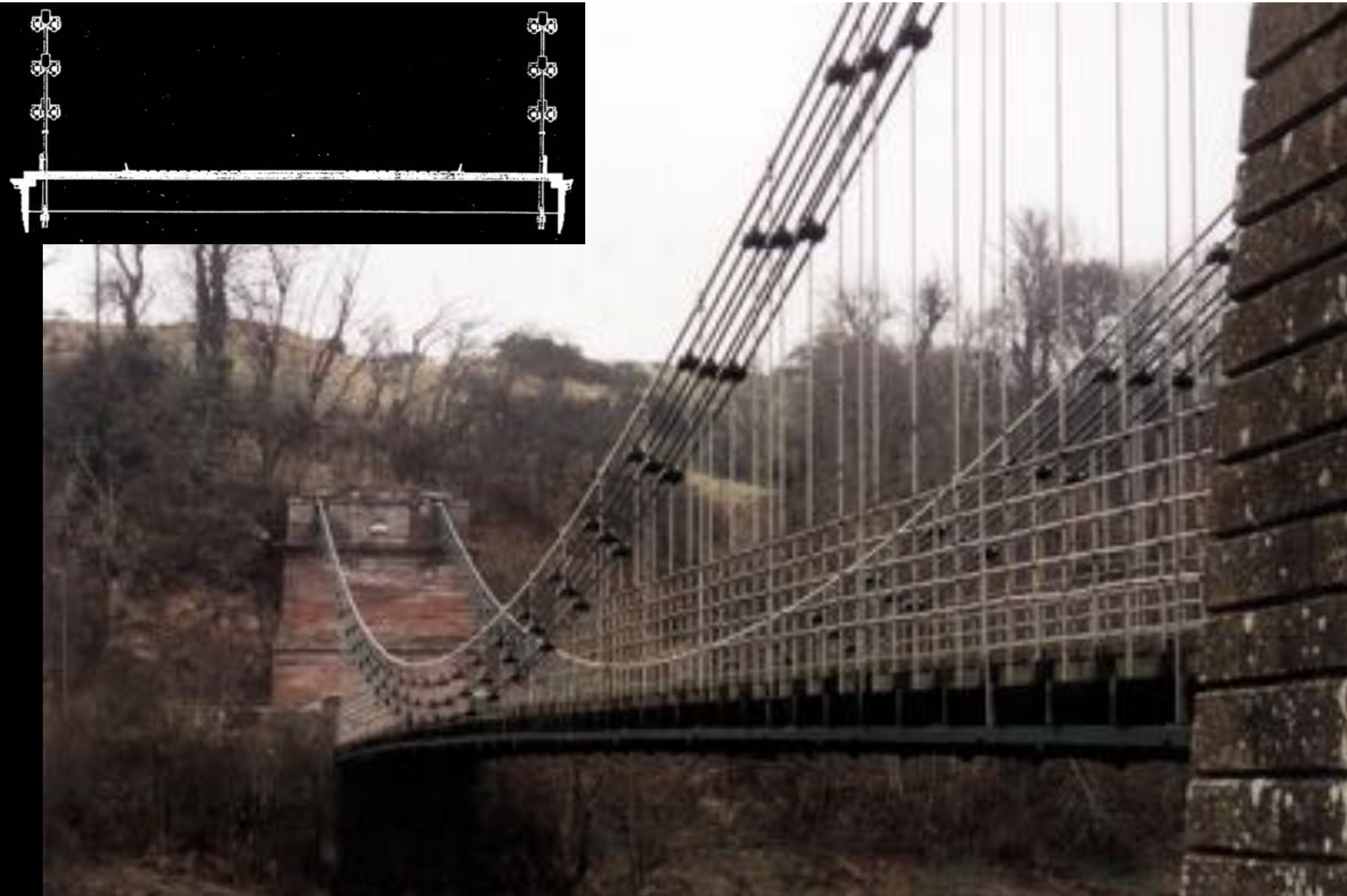




The Historical Record




Local unstiffened suspension bridge example
Patapsco Valley State Park “Swinging Bridge” (Early 1800’s)

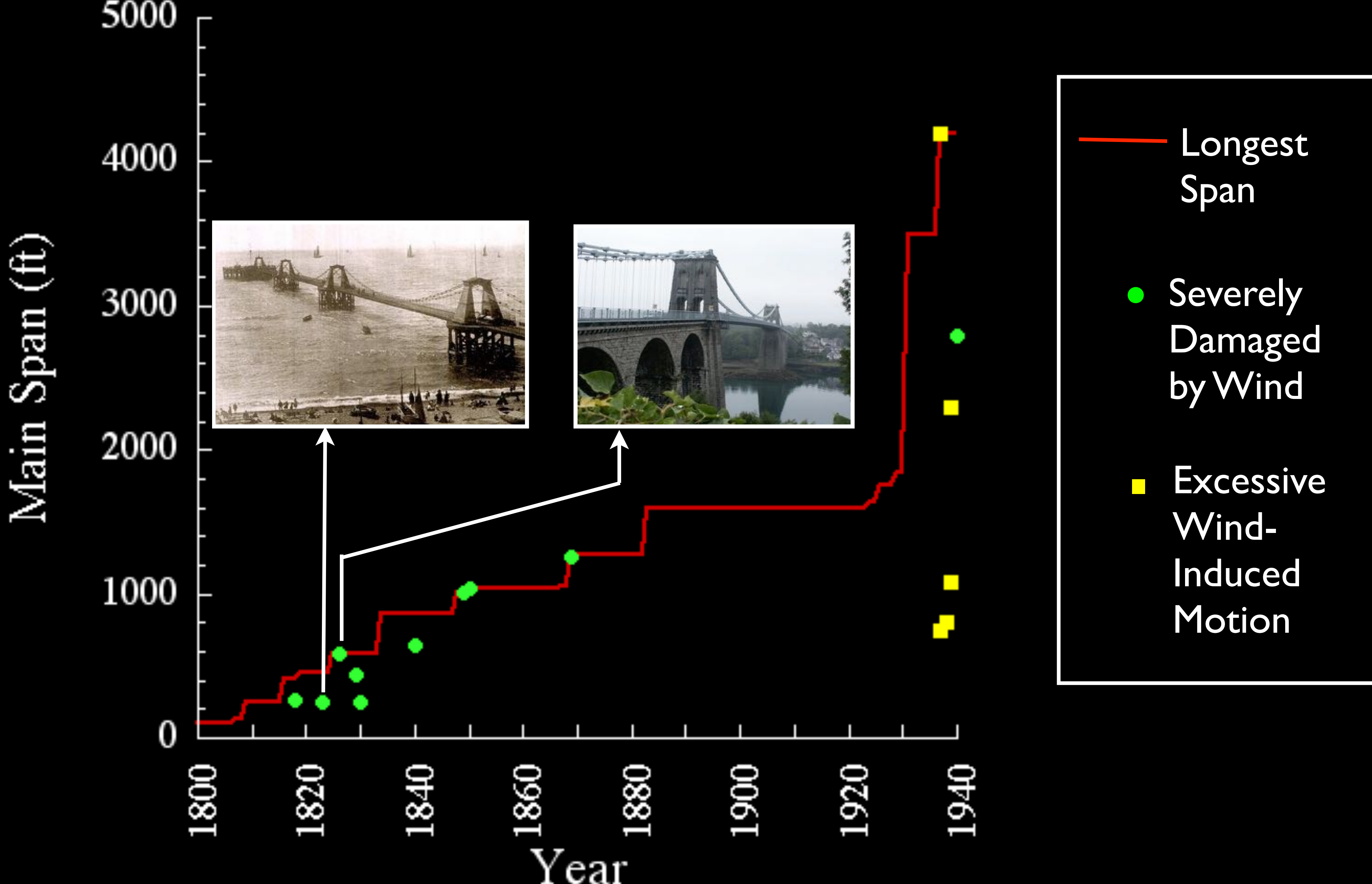


Union Bridge (1820)
Samuel Brown

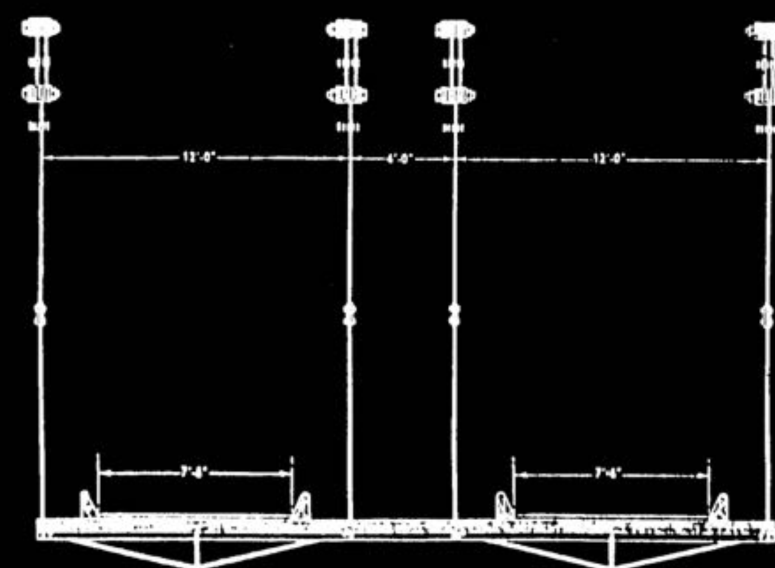
449 ft [137m] span
England

Brighton Chain Pier (1823)
Samuel Brown

225 ft [69 m] spans
England



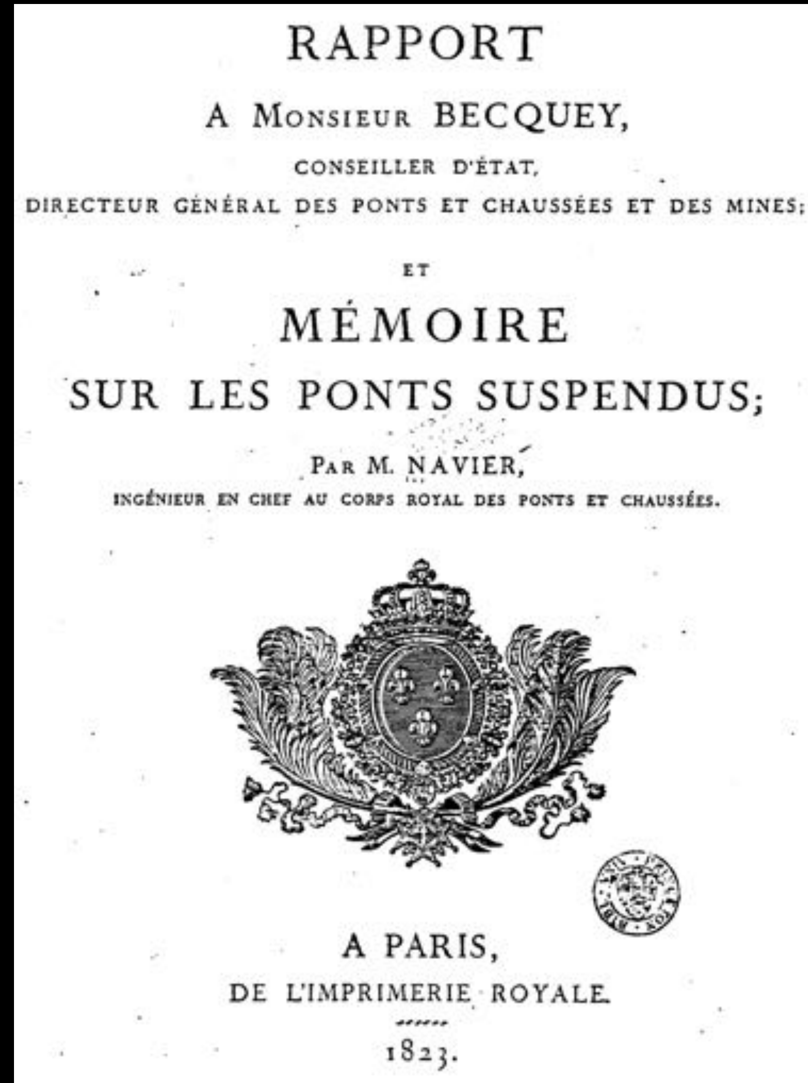
5000
4000
3000
2000
1000
0
Main Span (ft)
1800
1820
1840
1860
1880
1900
1920
1940
Year
Longest Span
Severely Damaged by Wind
Excessive Wind-Induced Motion



Menai Straits Bridge (1826)
Thomas Telford

580 ft [177 m] span
Wales

C.L.M.H. Navier



RAPPORT

A MONSIEUR BECQUEY,

CONSEILLER D'ÉTAT,

DIRECTEUR GÉNÉRAL DES PONTS ET CHAUSSÉES ET DES MINES;

ET

MÉMOIRE

SUR LES PONTS SUSPENDUS;

PAR M. NAVIER,

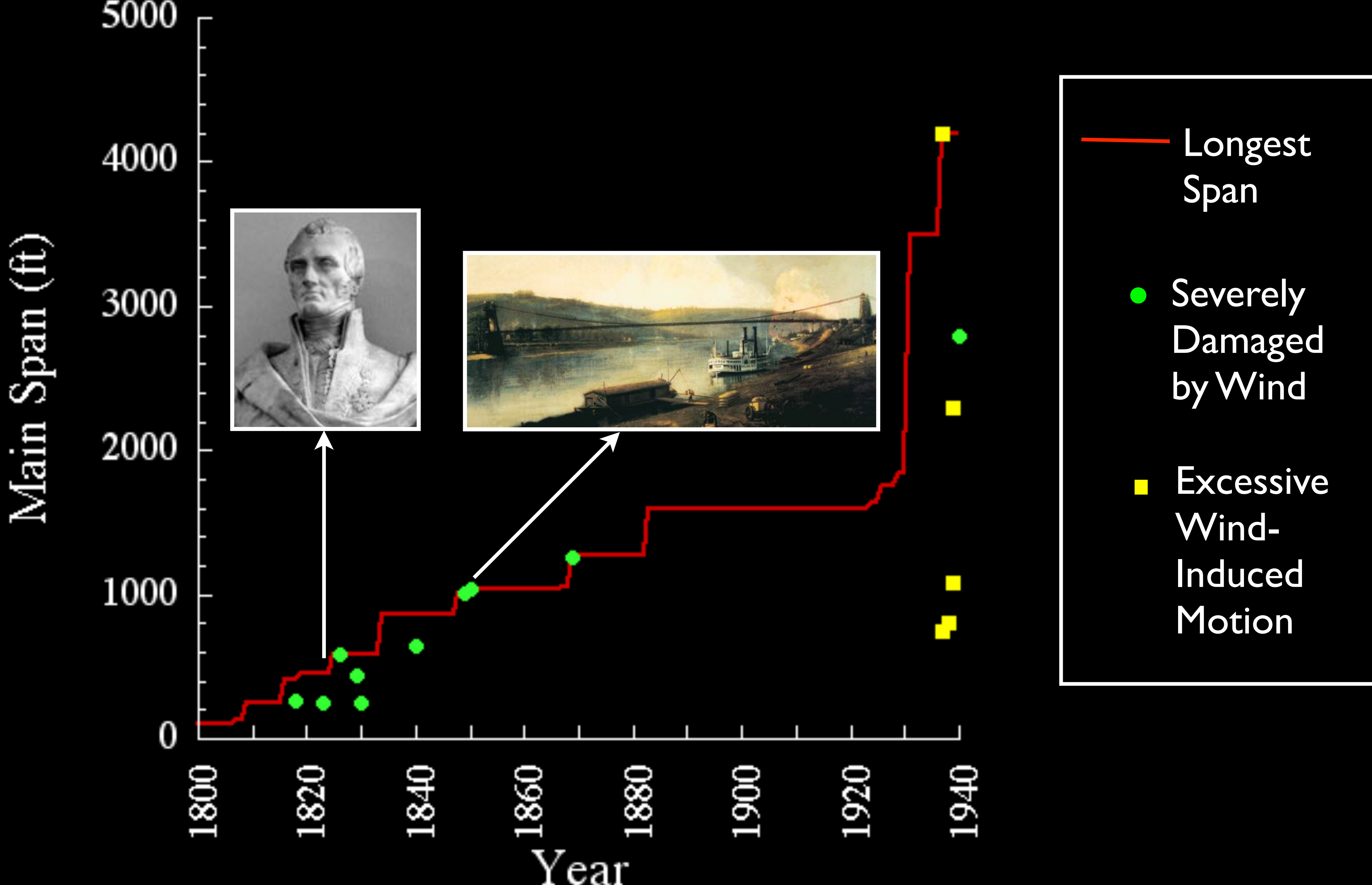
INGÉNIEUR EN CHEF AU CORPS ROYAL DES PONTS ET CHAUSSÉES.

A PARIS,

DE L'IMPRIMERIE ROYALE.

1823.

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



5000
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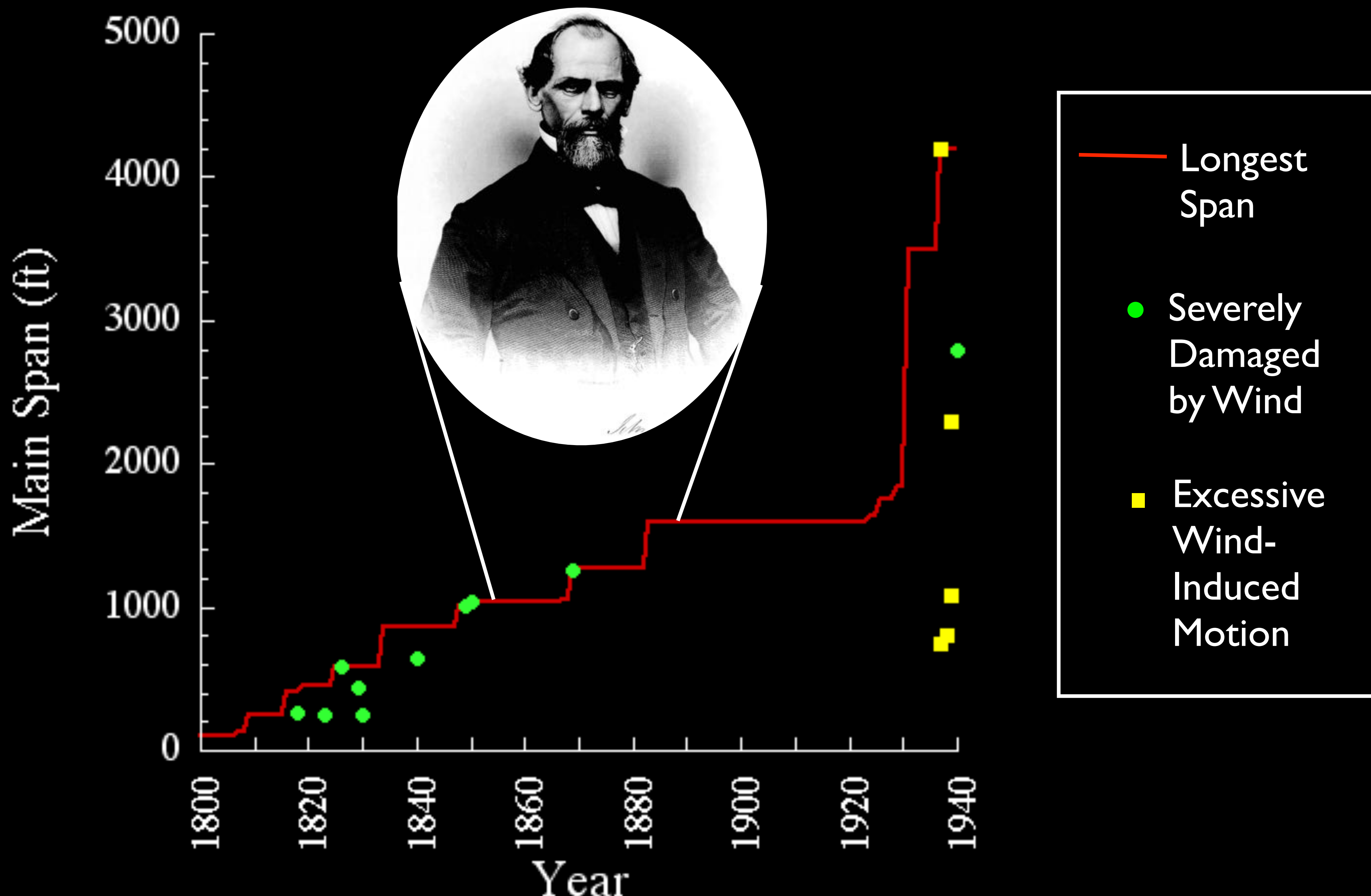
Main Span (ft)
1800
1820
1840
1860
1880
1900
1920
1940
Year
Longest Span
Severely Damaged by Wind
Excessive Wind-Induced Motion

Wheeling Bridge (1849)
Charles Ellett

1010 ft [308 m] span
West Virginia

Niagara Railroad Bridge (1849)
John A. Roebling

822 ft [250 m] span
Niagara River


Main Span (ft)
5000
4000
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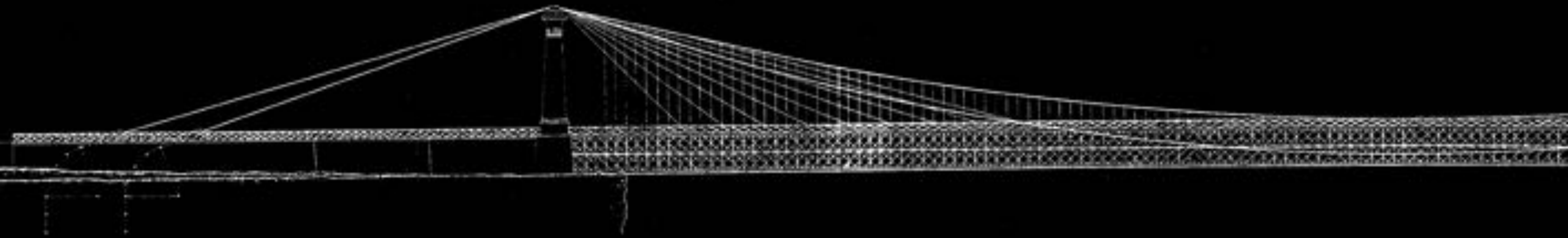
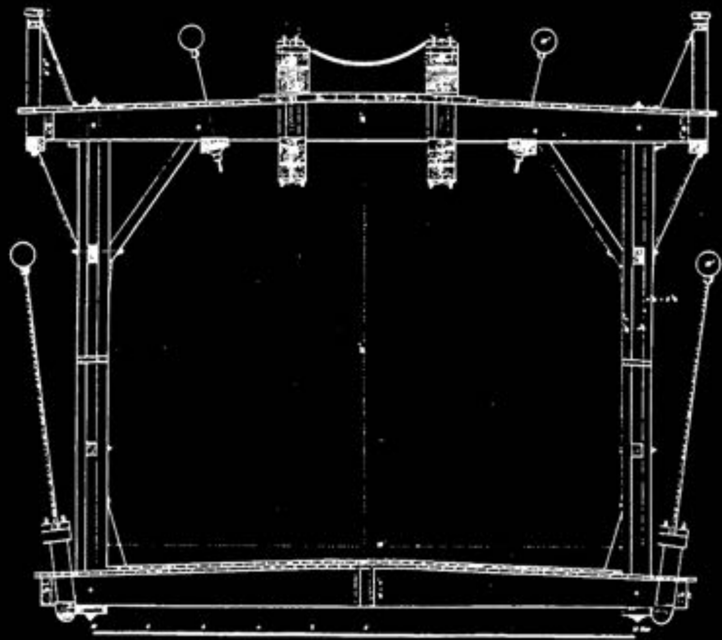
1800
1820
1840
1860
1880
1900
1920
1940
Year
Longest Span
Severely Damaged by Wind
Excessive Wind-Induced Motion

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 [250 m] span
Niagara River

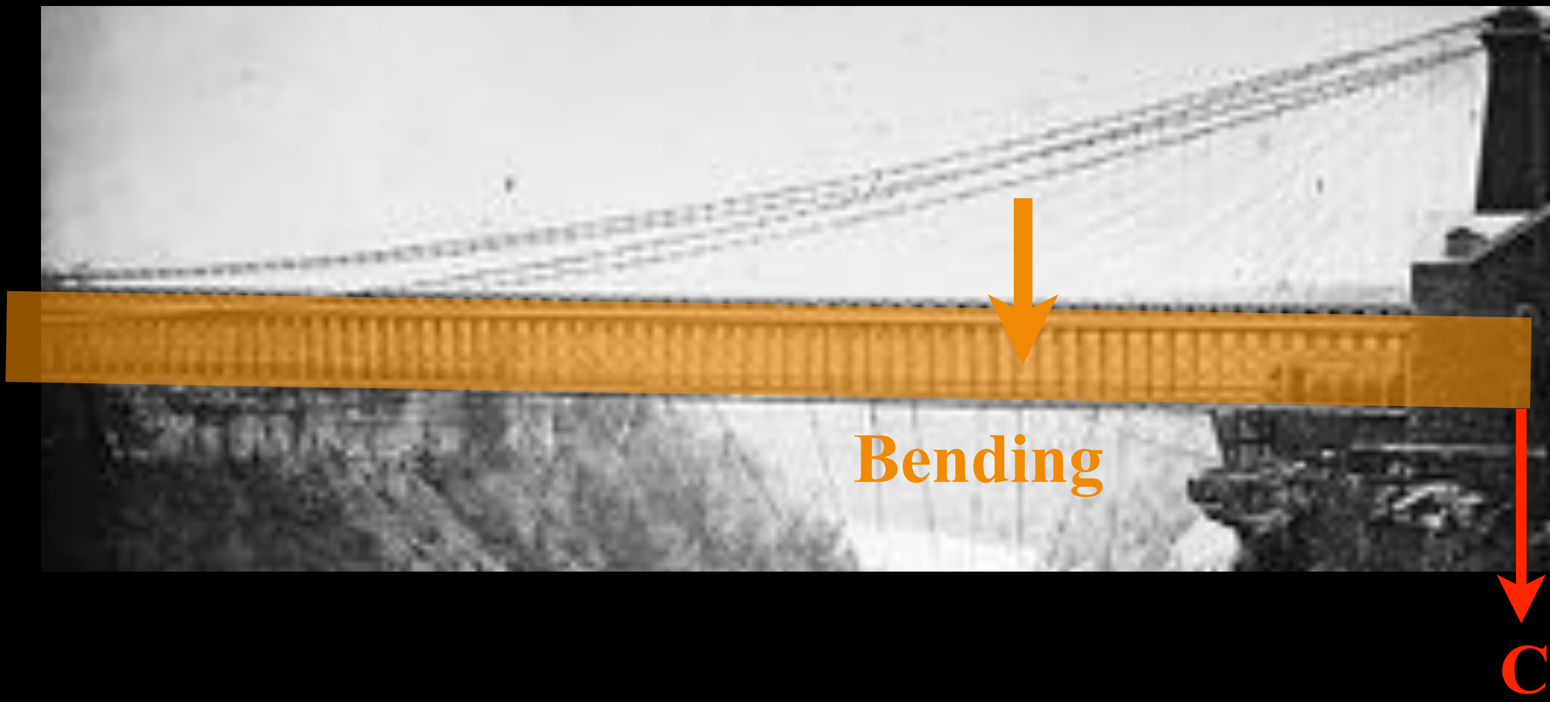
Load Paths in Suspension Bridges

Vehicle on Bridge Deck

1. Suspension Cables
2.
3.

Load Paths in Suspension Bridges

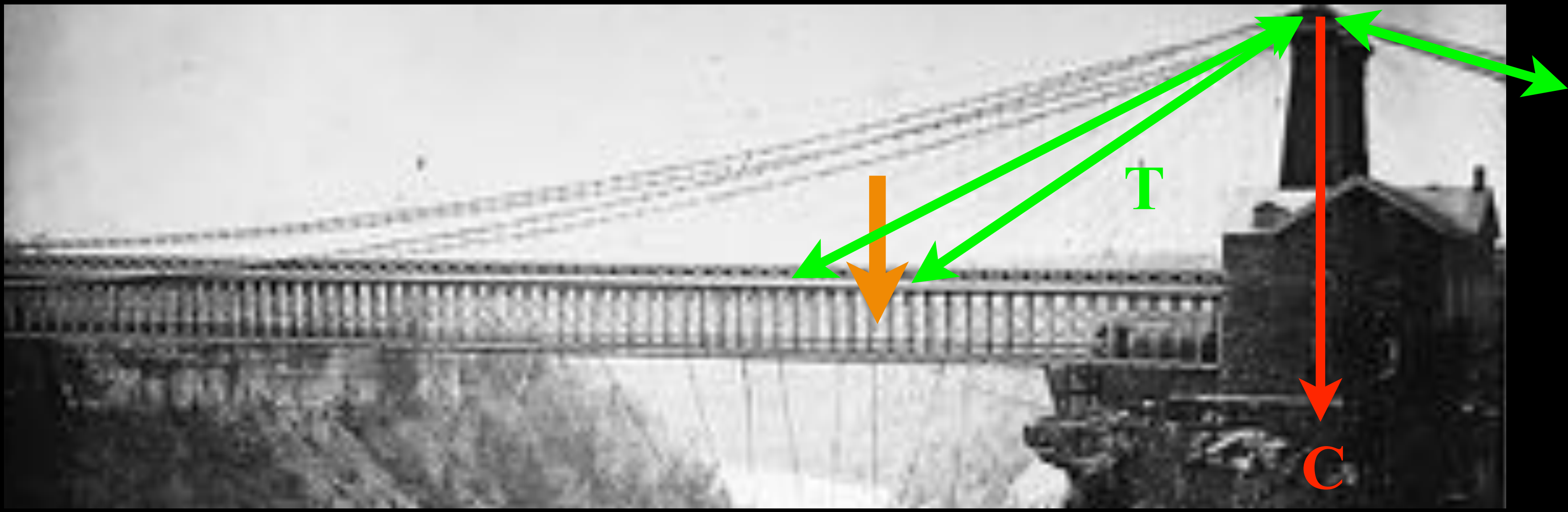
Vehicle on Bridge Deck



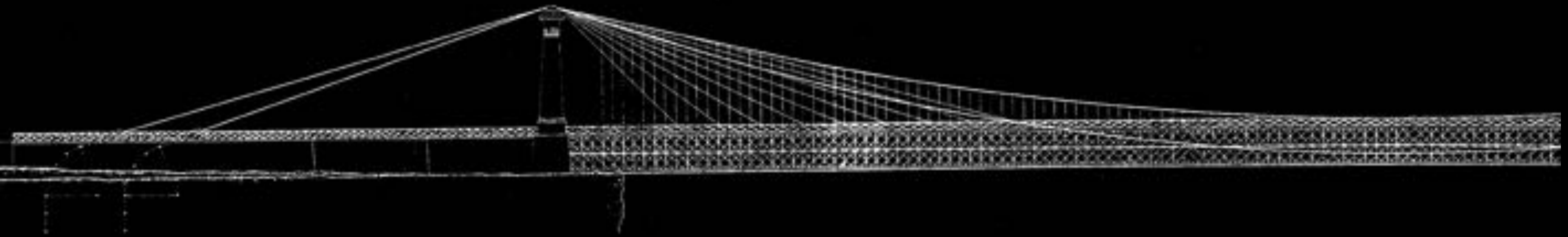
1. Suspension Cables
2. Bridge Deck
3.

Load Paths in Roebling's Bridges

Vehicle on Bridge Deck



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



"The means employed are:
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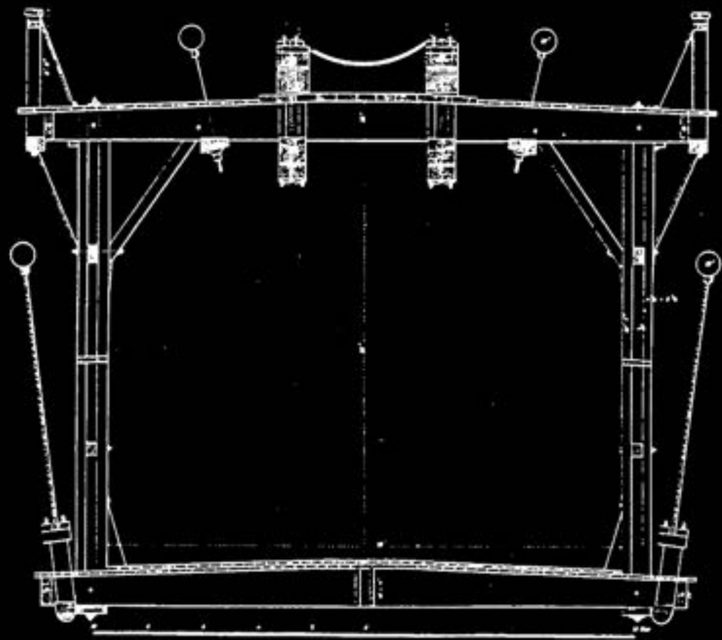
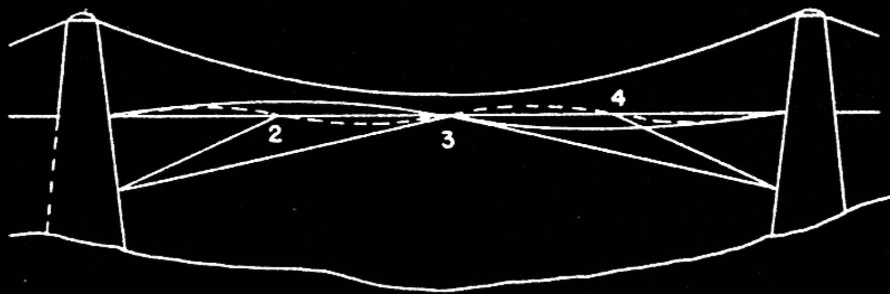
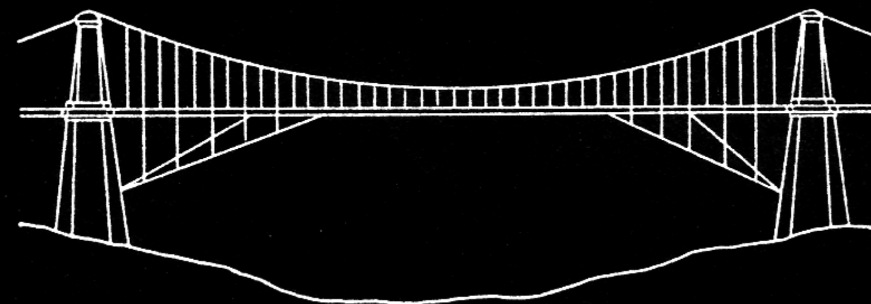


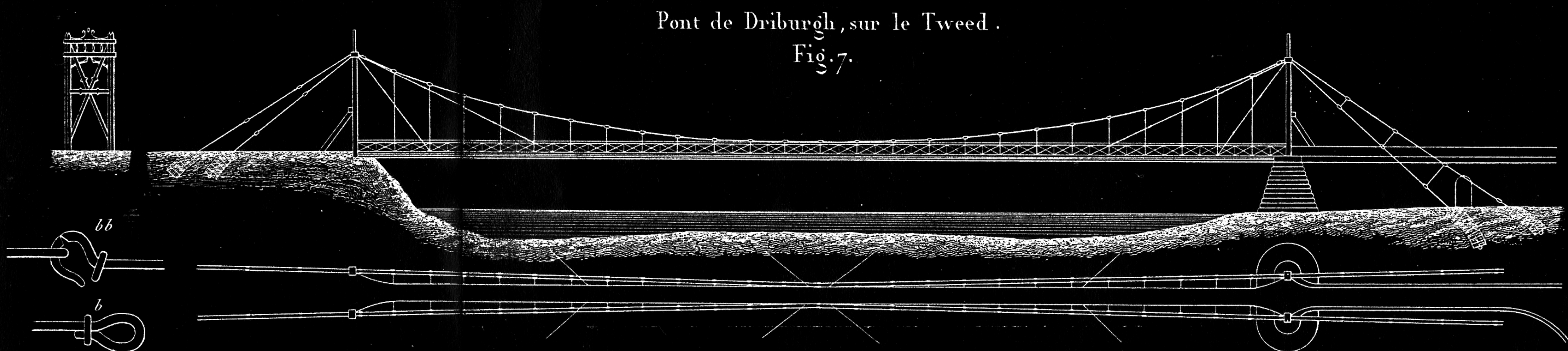
Niagara Railroad Bridge (1849)
John A. Roebling

822 ft [250 m] span
Niagara River





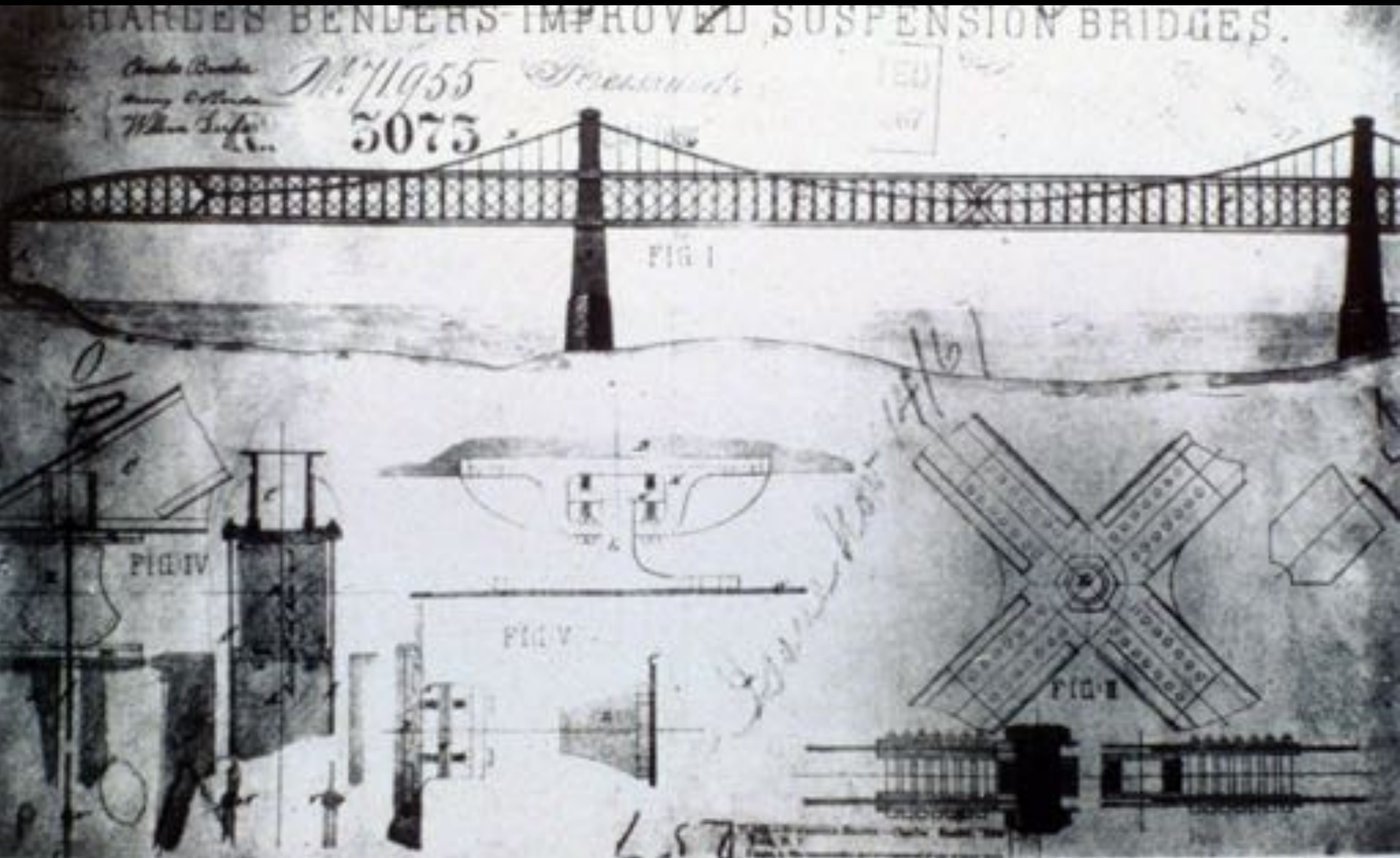
John Scott Russell (1839)



2nd Dryburgh Abbey Bridge (1818)

260 ft span

Second Montrose Bridge (1840) 432 ft [132 m] span


HARLES BENDERS IMPROVED SUSPENSION BRIDGES.
No. 71955
3073
FIG I
FIG IV
FIG V

Deck is so stiff you don't need the cables anymore. Efficiency?

Britannia Bridge (1850)
Robert Stephenson

460 ft [140 m] 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
Relative Stiffness	1.5	1

John Augustus Roebling
1806-1869

Niagara R.R. Susp.n Bridge | Completed ... 1855 | John A. Roebling Engineer

Manufacture of

Patent Wire Rope

of

JOHN A. ROEBLING,

Civil Engineer.

TRENTON N.J.

John Roebling's Suspension Bridges

1844 Allegheny aqueduct at Pittsburgh

1845 Smithfield Street Bridge

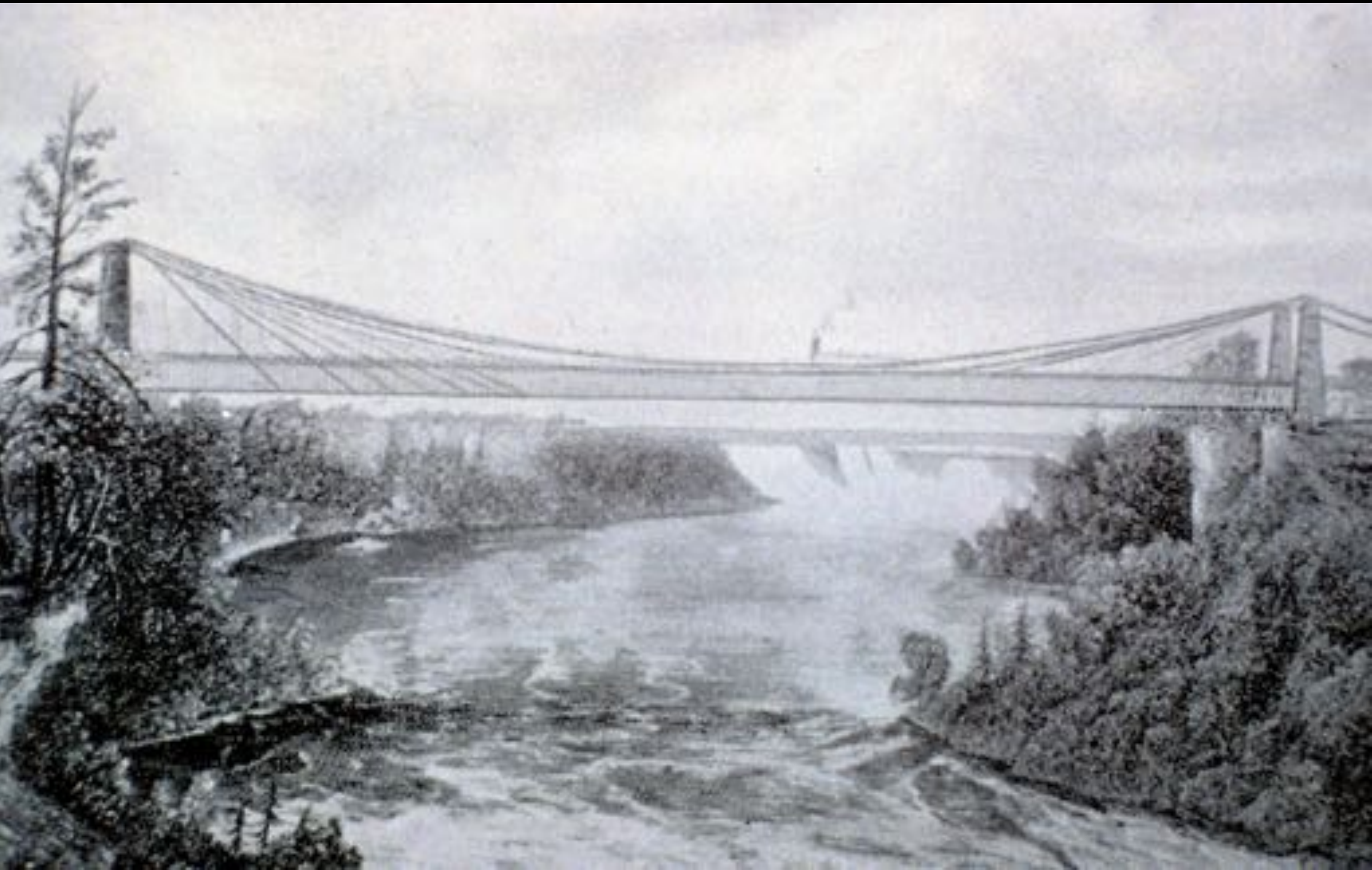
1849 Delaware and Hudson aqueducts

1855 Niagara suspension bridge

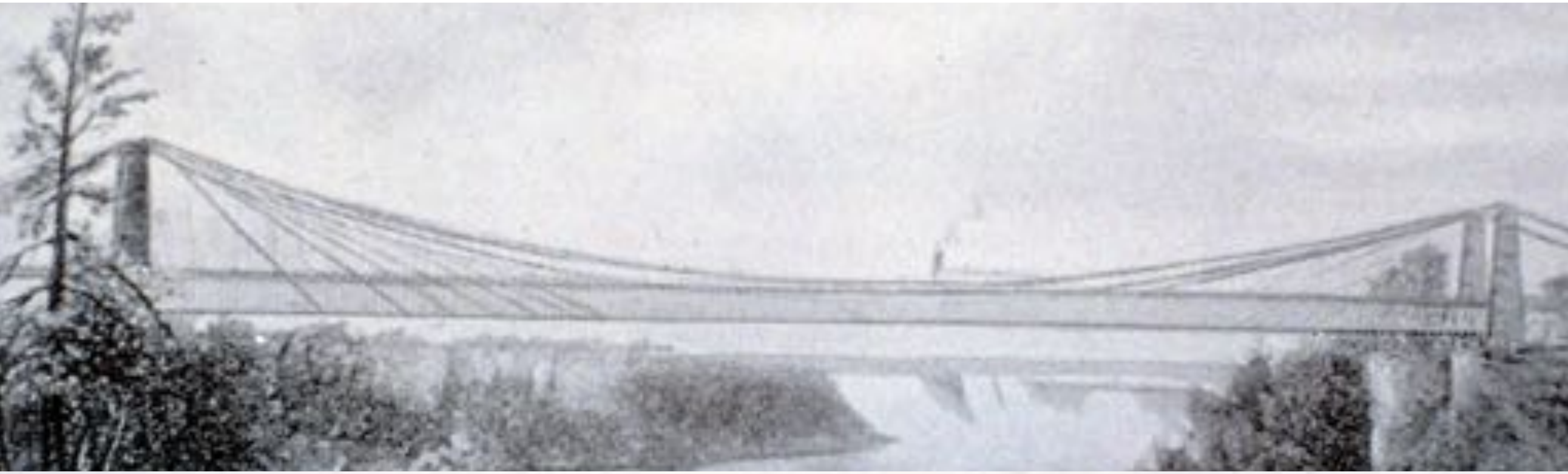
1856 Ohio river bridge at Cincinnati

1860 Sixth Street Bridge

1883 Brooklyn Bridge



Niagara suspension bridge - 1855

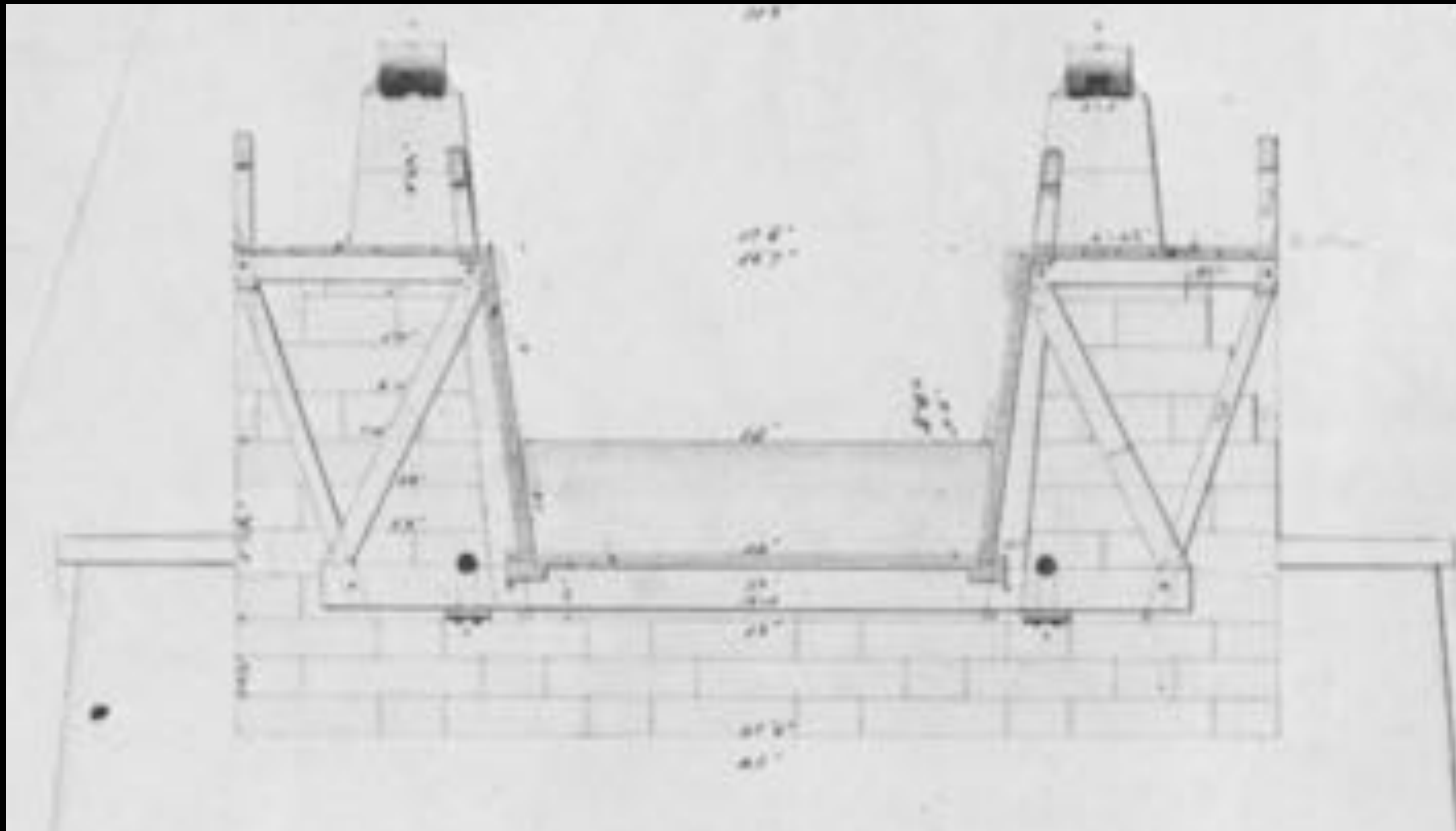


Smithfield Street Bridge (1846)
John A. Roebling

188 ft [57 m] spans
Pittsburgh

Sixth Street Bridge (1860)
John A. Roebling

344 ft [105 m] spans
Pittsburgh



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.

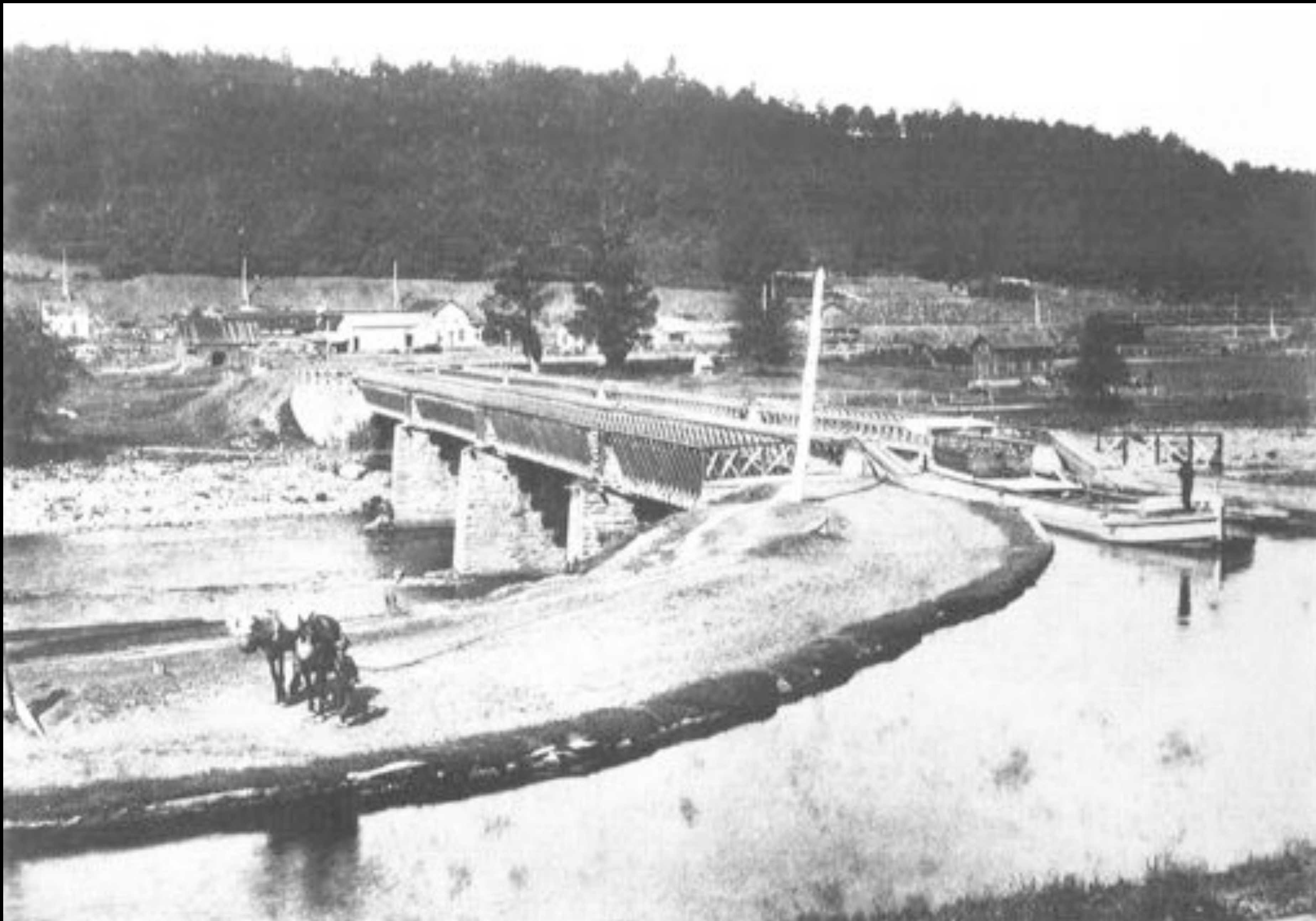
Allegheny River Aqueduct (18xx)
John A. Roebling

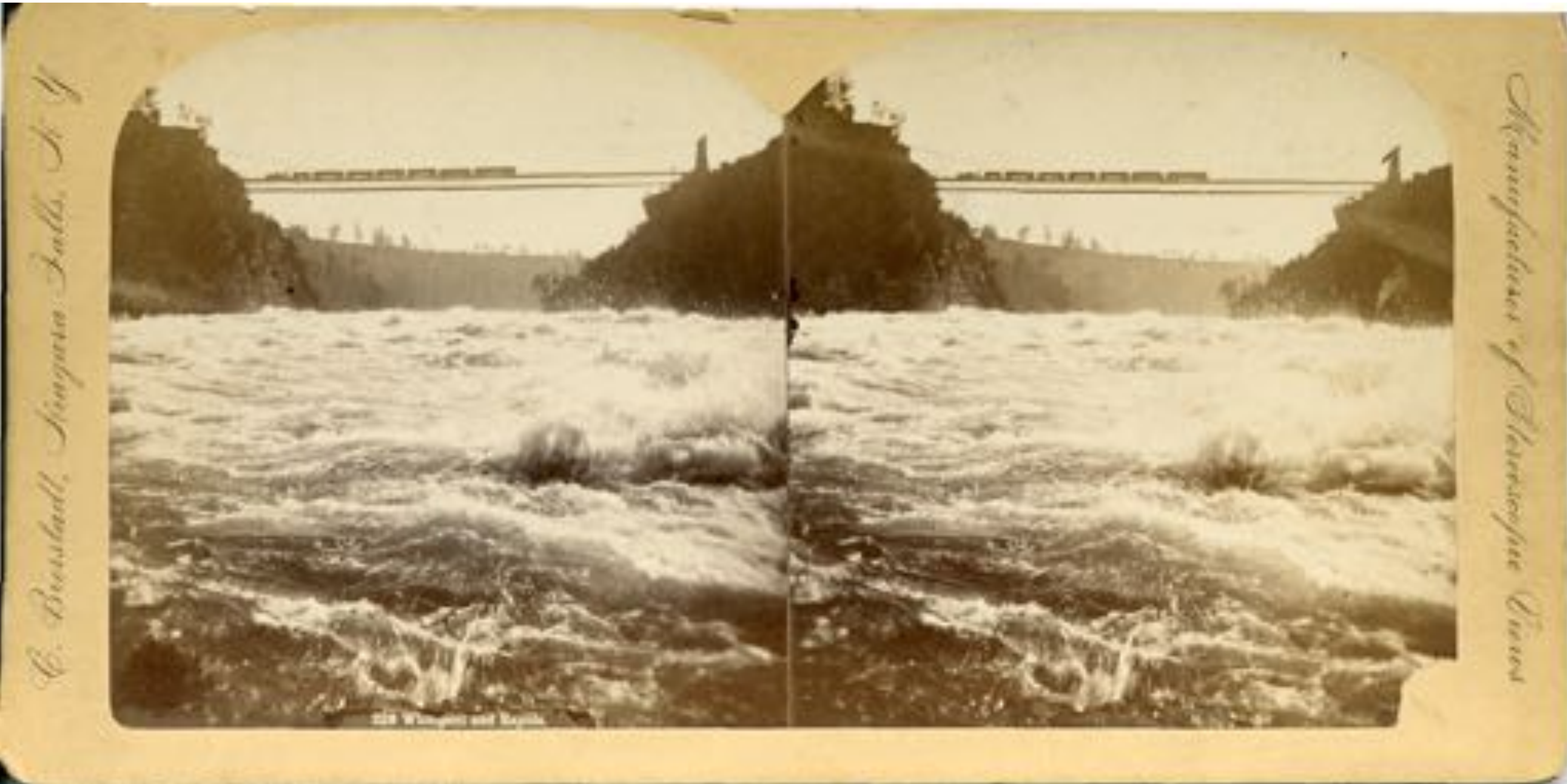
188 ft [57 m] spans
Pittsburgh

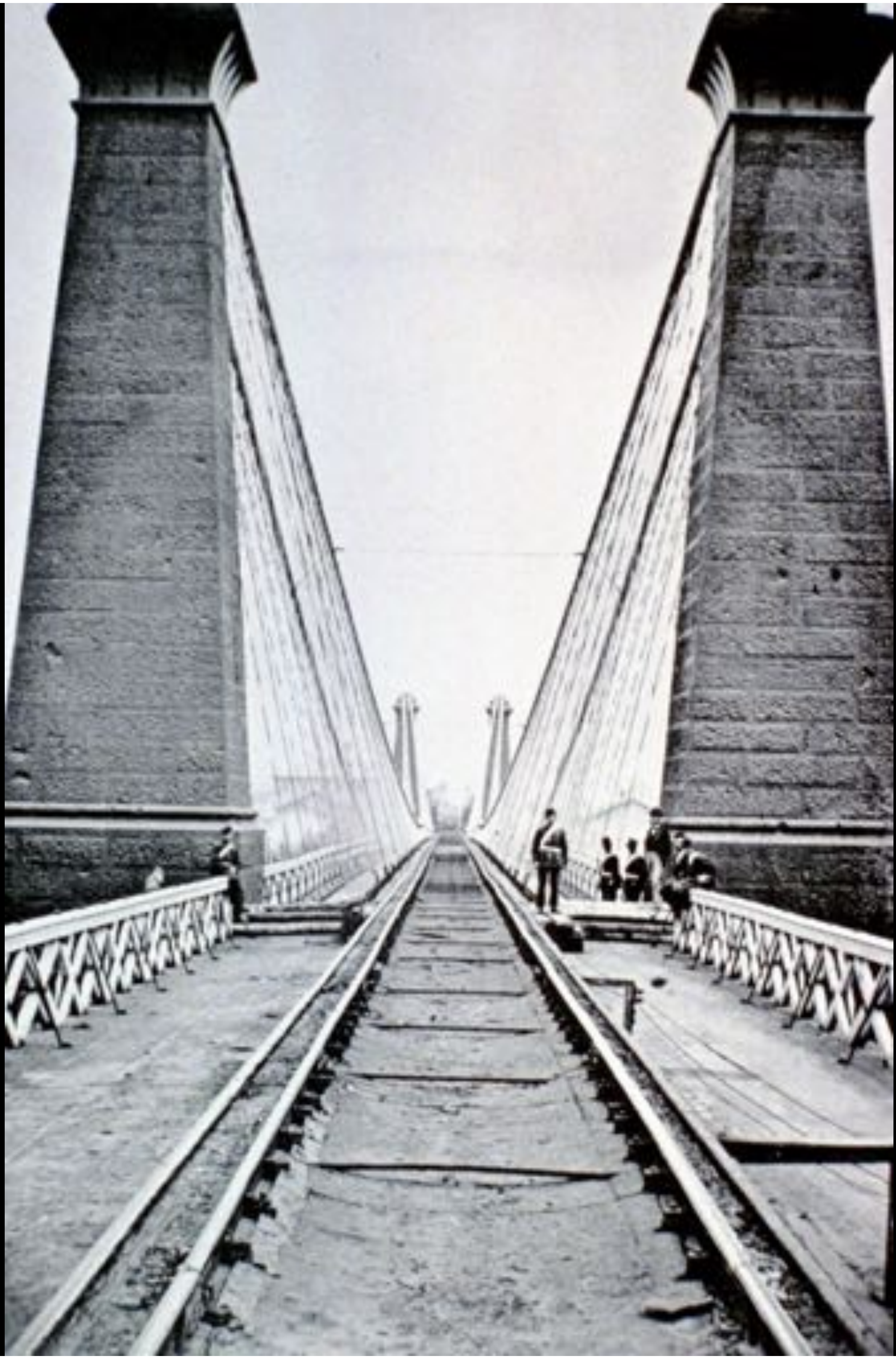
THE DELAWARE AND HUDSON CANAL AND GRAVITY RAILROAD, 1865

Delaware and Hudson Canal Aqueducts (1847-1850)

114 ft to 170 ft [35 m to 52 m] spans Pennsylvania & New York

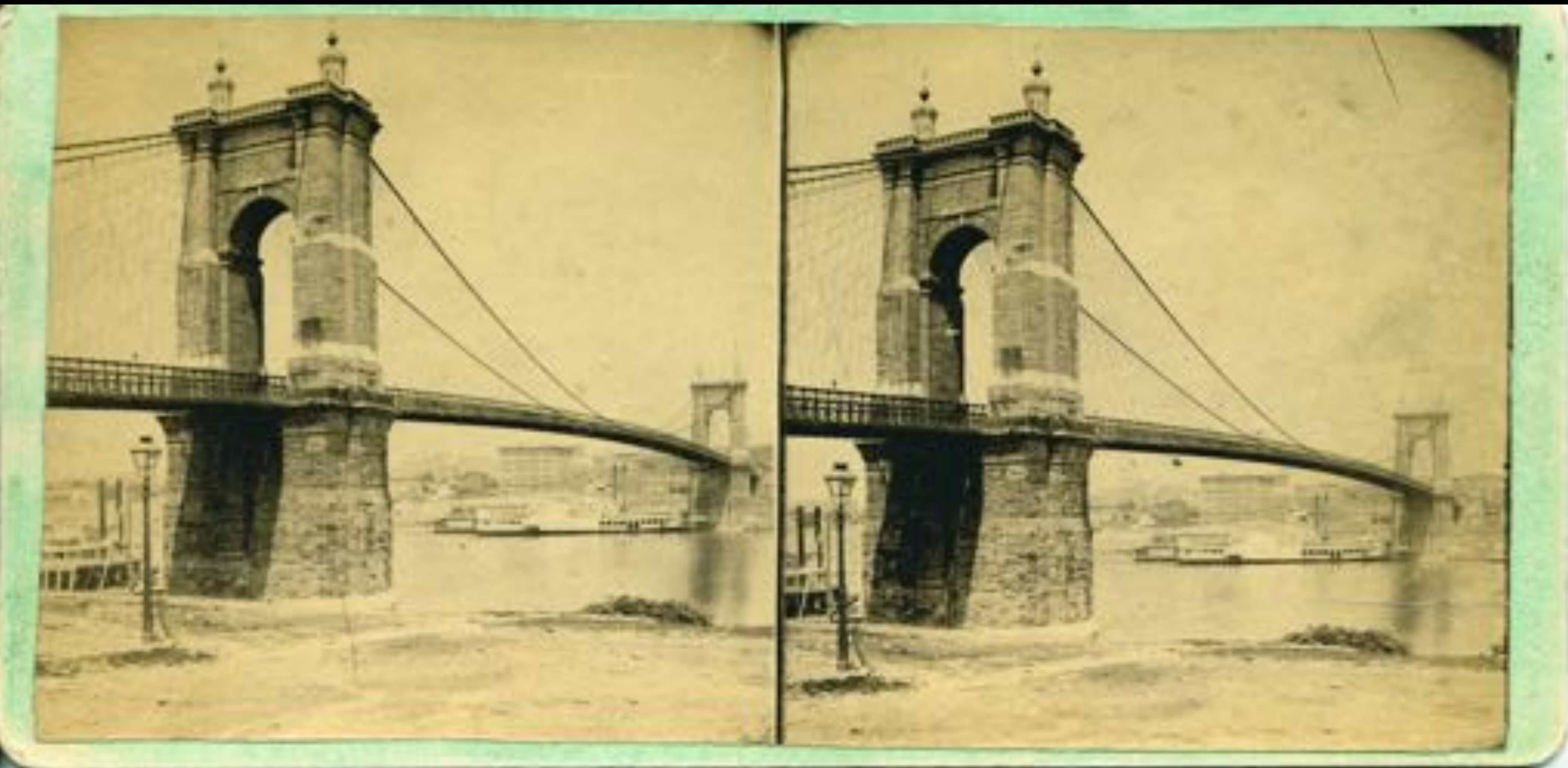



C. Bierstadt, Niagara Falls, N.Y.
Manufacturer of Stereoscopic Views



Ohio River Bridge (1856)
John A. Roebling

1057 ft [322 m] span
Cincinnati



LONG AND SHORT SPAN

RAILWAY BRIDGES.

BY

JOHN A. ROEBLING,

CIVIL ENGINEER.

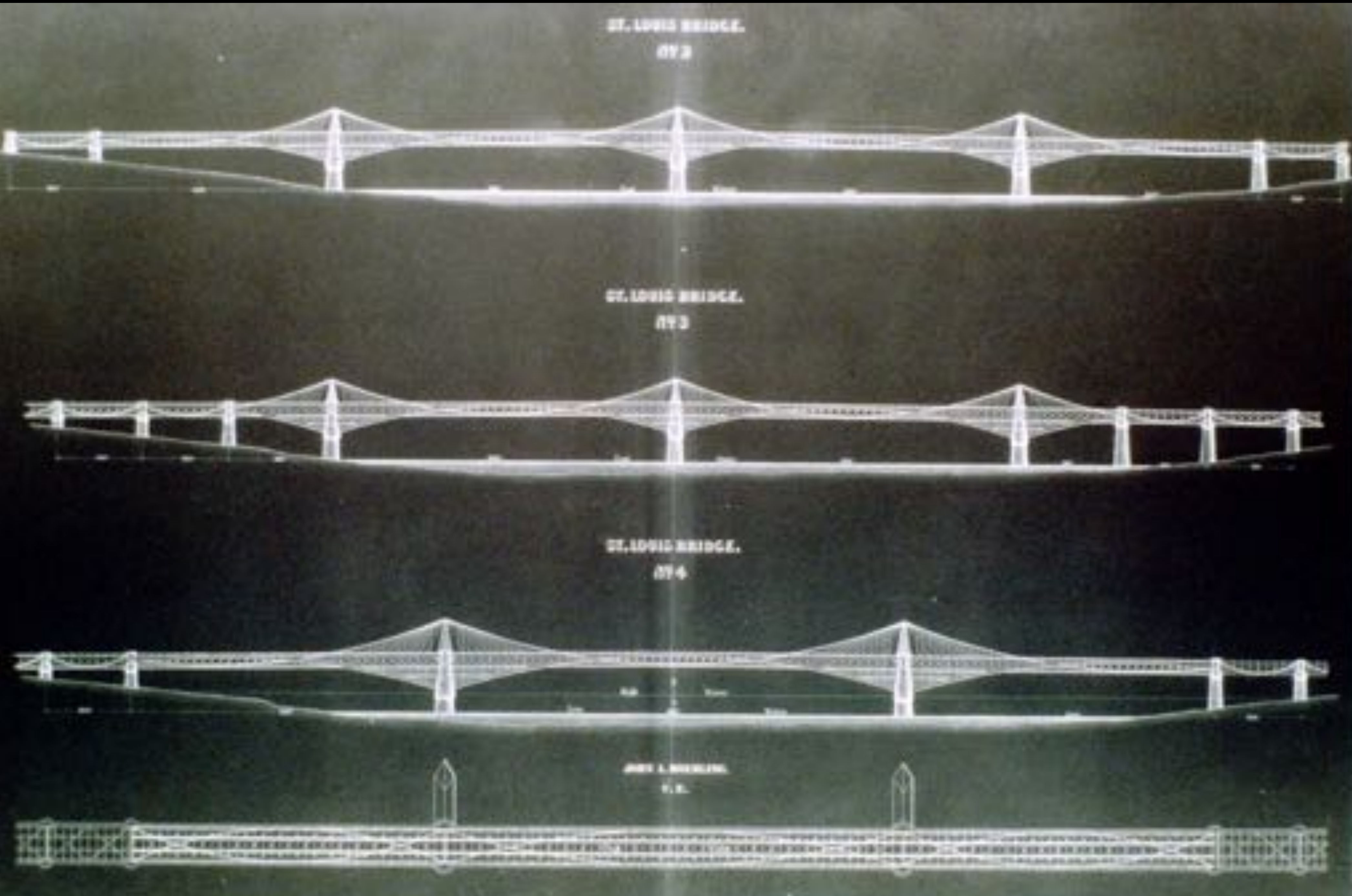
The greatest economy in Bridging can only be obtained by a judicious application of the Parabolic Truss.

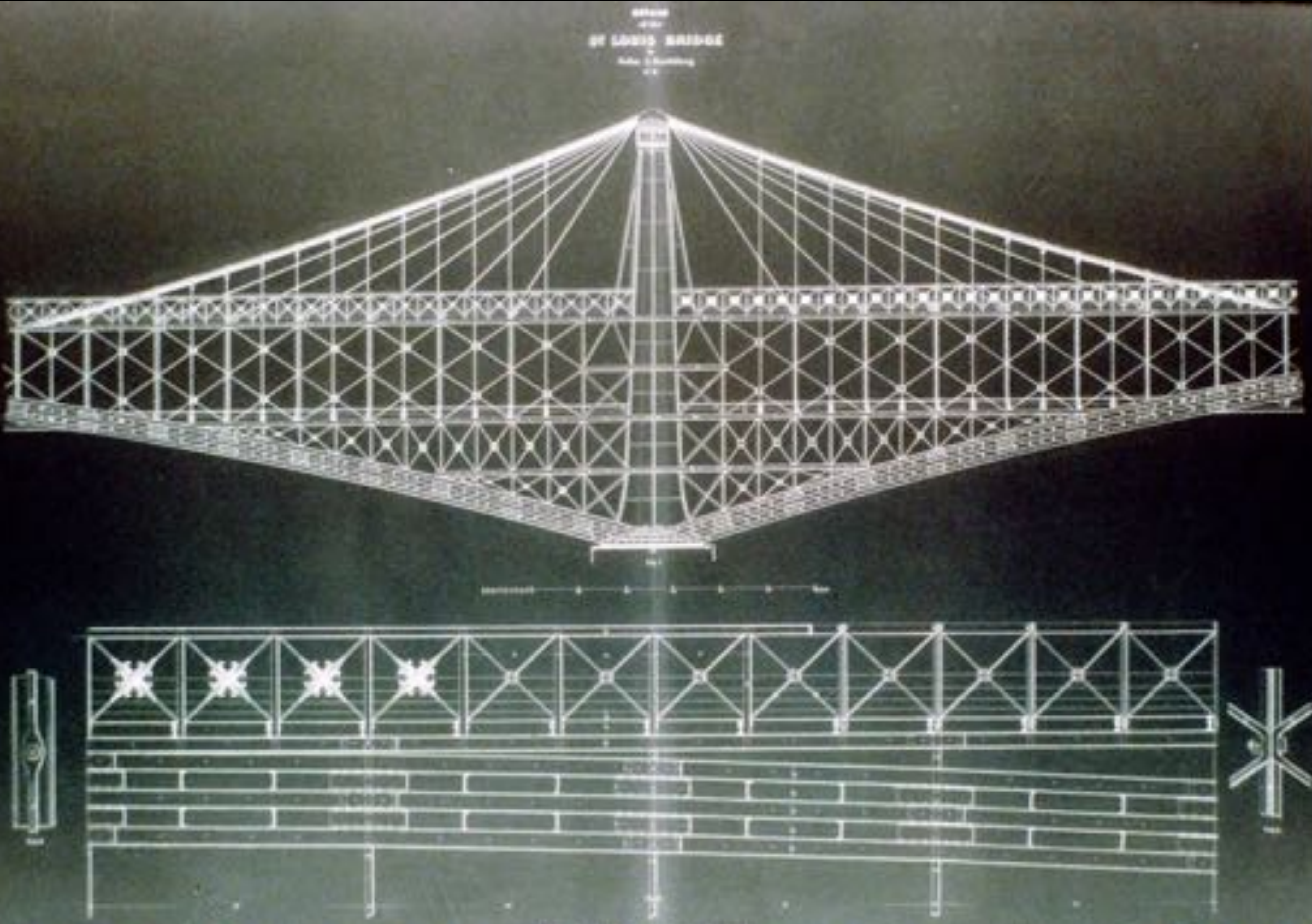
NEW YORK:

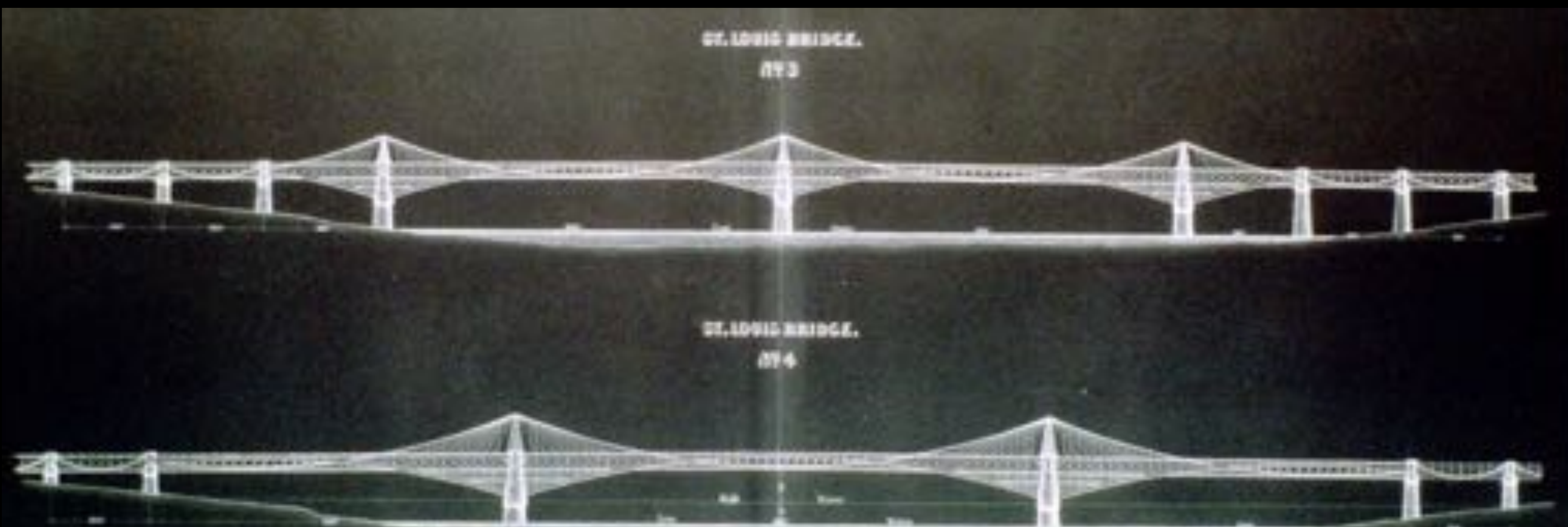
D. VAN NOSTRAND, PUBLISHER,

23 MURRAY STREET & 27 WARREN STREET.

[illegible]


ST. LOUIS BRIDGE.
ST. LOUIS BRIDGE.
No 3
ST. LOUIS BRIDGE.
No 4

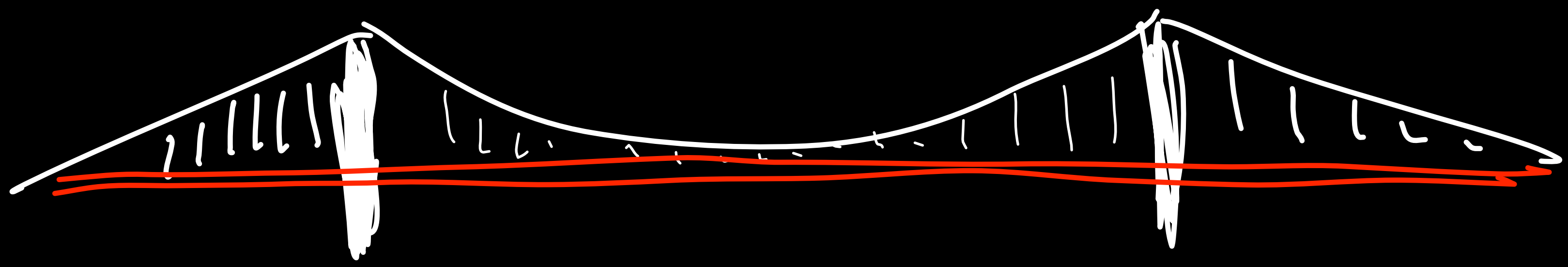

St LOUIS BRIDGE


ST. LOUIS BRIDGE.
No 3
ST. LOUIS BRIDGE.
No 4

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)

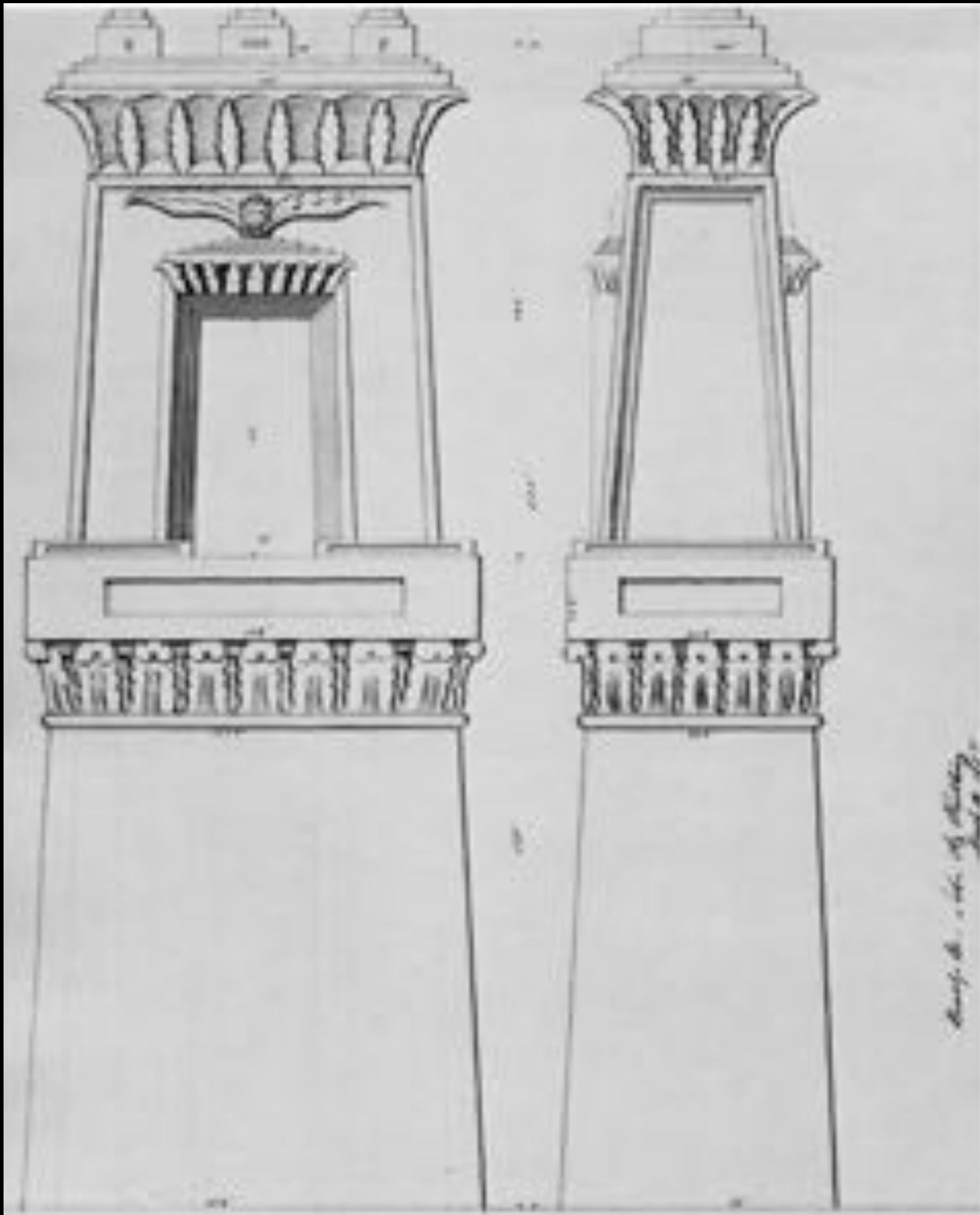
JOHN ROEBLING'S DREAM—ORIGINAL DESIGN OF THE BROOKLYN BRIDGE

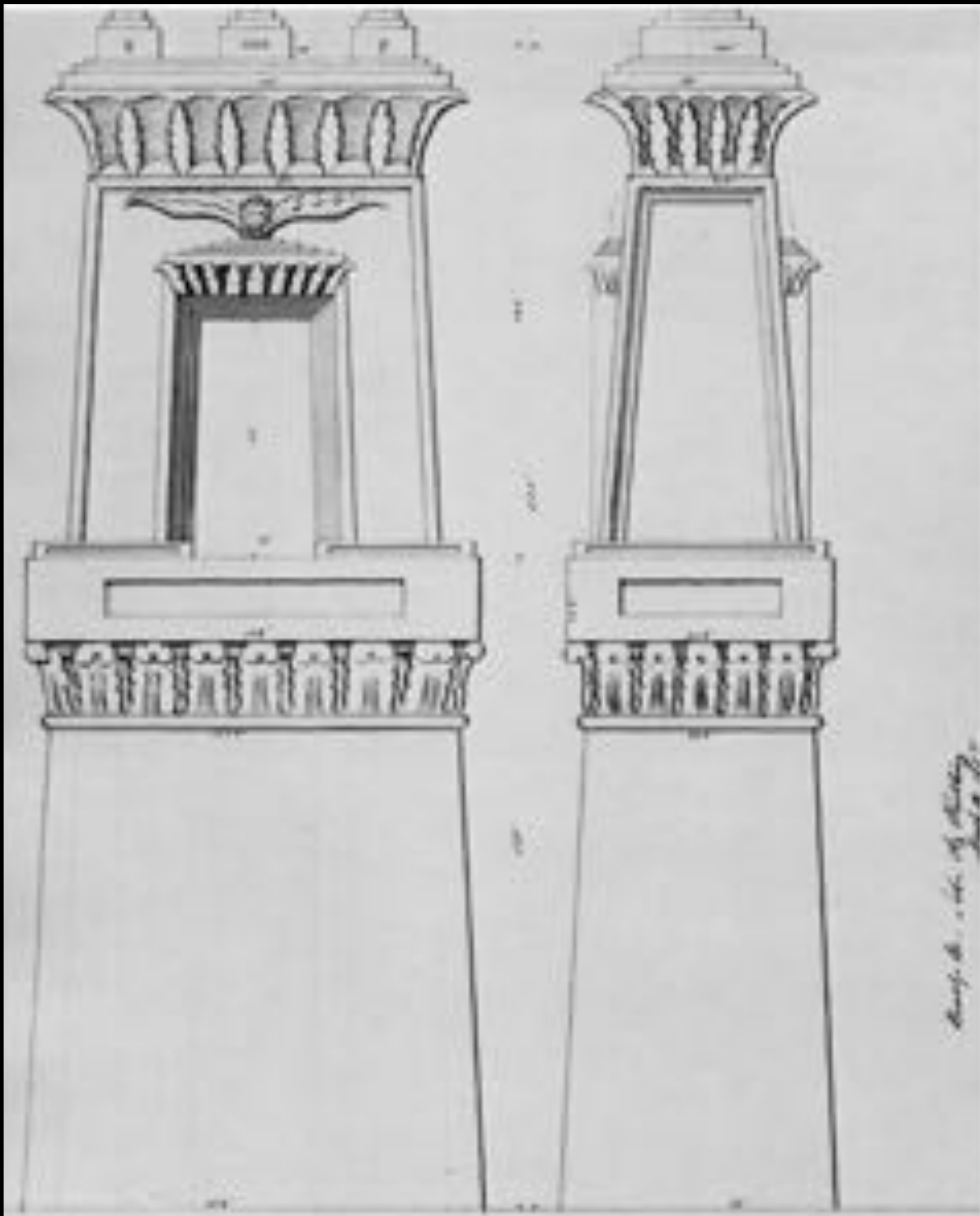
The contemplated work, when constructed in accordance with my designs, will not only be the greatest Bridge in existence, but it will be the great engineering work of this continent, and of the age. Its most conspicuous features, the great towers, will serve as landmarks to the adjoining cities, and 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.

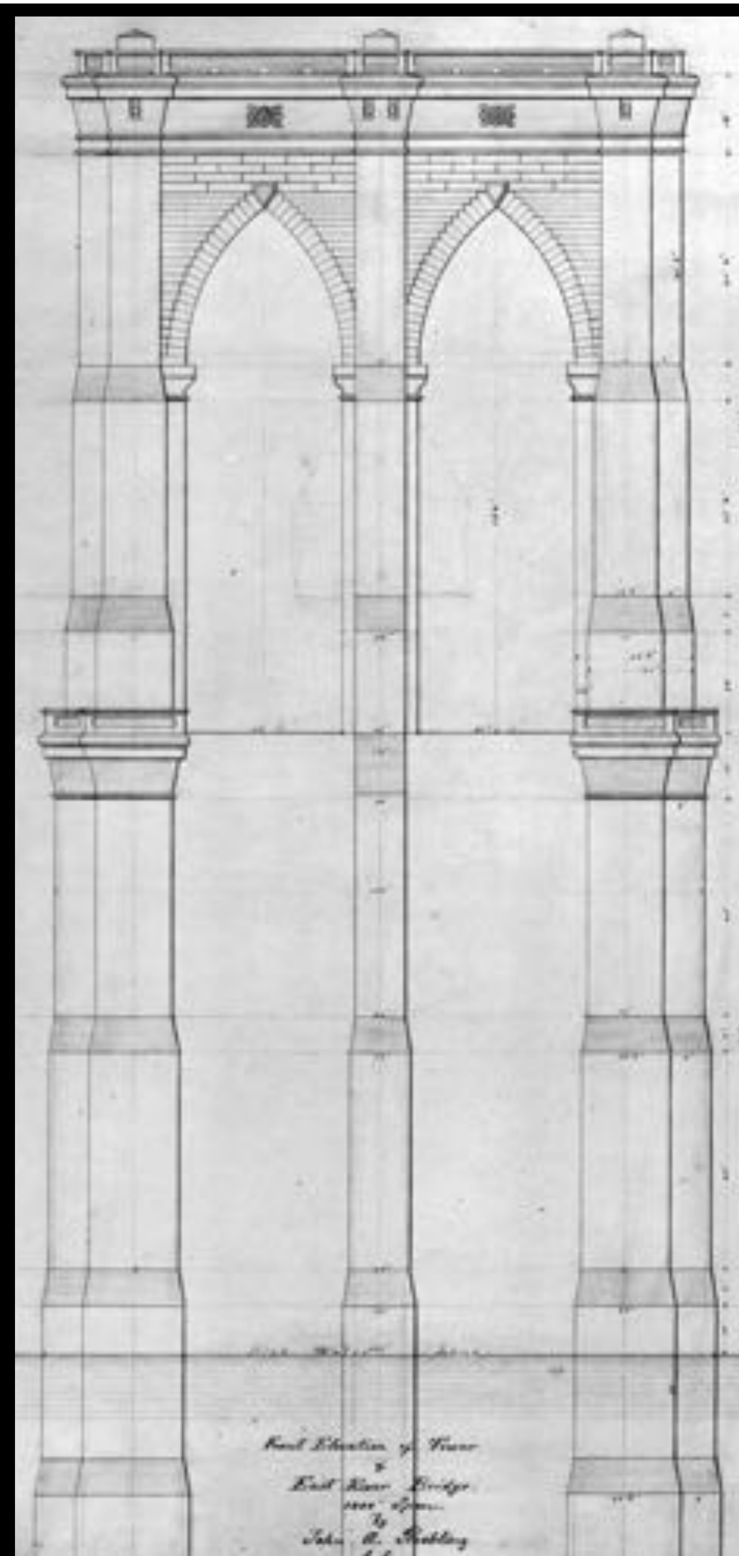
Respectfully submitted,

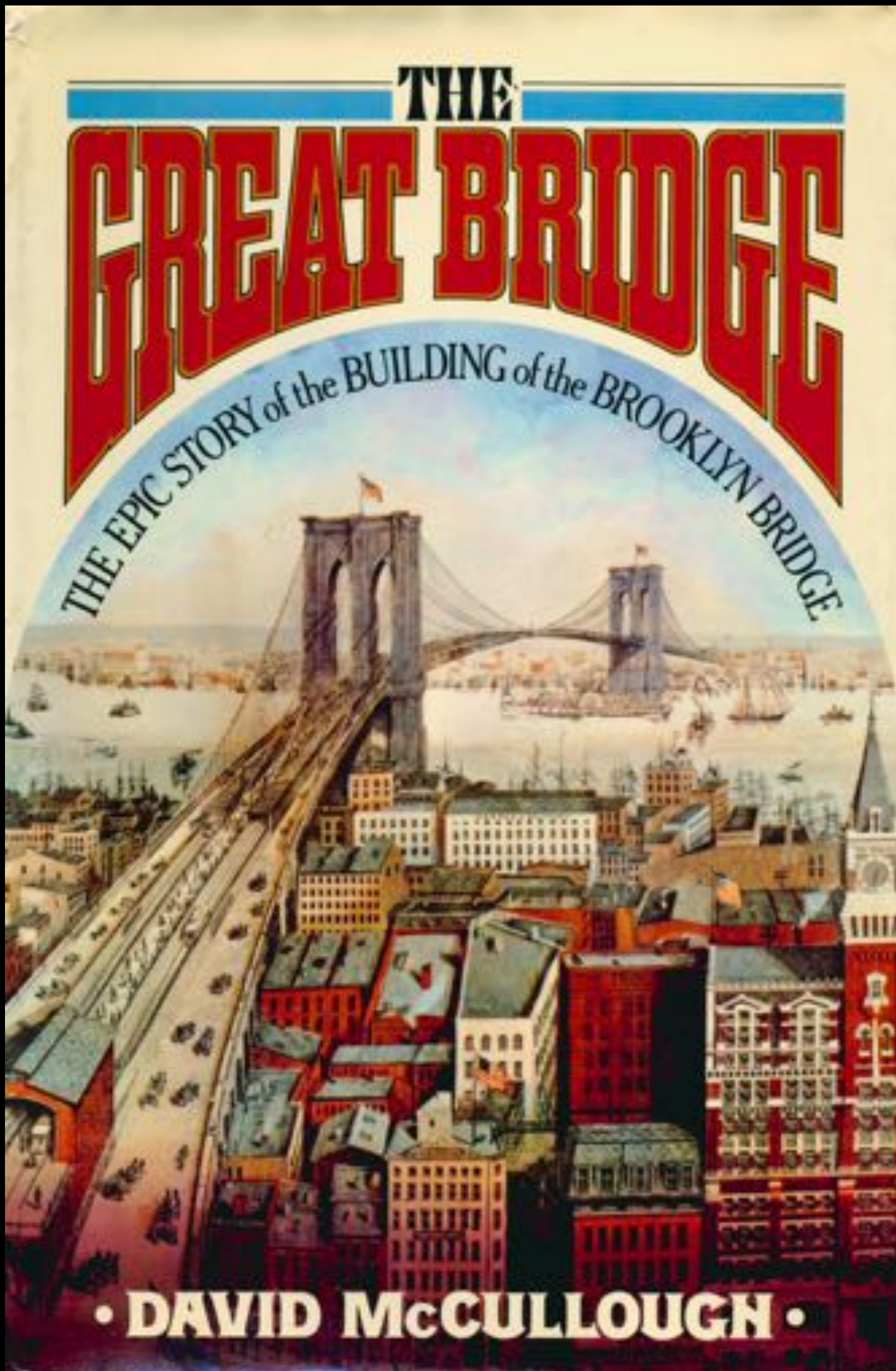
JOHN A. ROEBLING.

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

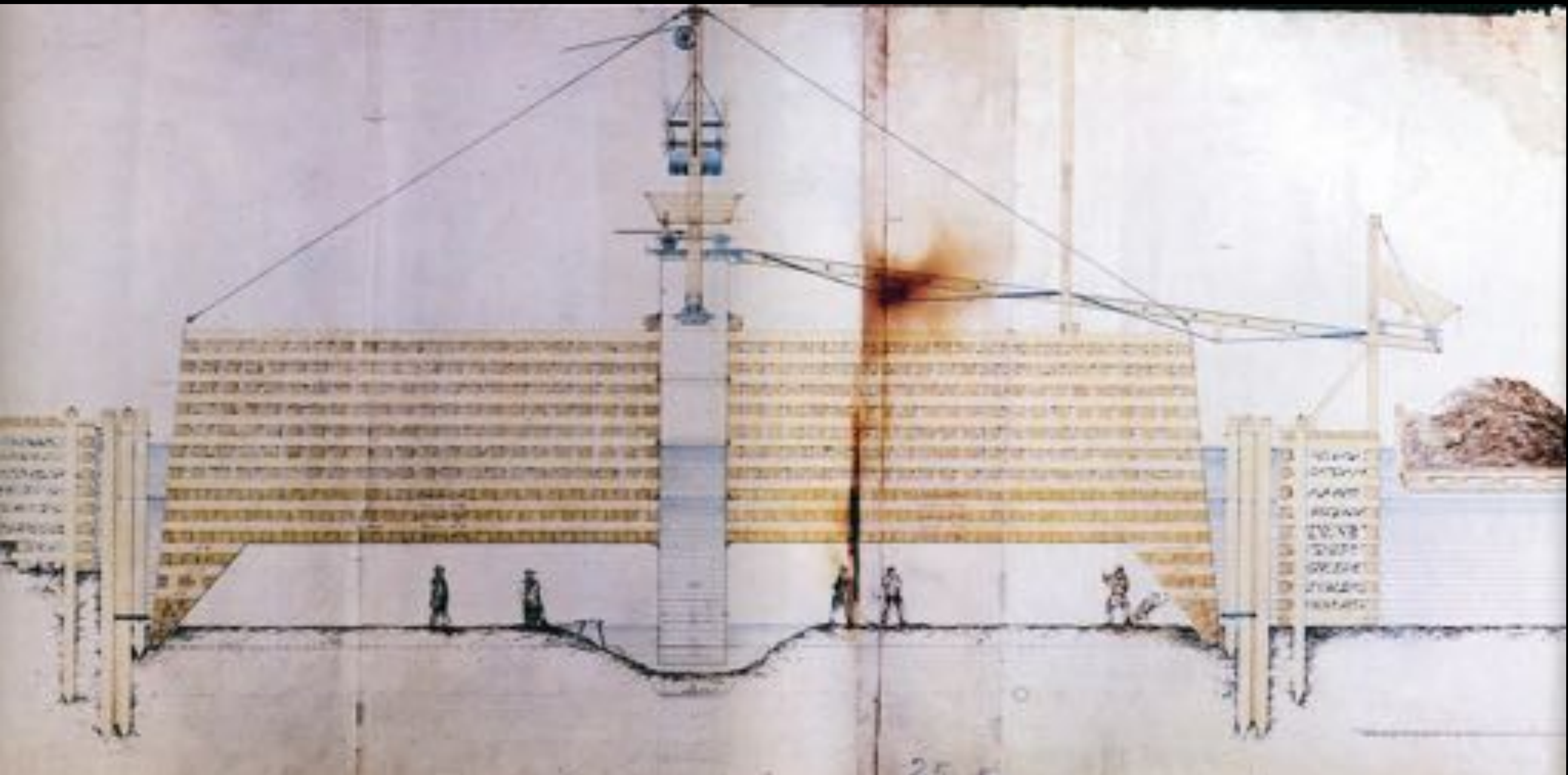





Front Elevation of Tower
&
East River Bridge
by
John A. Roebling
C.E.



Washington Roebling



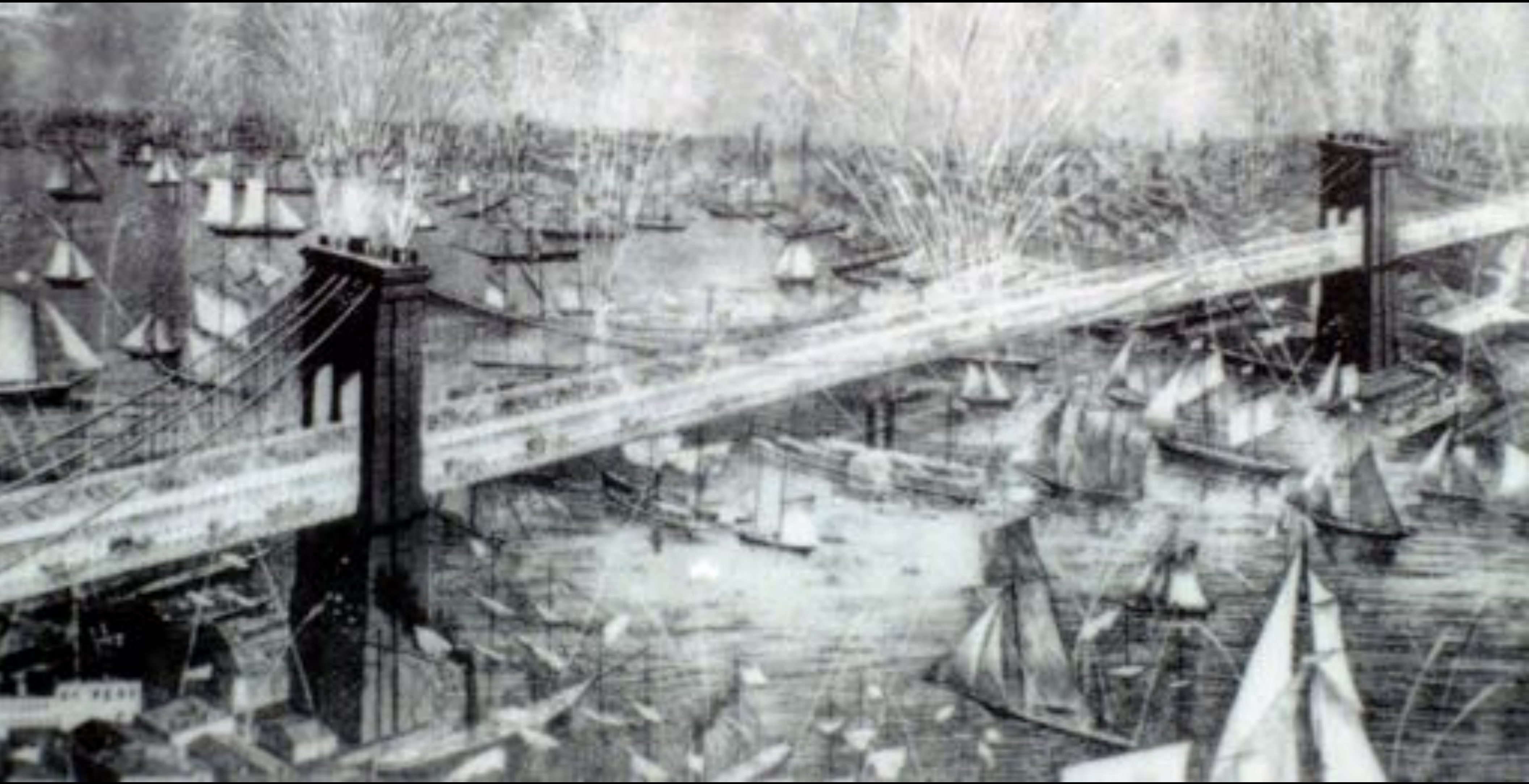
Boss Tweed

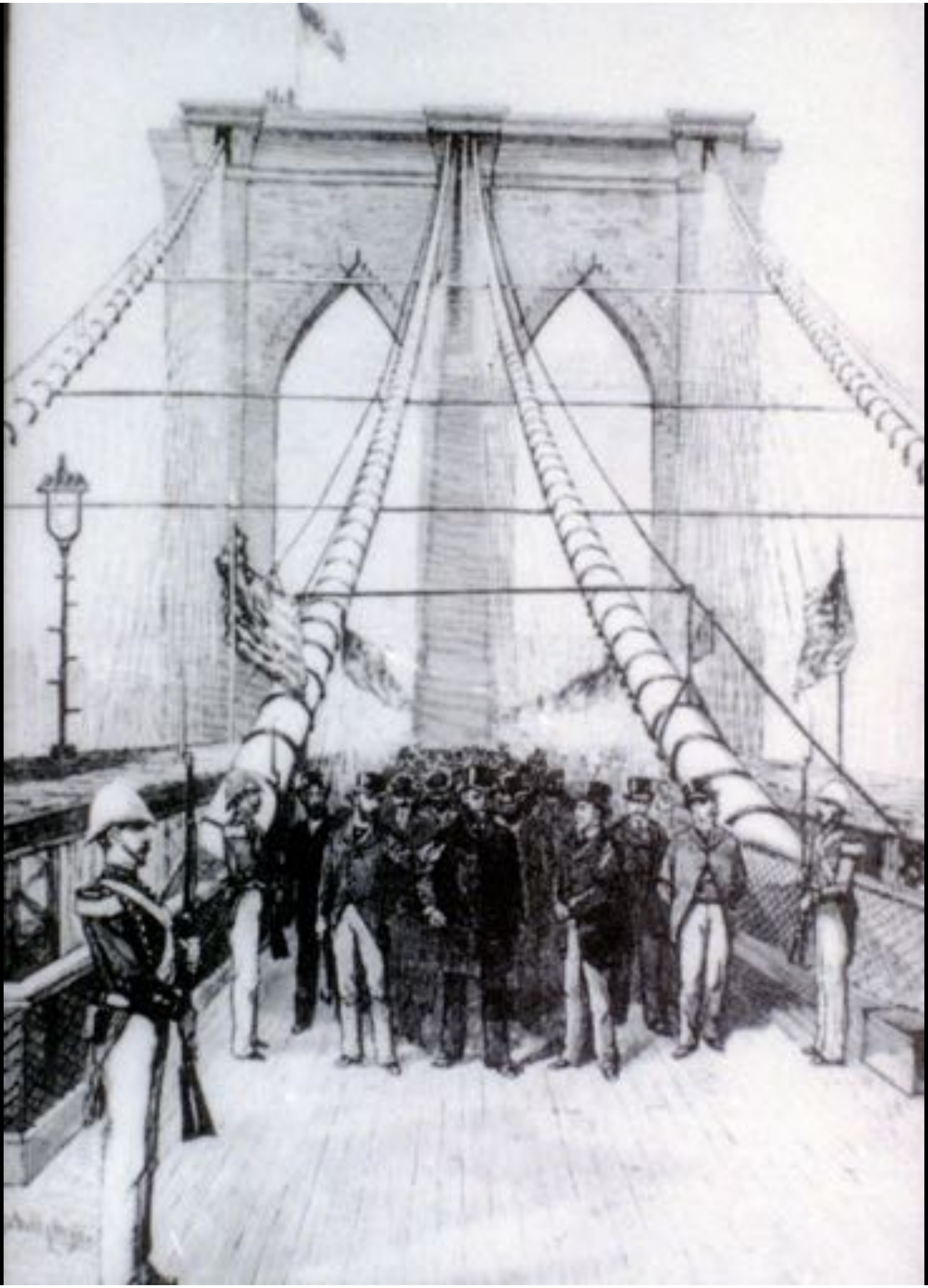
Tammany Hall


LIQUOR

Abraham Hewitt

Emily Roebling



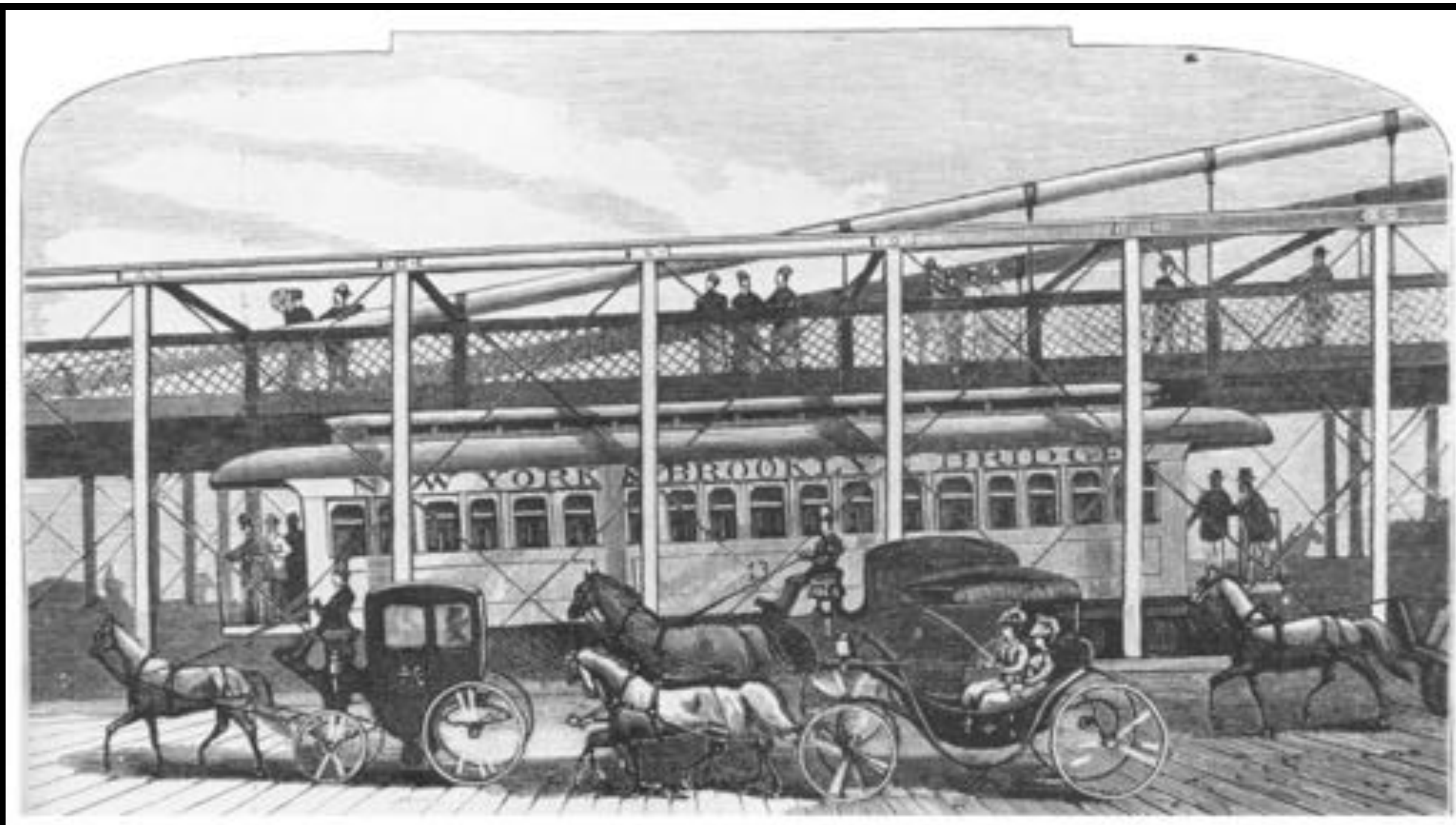


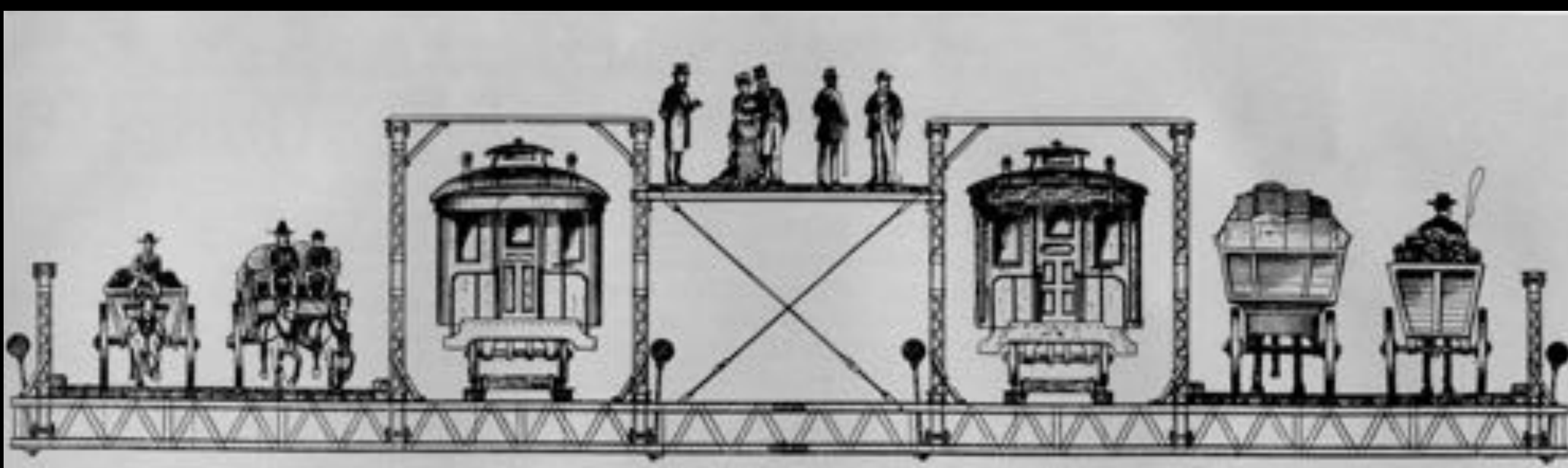
Brooklyn Bridge (1883)
John and Washington Roebling

1595.5 ft [486 m] main span
New York

Roebling on his stay cables…

extensive system of stays forms the third. The stays are arranged in four distinct planes, connected by the floor. The latter in connection with the stays will support itself without the assistance of the cables. If the structure is viewed





1888

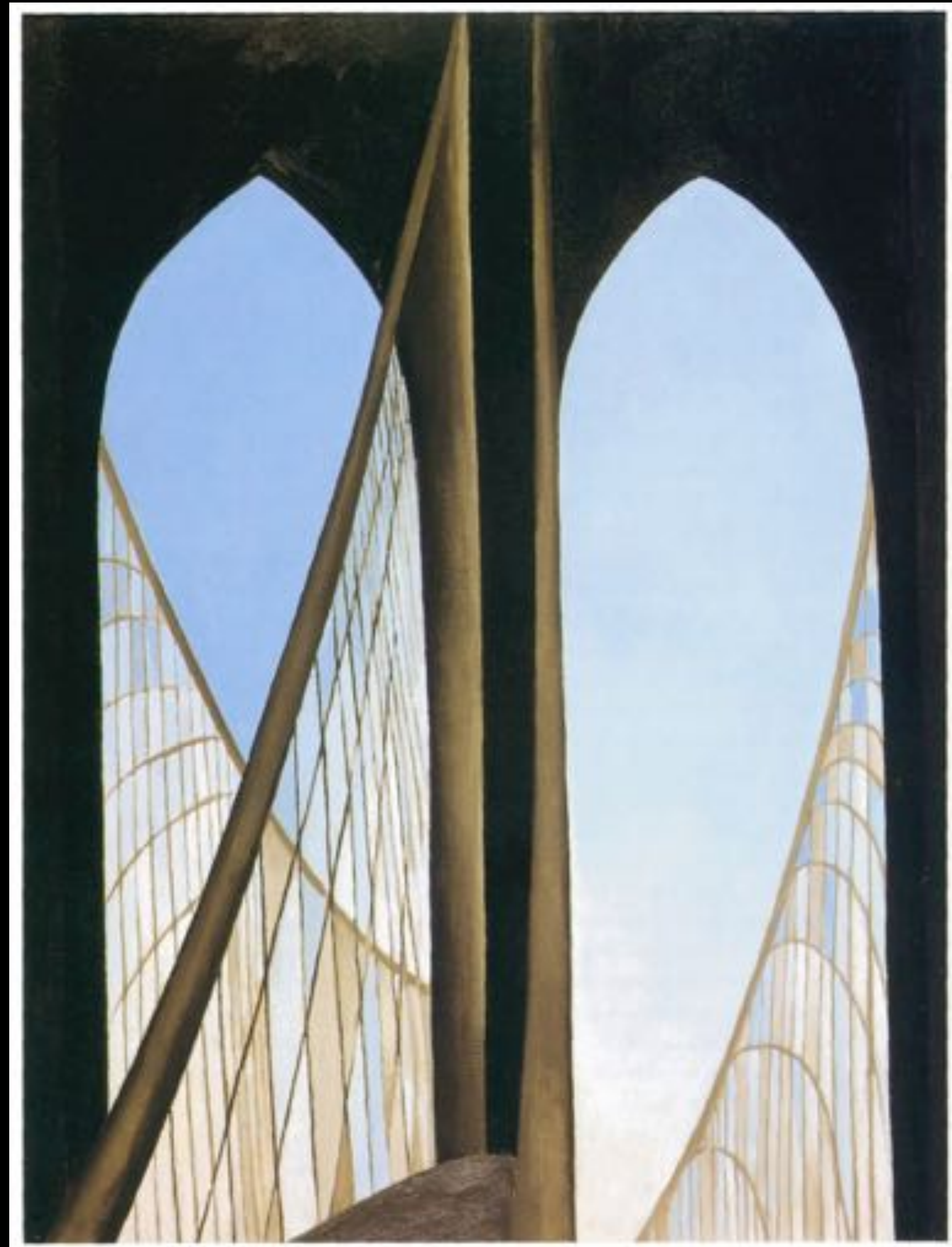
2006

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?

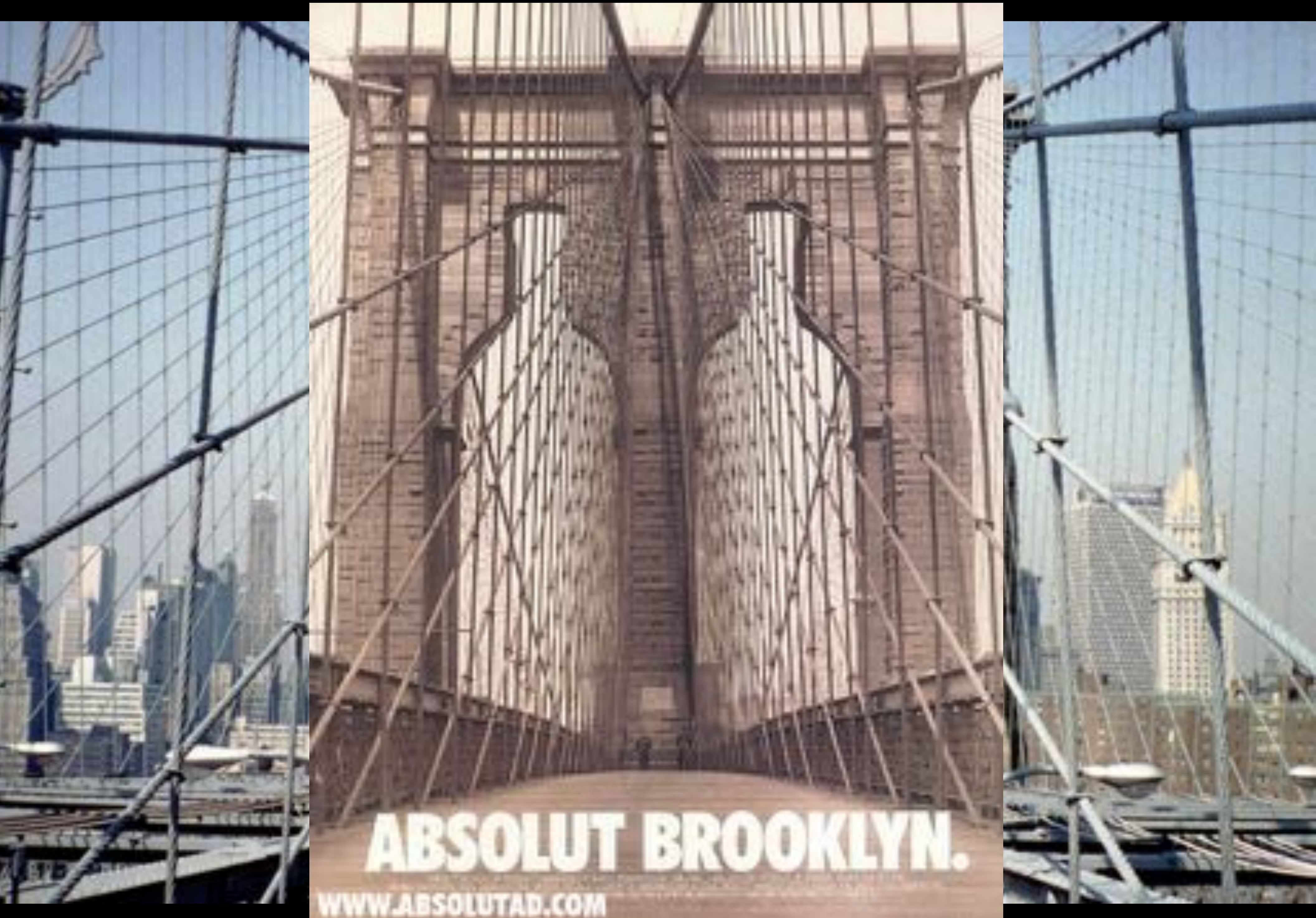
Were the results positive, negative, mixed?

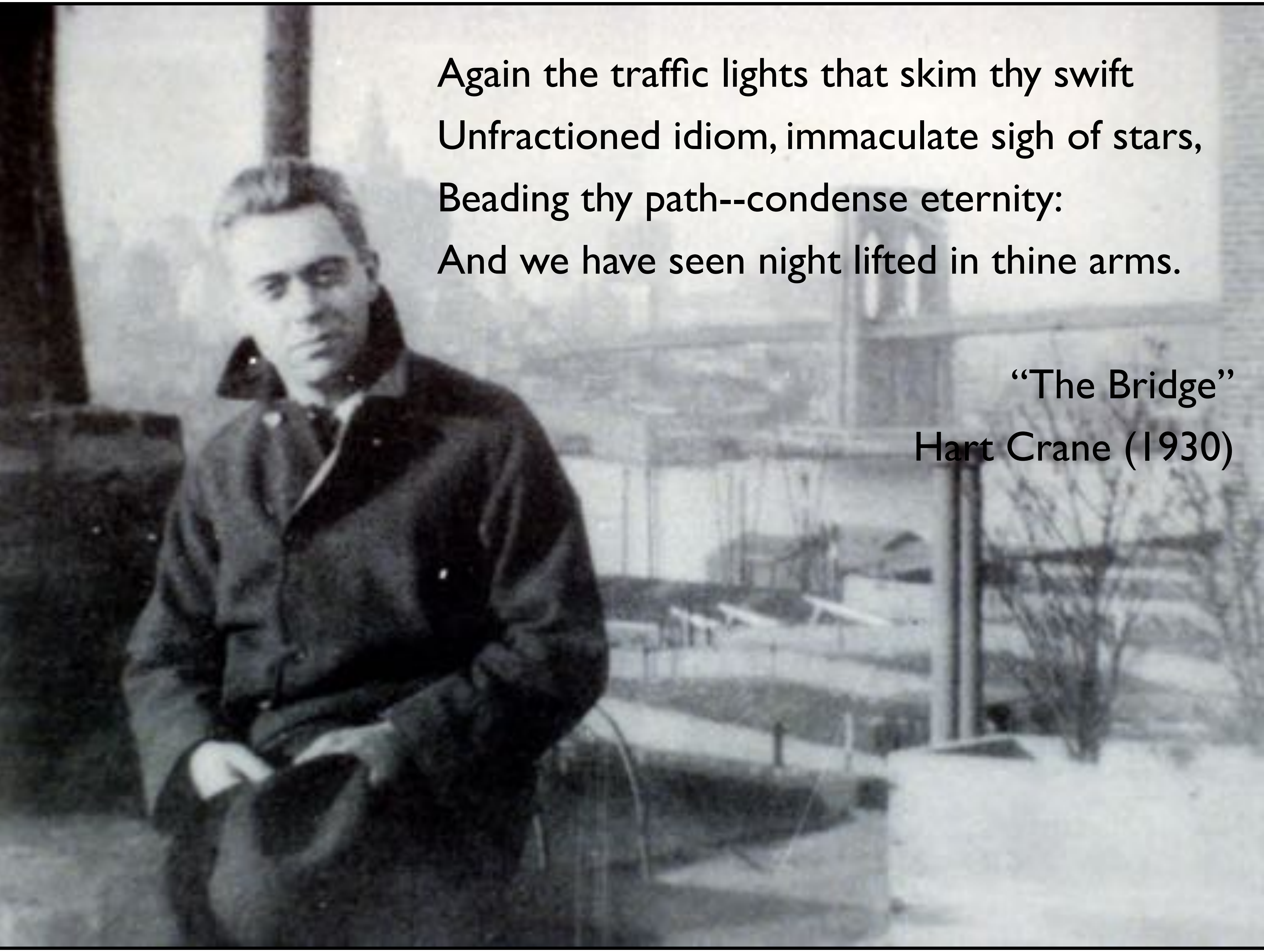


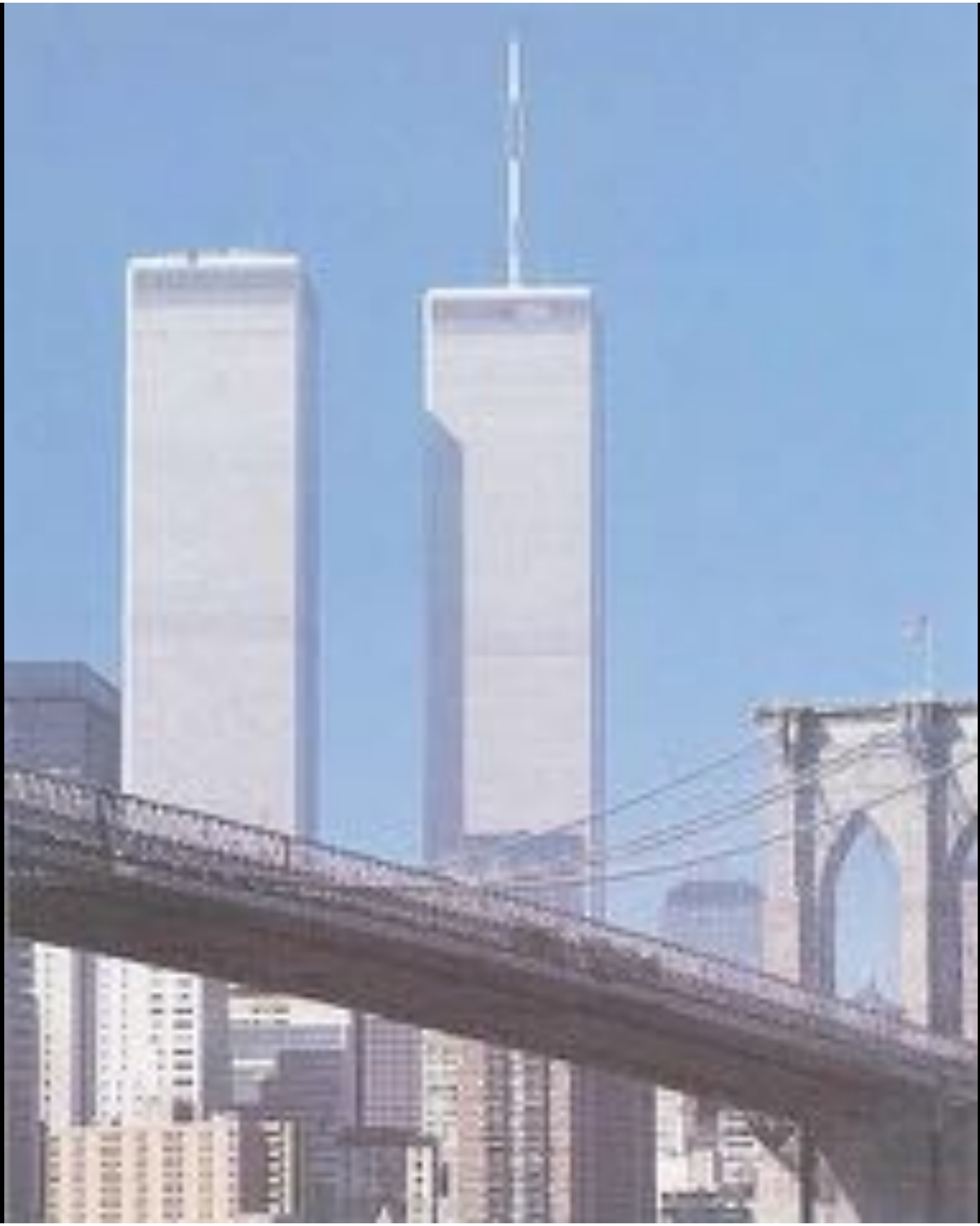
PENNSYLVANIA RAILROAD

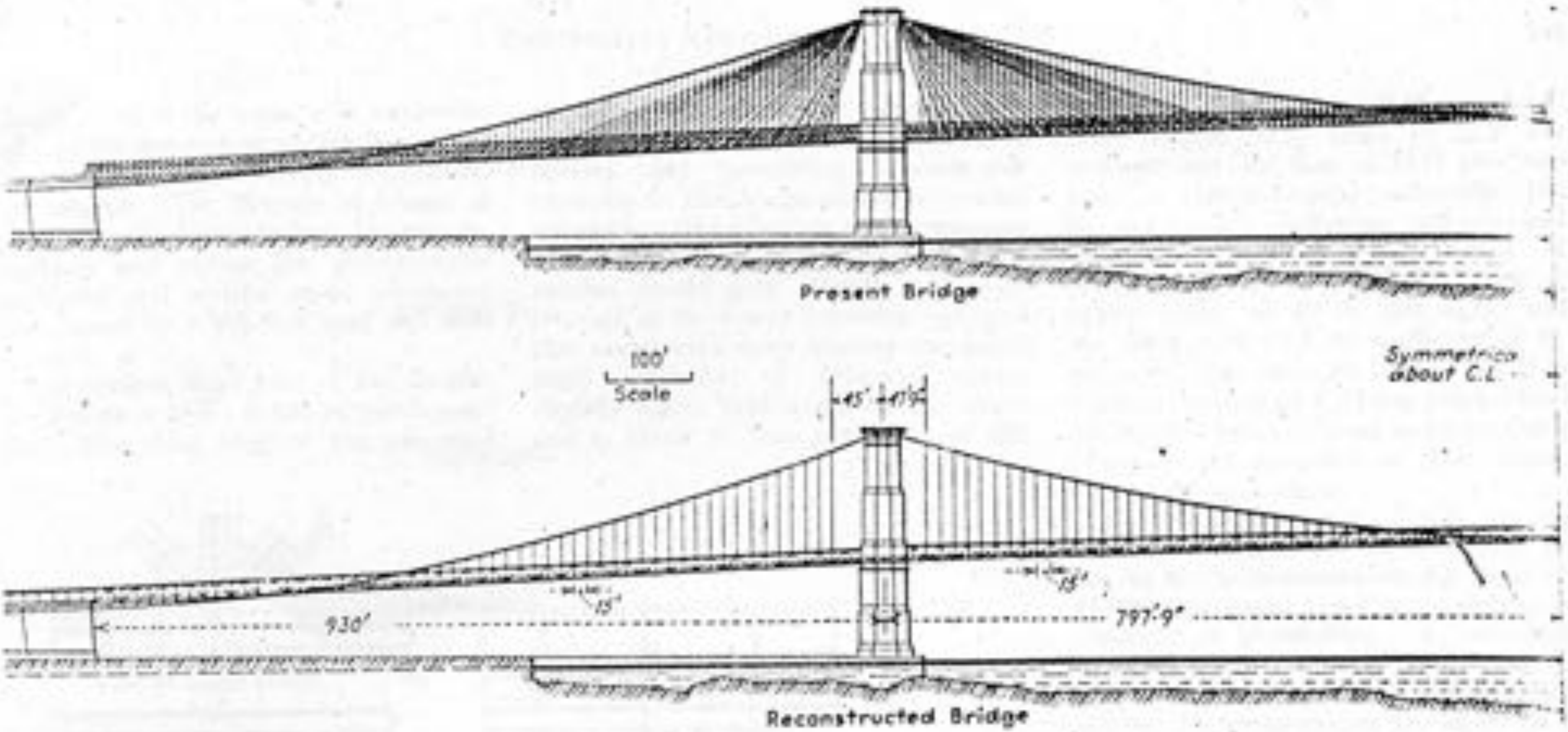

BOAT SUPPLIES
MANILA ROPE WIRE ROPE
CHAIN HOISTS BLOCKS TURNBUCKLES
CLIPS HOOKS CHAINS ANCHORS
& SHACKLES
BOAT COVERS



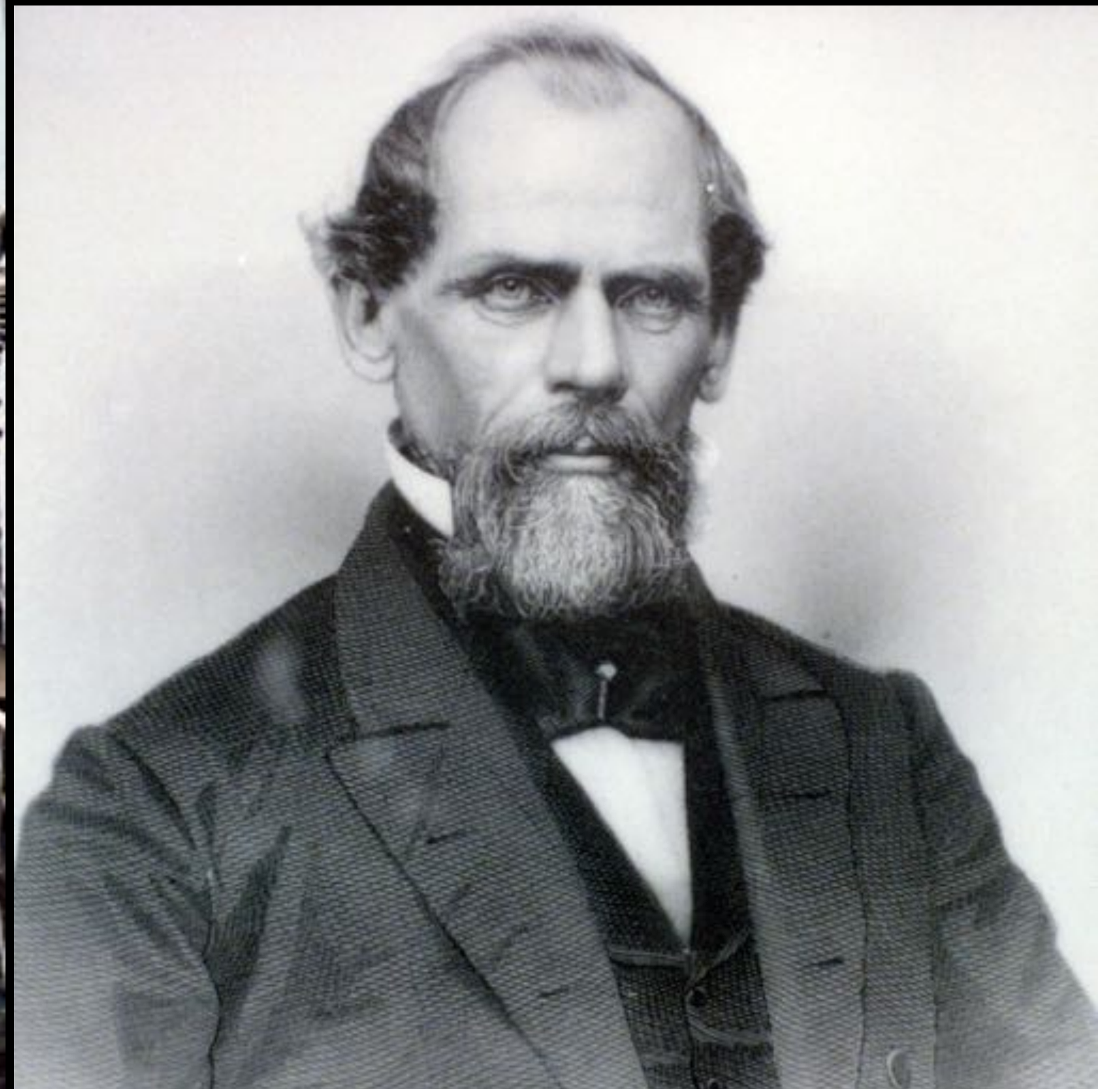
ABSOLUT BROOKLYN.
WWW.ABSOLUTAD.COM


Again the traffic lights that skim thy swift
Unfractioned idiom, immaculate sigh of stars,
Beading thy path--condense eternity:
And we have seen night lifted in thine arms.
“The Bridge”
Hart Crane (1930)





Present Bridge
100'
Scale
Symmetrical about C.L.
45'
47½'
15'
15'
930'
797'-9"
Reconstructed Bridge

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. (McCullogh, 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.

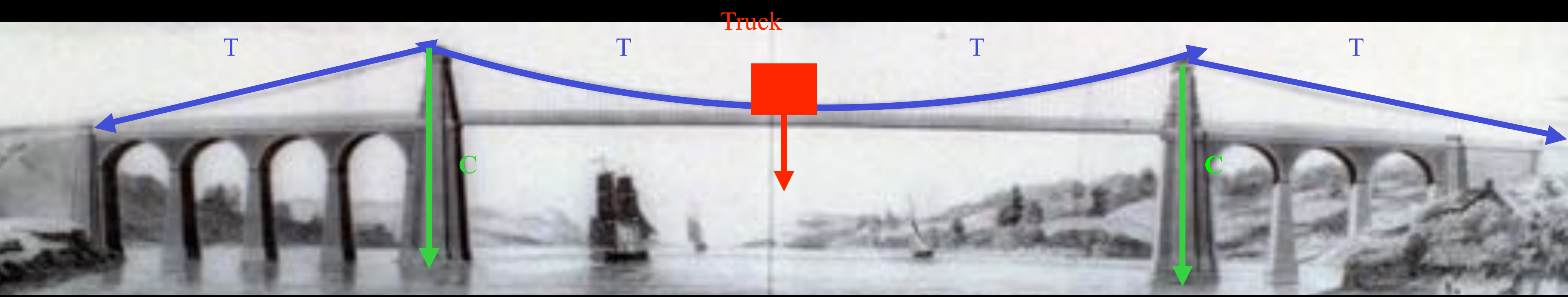
Brooklyn Bridge

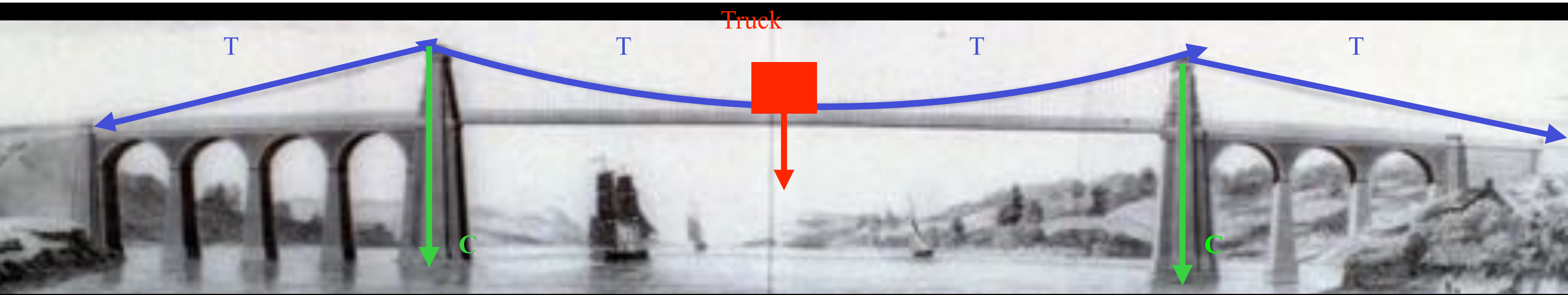
Scientific	Innovative structural system of cables, stays and truss Longest span in the world
Social	Construction amidst political corruption Transforms city of New York (connects the city) Bridge itself is a unique experience
Symbolic	Inspires numerous works of art The image of New York City

Suspension Bridge Statics

Load Path

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

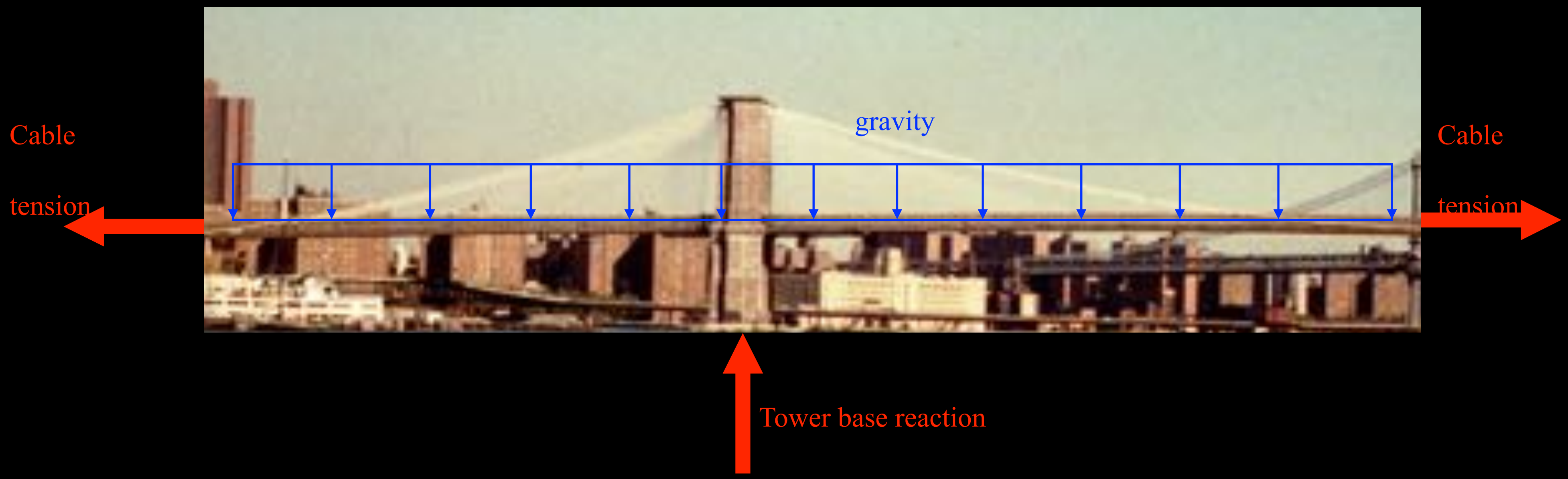


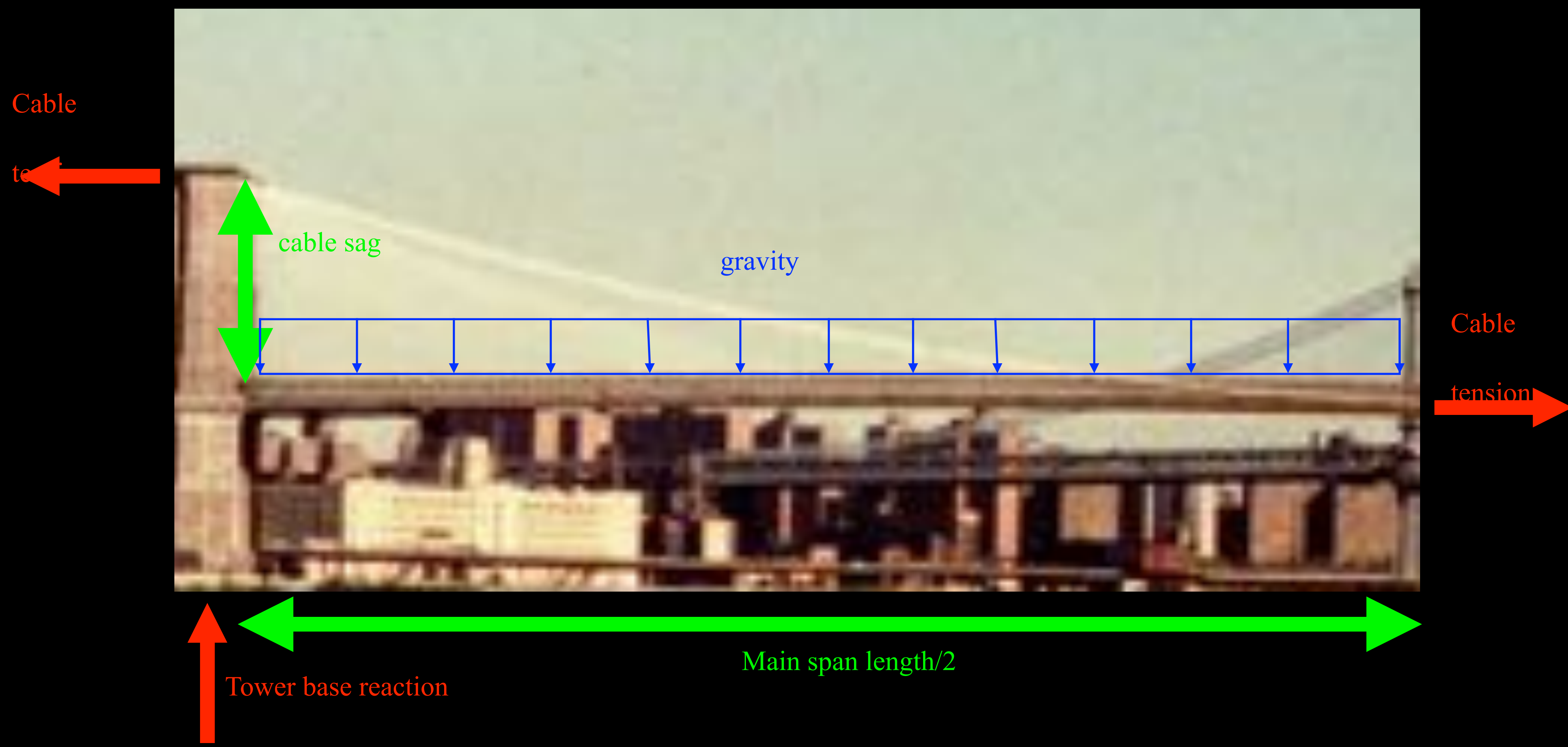


How does Roebling’s introduction of diagonal stays introduce ambiguity to the load path?

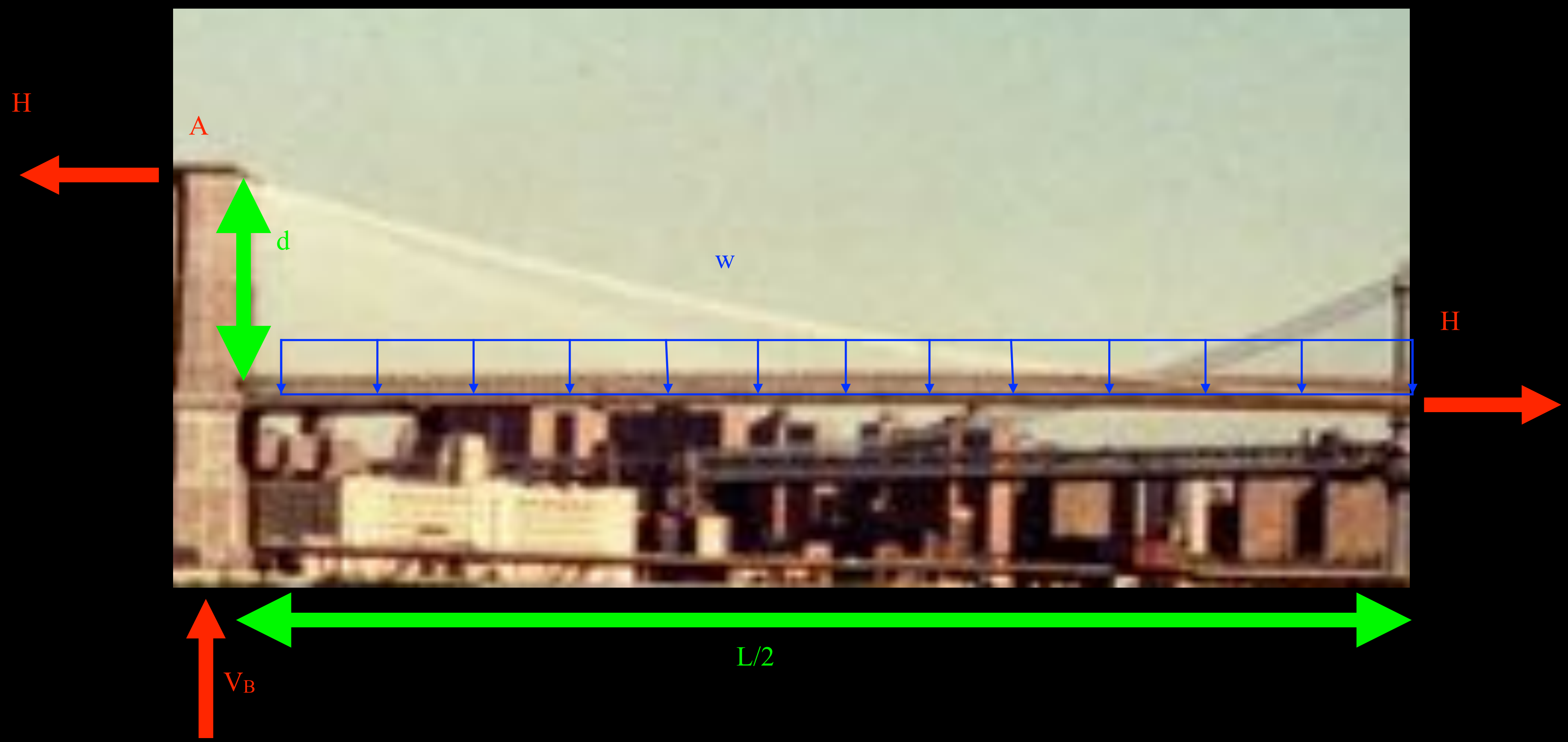
Free Body Diagrams

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

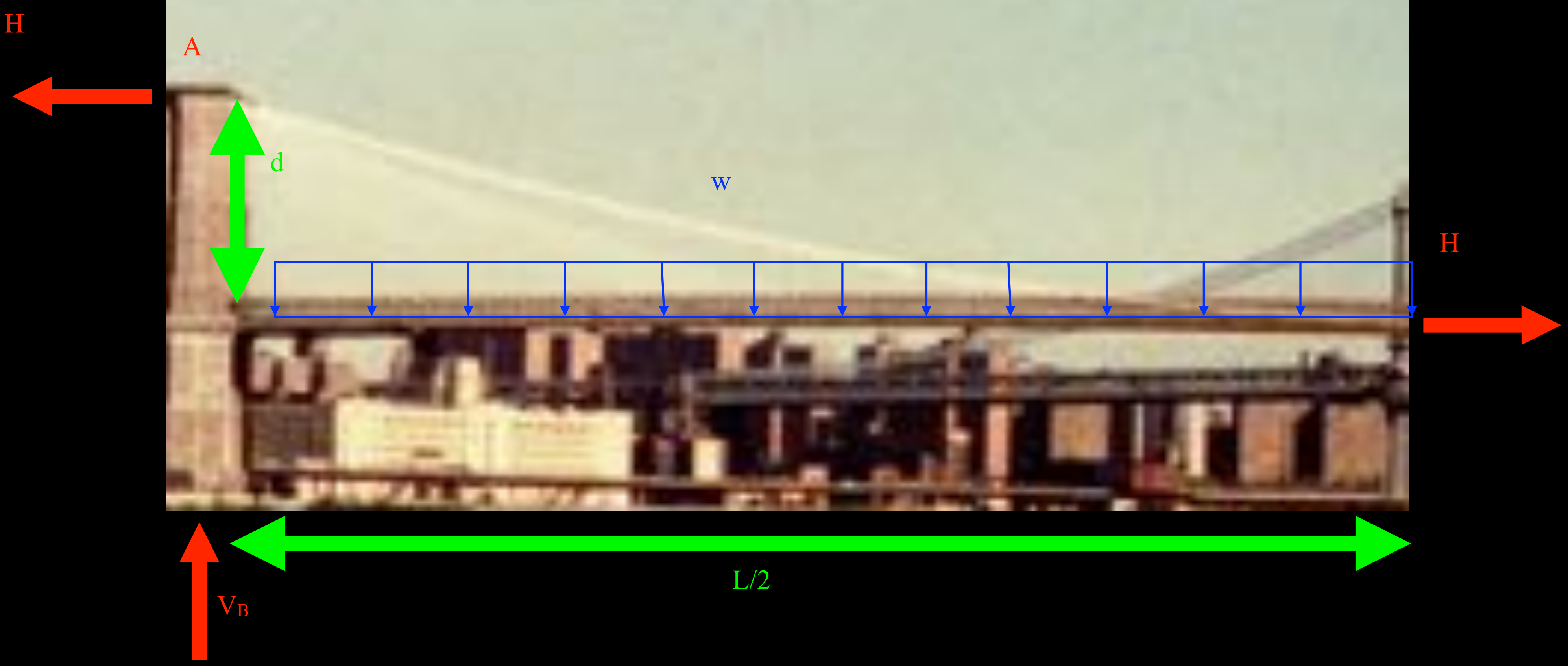



Cable
cable sag
gravity
Cable
tension
Main span length/2
Tower base reaction

Notation

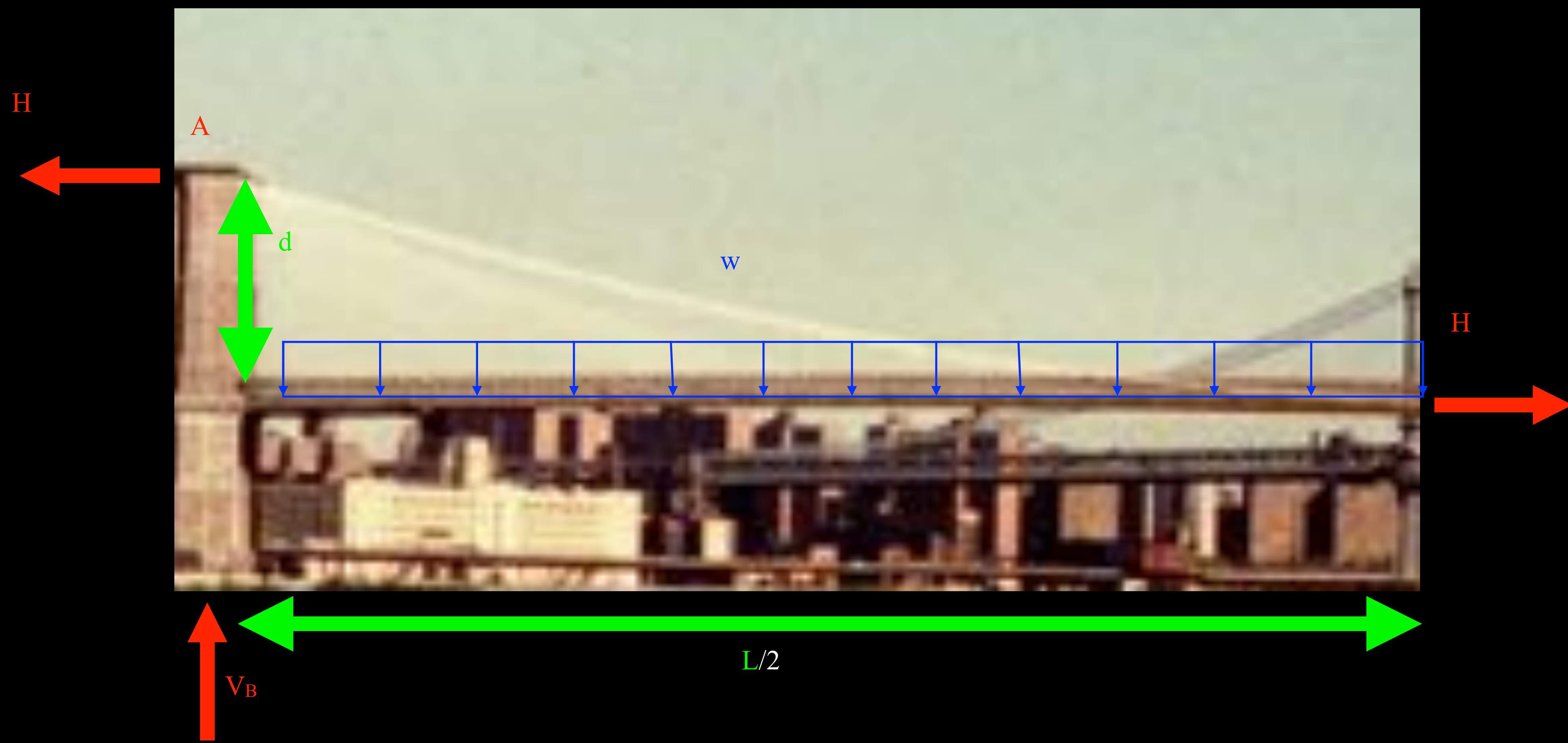


Equilibrium



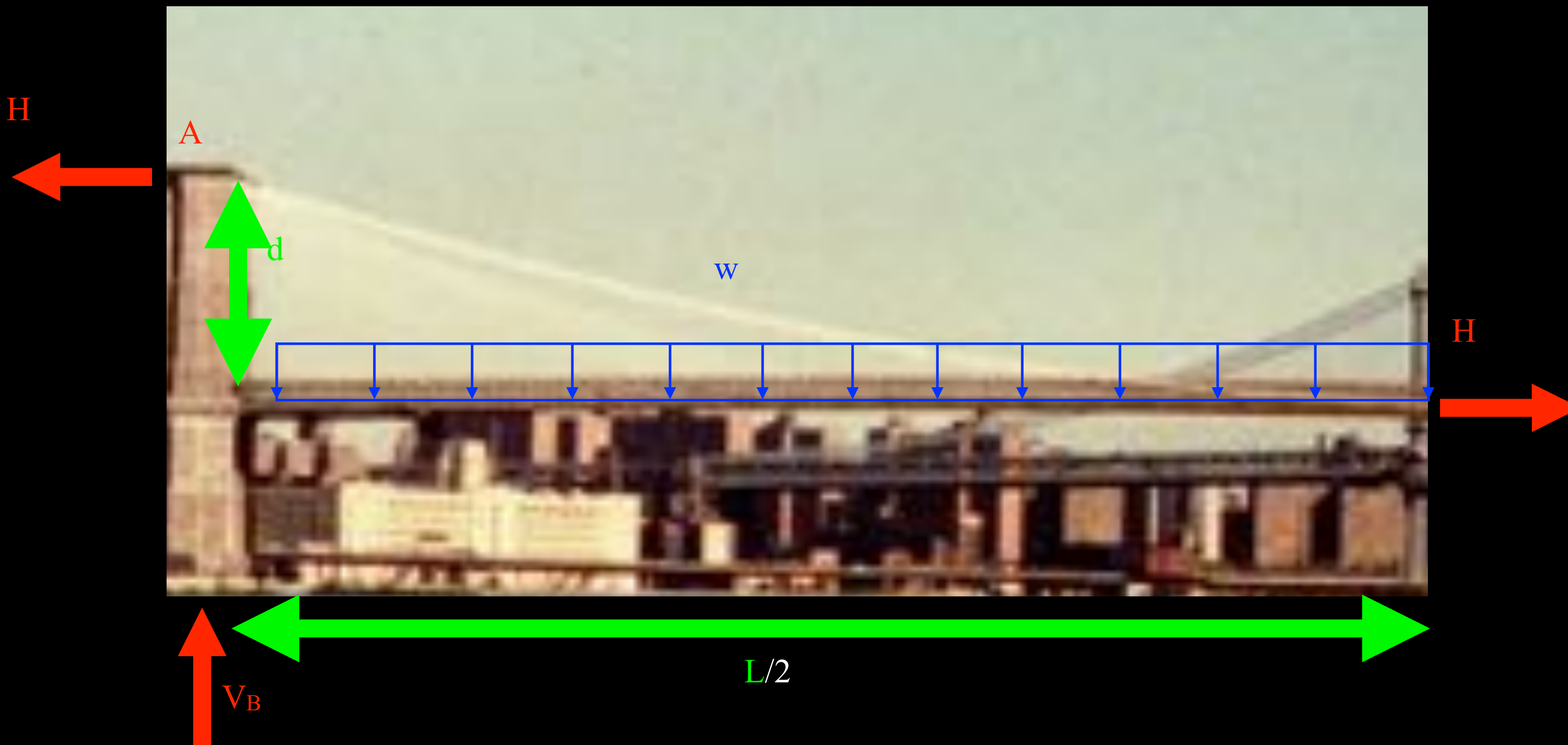
$$\Sigma M_A = 0$$

Equilibrium



$$\Sigma M_A = 0, \quad Hd - wL^2/8 = 0, \quad H = wL^2/8d$$

Cable tension



$H = wL^2/8d$

$R = L/d$

$H = wLR/8$

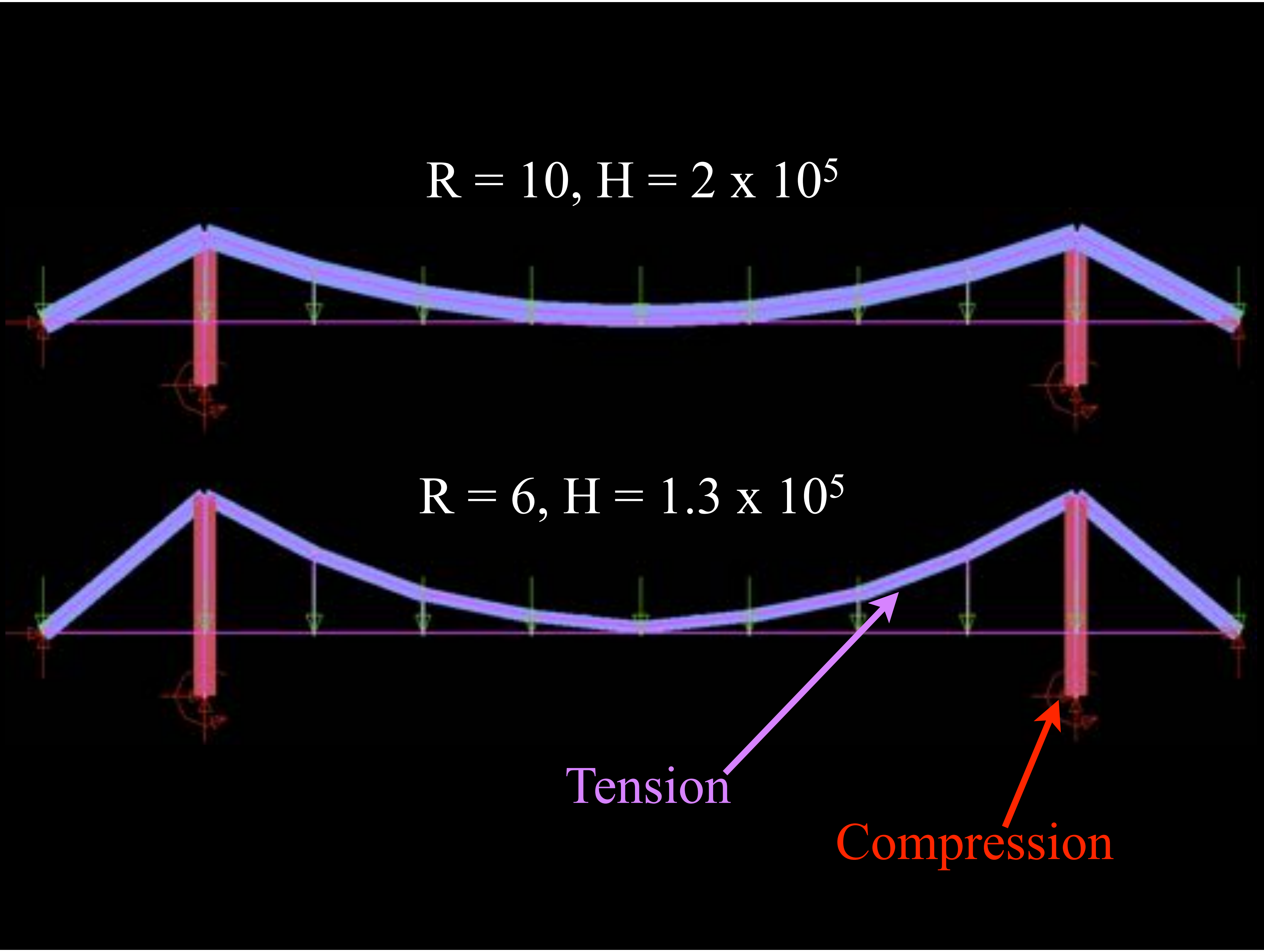
w = load

L = size

R = form

H = function

R,L transform w into H


R = 10, H = 2 x 10^5
R = 6, H = 1.3 x 10^5
Tension
Compression