Eads, Eiffel and the Forth Bridge

The big 19th century iron and steel bridges

1. How arches carry load: Eads Bridge
2. Two hinged arches: Garabit
3. Details of form in metal arches: Garabit and Mungstener
4. Influence of structural failure on subsequent design
5. Strength and safety in cantilever form: Forth Bridge

But first!

- An exercise to help with next week's homework and to help us identify the skills of your friends and neighbors in the class.

- Let's do a little statics exercise in the style of a *magazine quiz,* give yourself a point each time you know the answer to the questions that follow – we will sum points to find our statics gurus!

Q1

- In two dimensions what are the three equations of equilibrium?
  - (1)
  - (2)
  - (3)

- Give yourself a point if you know them.

Answer 1

- In two dimensions what are the three equations of equilibrium?
  - (1) $\Sigma F_x=0$
  - (2) $\Sigma F_y=0$
  - (3) $\Sigma M=0$

- Give yourself a point if you know them.

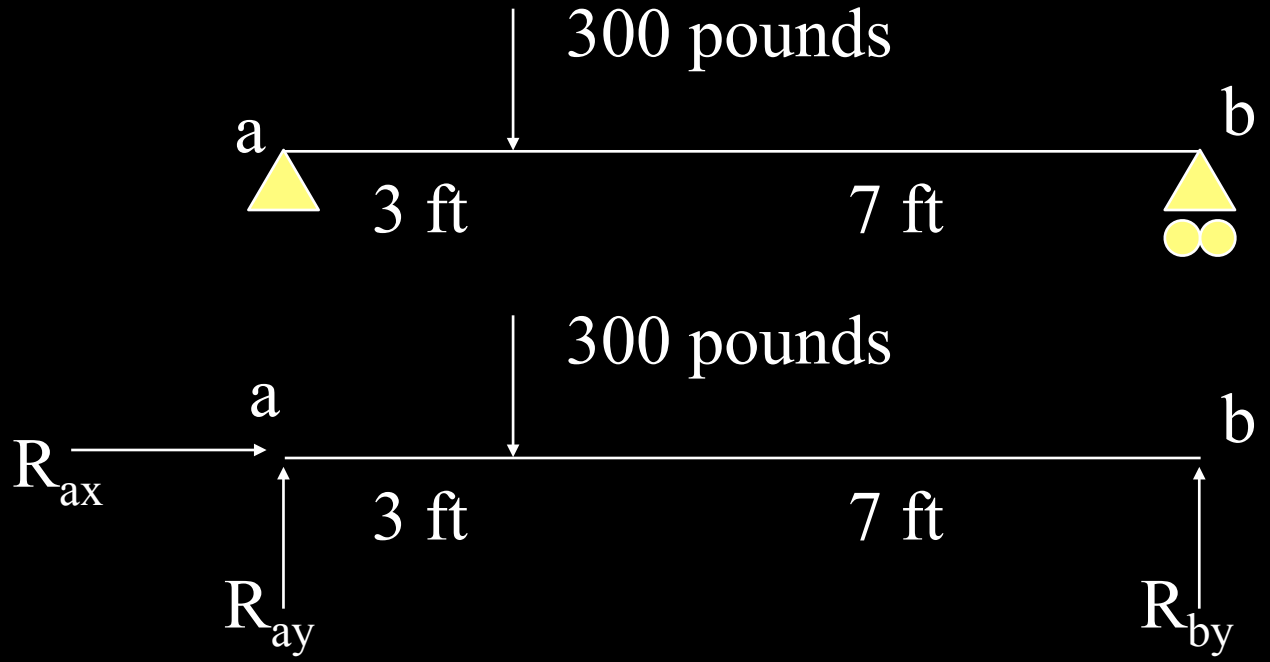
Q2

- Make a free body diagram of the following little bridge.

- Give yourself a point if you know how. ☺

Answer 2

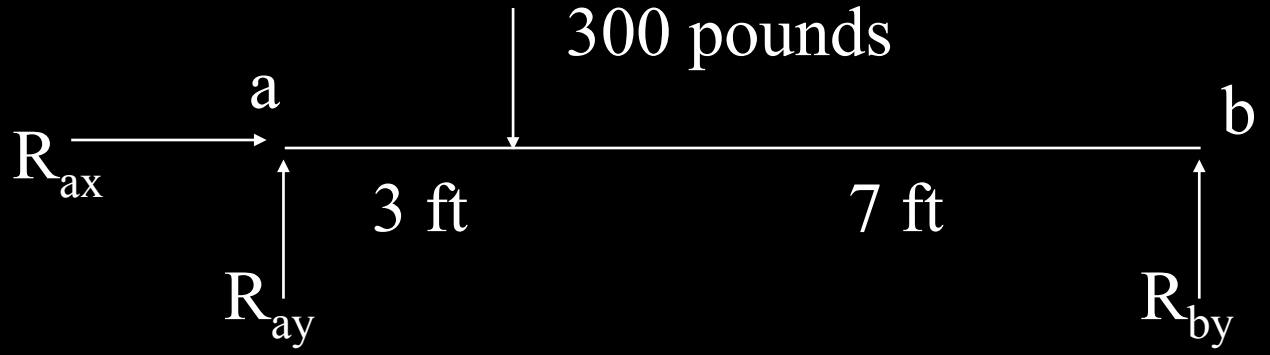
- Make a free body diagram of the following little bridge.



- Give yourself a point if you know how. ☺

Q3

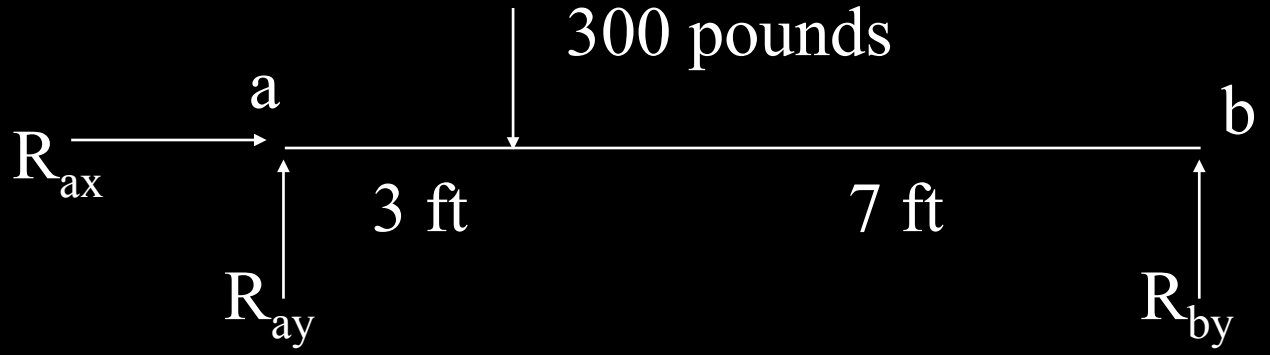
- Write the equation for sum of forces in the y



- Give yourself a point if you know how. ☺

Answer 3

- Write the equation for sum of forces in the y

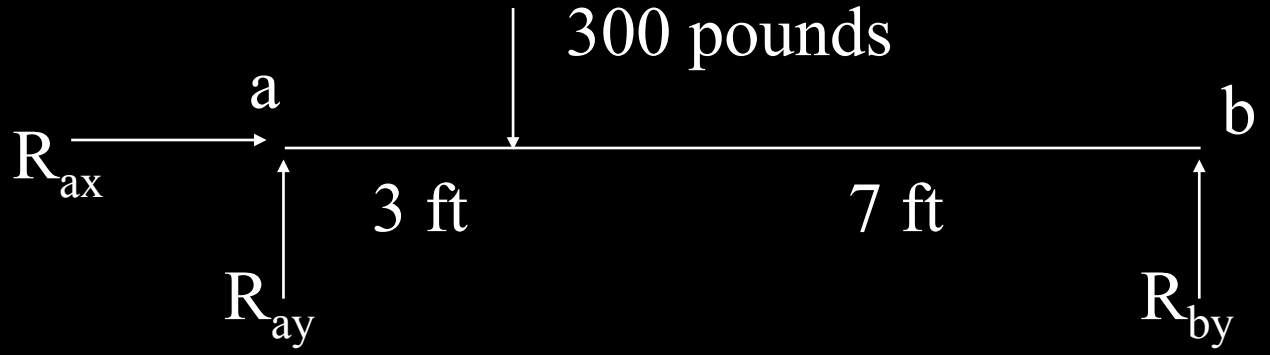


$$\Sigma F_y=0 \quad R_{ay}-300+R_{by}=0 \quad R_{ay}+R_{by}=300$$

- Give yourself a point if you know how. ☺

Q4

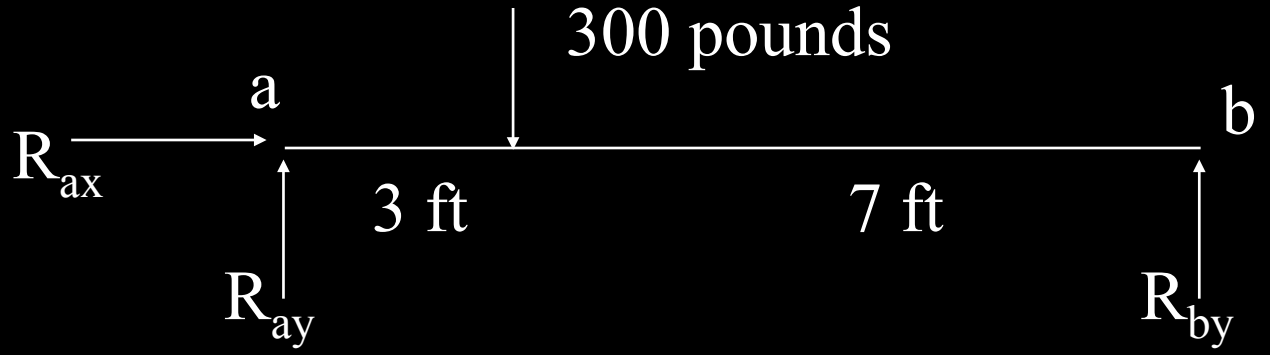
- Write the equation for sum of moments at a



- Give yourself a point if you know how. ☺

Answer 4

- Write the equation for sum of moments at a



$\Sigma M_a=0 \quad 10ft*R_{by}-3ft*300lbs=0$

$R_{by}=90lbs$

& $R_{ay}=300-90=210lbs$

- Give yourself a point if you know how. ☺

Q5

- I enjoy helping others because it helps me to understand concepts better too.

- Give yourself a point if you agree with the above statement.

Totals

- 1 – No worries, but expect to ask some questions of your new friends and neighbors (and just wait until I ask them to draw or write.. ☺)
- 2 – Hey this stuff is new to me! That's OK, lean on your friend and neighbors a bit
- 3 – Statics is neither your friend nor your enemy - help and be helped!
- 4 – Great, you know a lot and can help others, please do so!
- 5 – Statics Guru with a positive attitude. Your help is needed and expected!

Moving time
(just for today)

- Establish the 3's, 4's and 5's..
- Find our way into groups of 2 or 3 –
  these are not permanent groups, don't fret!
- Introduce yourself

Moving time
(just for today)

- Establish the 3's, 4's and 5's..
- Find our way into groups of 2 or 3 –
  these are not permanent groups, don't fret!
- Introduce yourself
- Please exchange contact information
  amongst your group (cell, email, whatever)
- Now we are ready!

Eads, Eiffel and the Forth Bridge

The big 19th century
iron and steel bridges

1850 IRON

1869 IRON

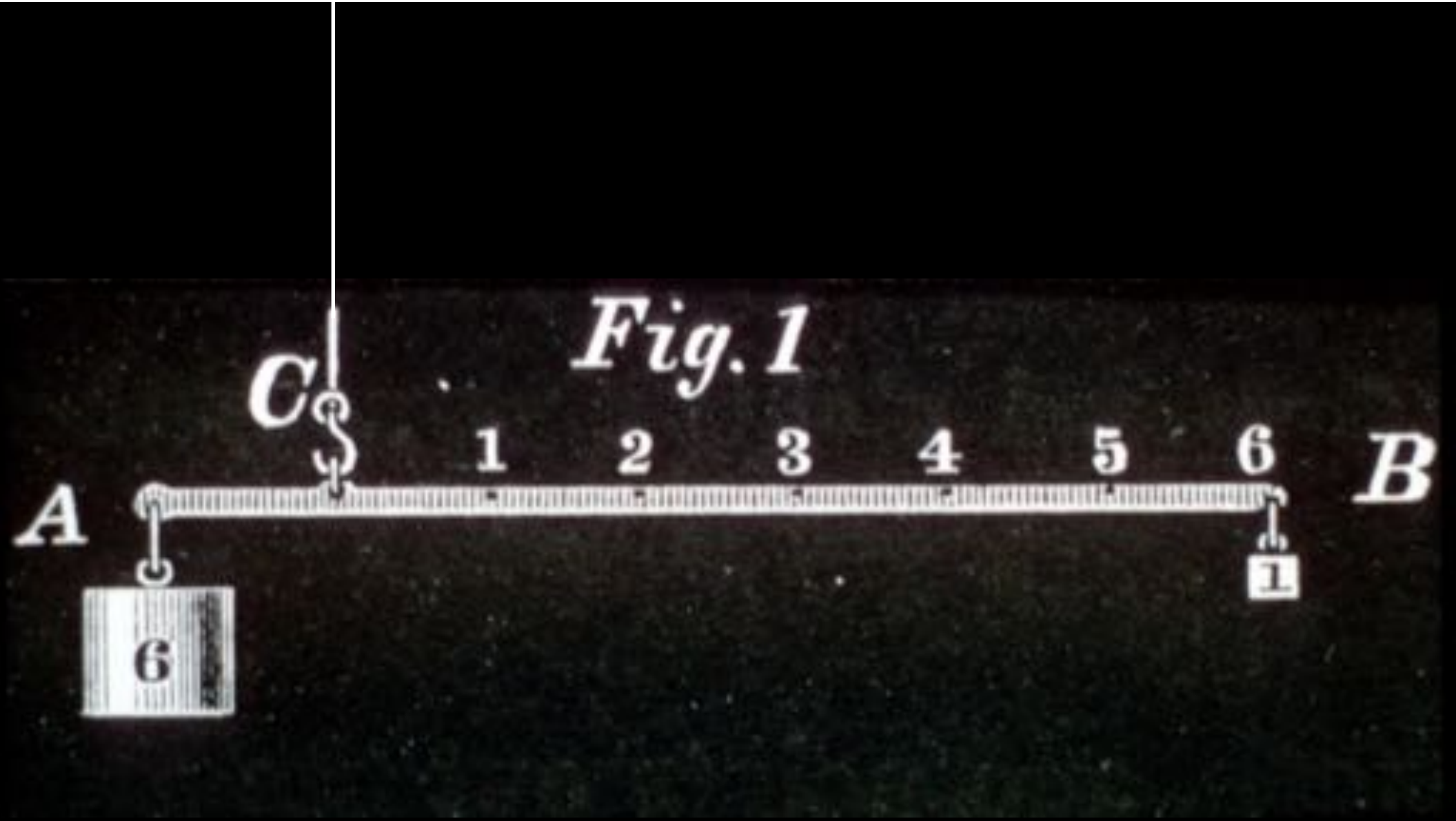
1856 IRON

1864 IRON

Eads Bridge - Steel - 520 feet [158 m] - 1874

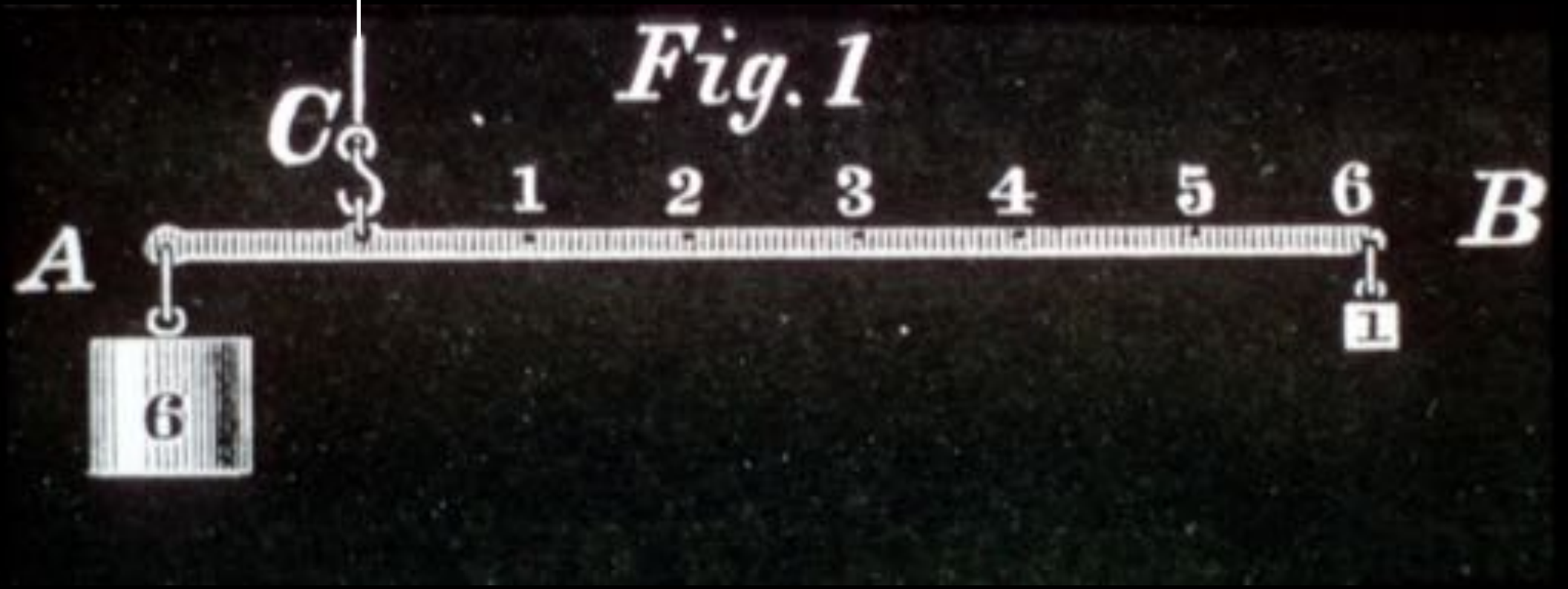
Koblenz

James Buchanan Eads
1820-1887



From a book written by Eads

Q: Why doesn't this tip over?




MONTMARTRE


Fig. 2
C
1
2
3
4
5
6
B
1
A

Fig. 2

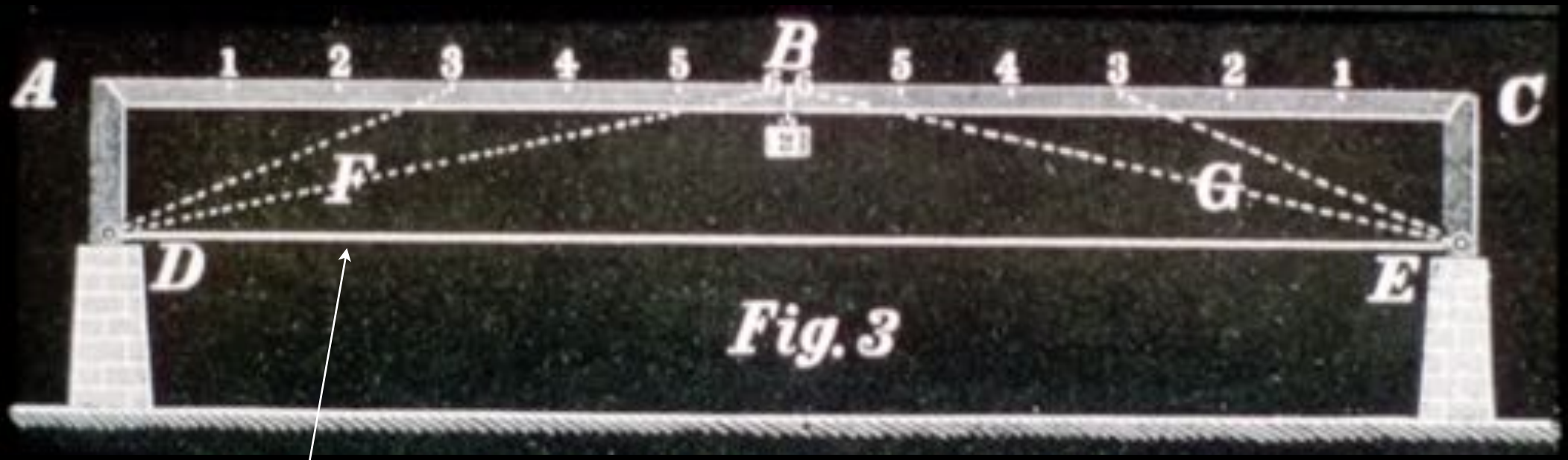


Fig. 3

Tension tie provides reaction

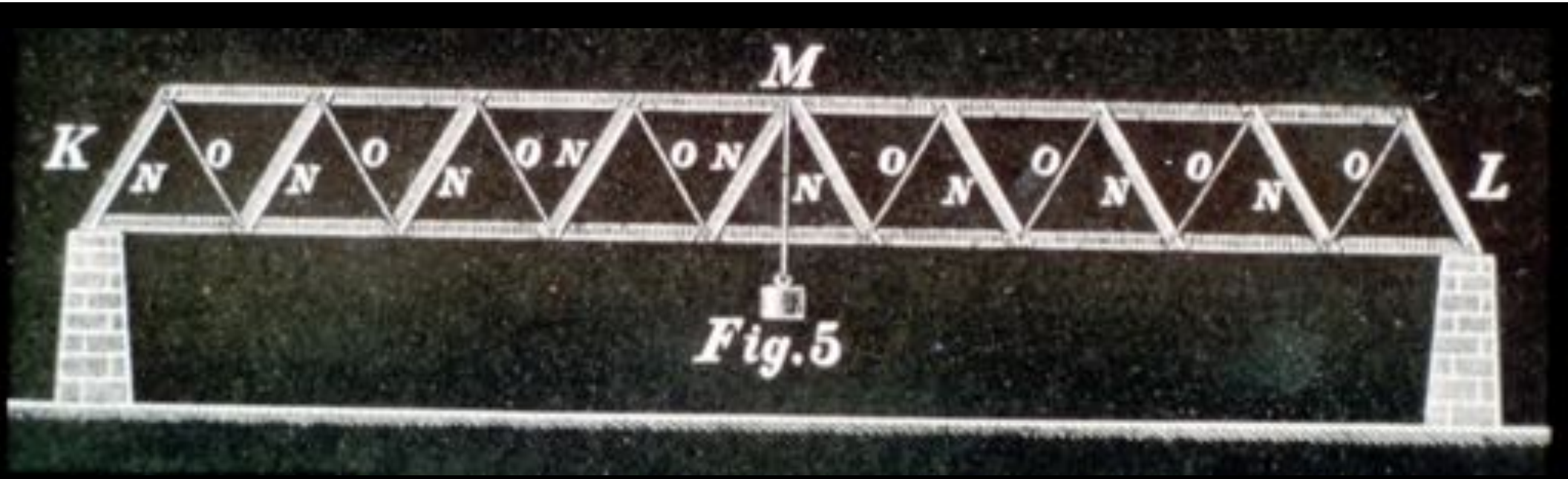


Fig.5

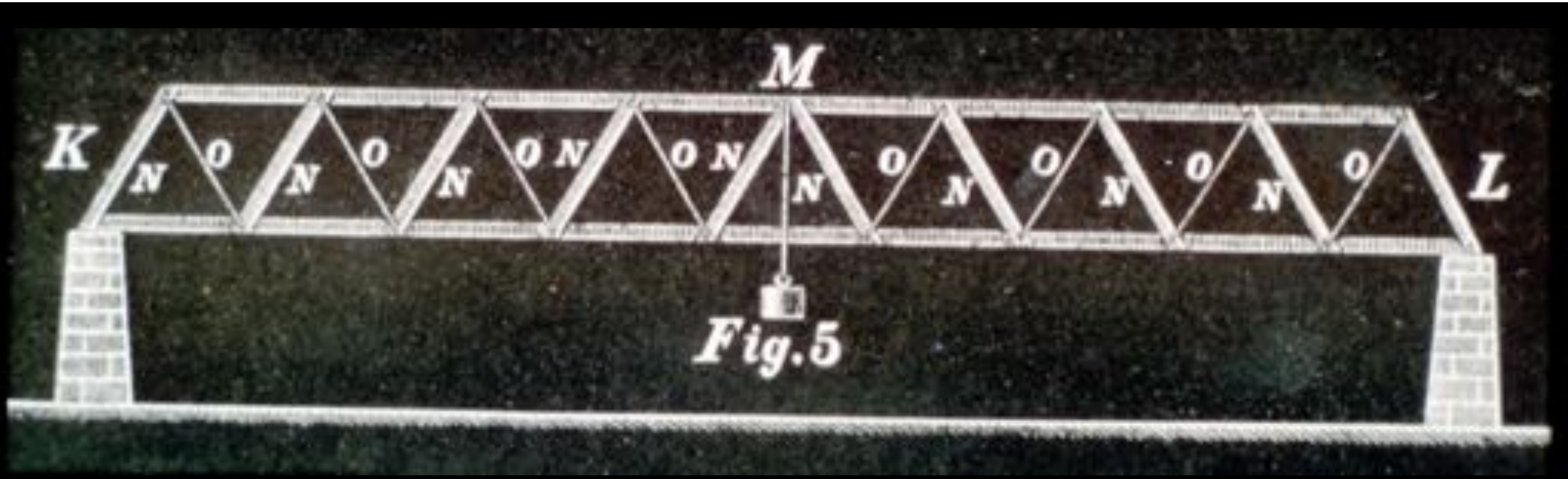


Fig.5

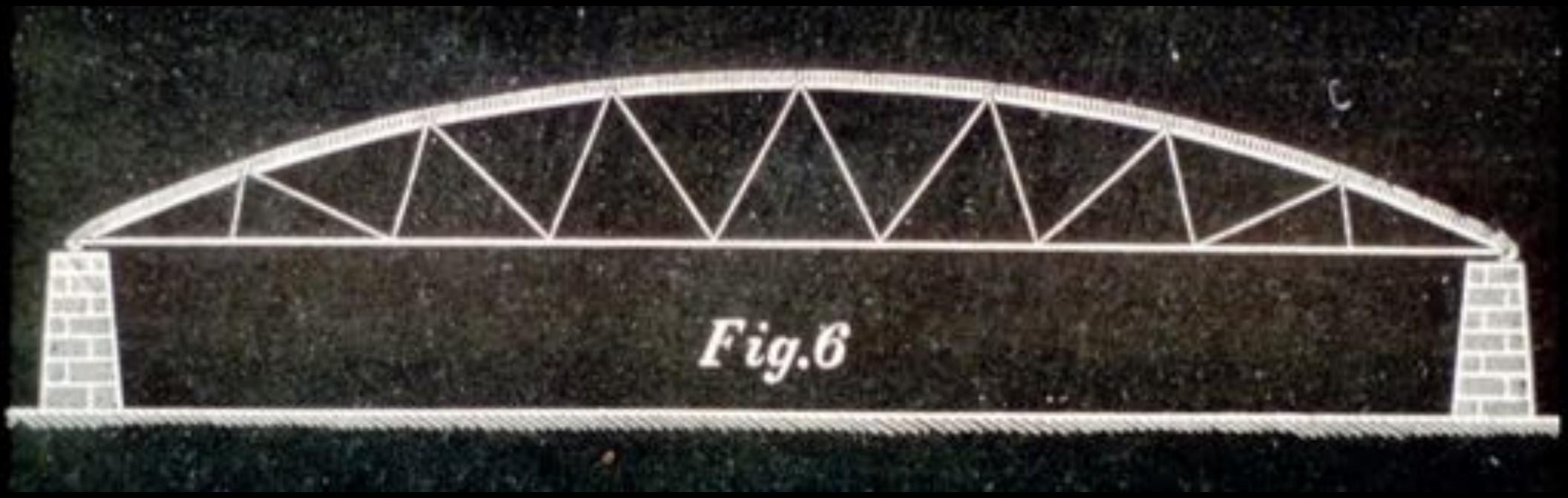


Fig.6

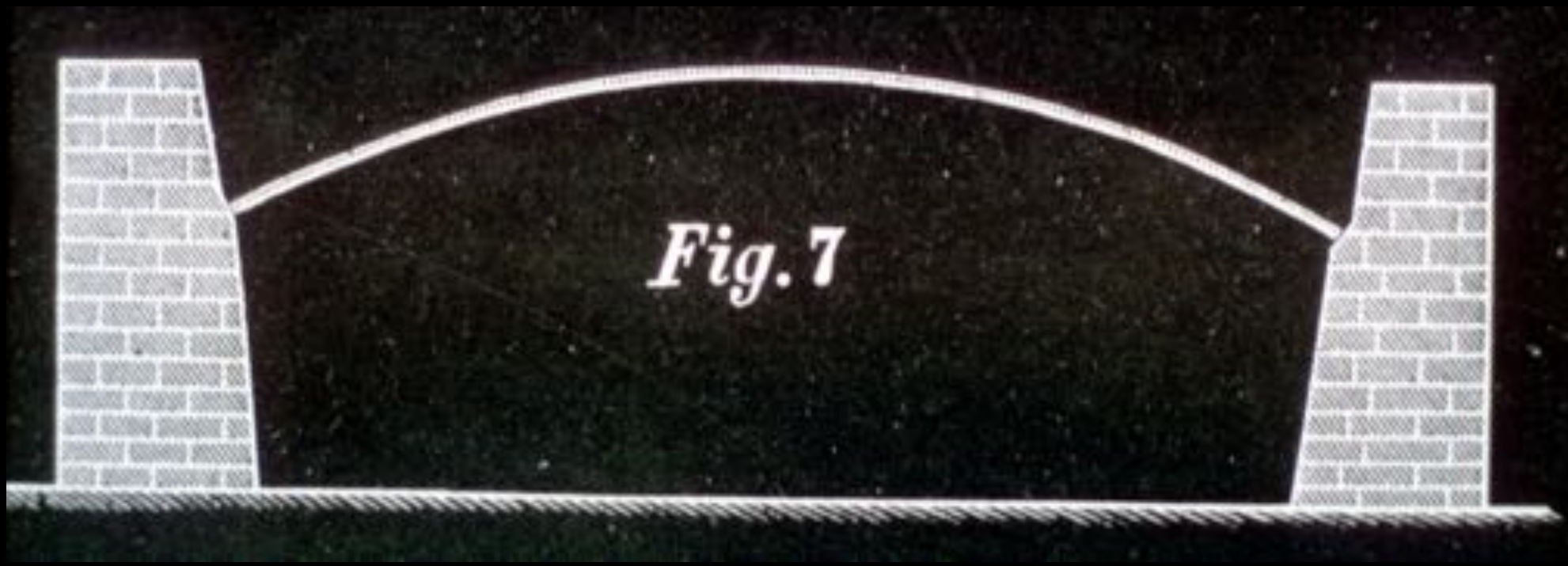


Fig. 7

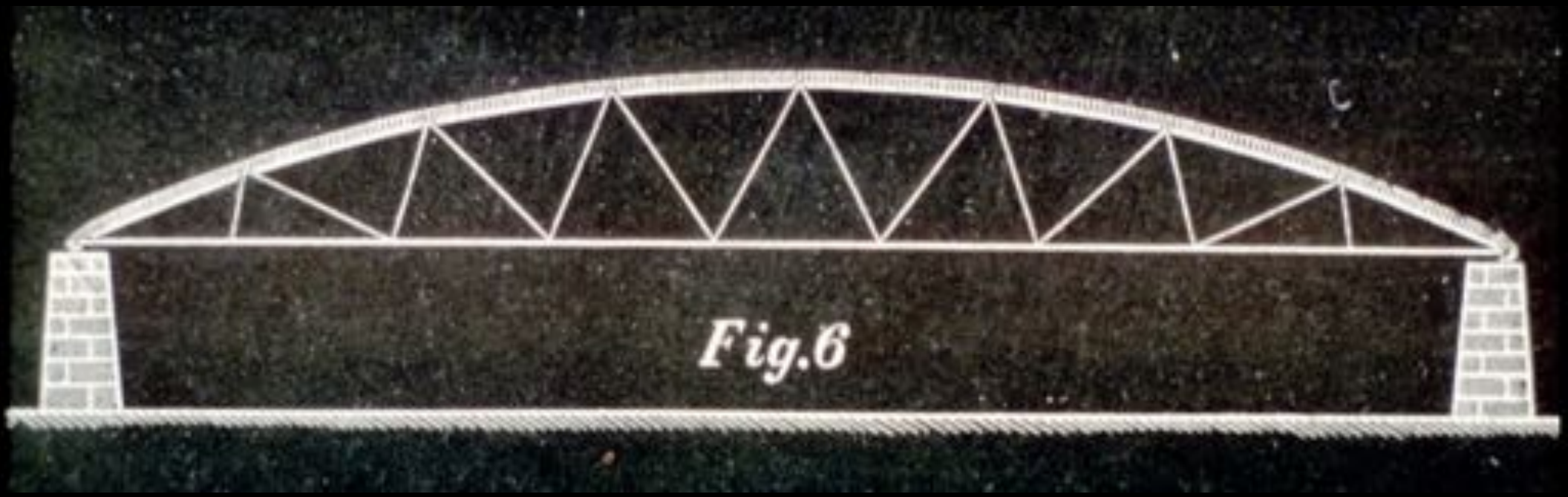


Fig. 6


Fig. 7

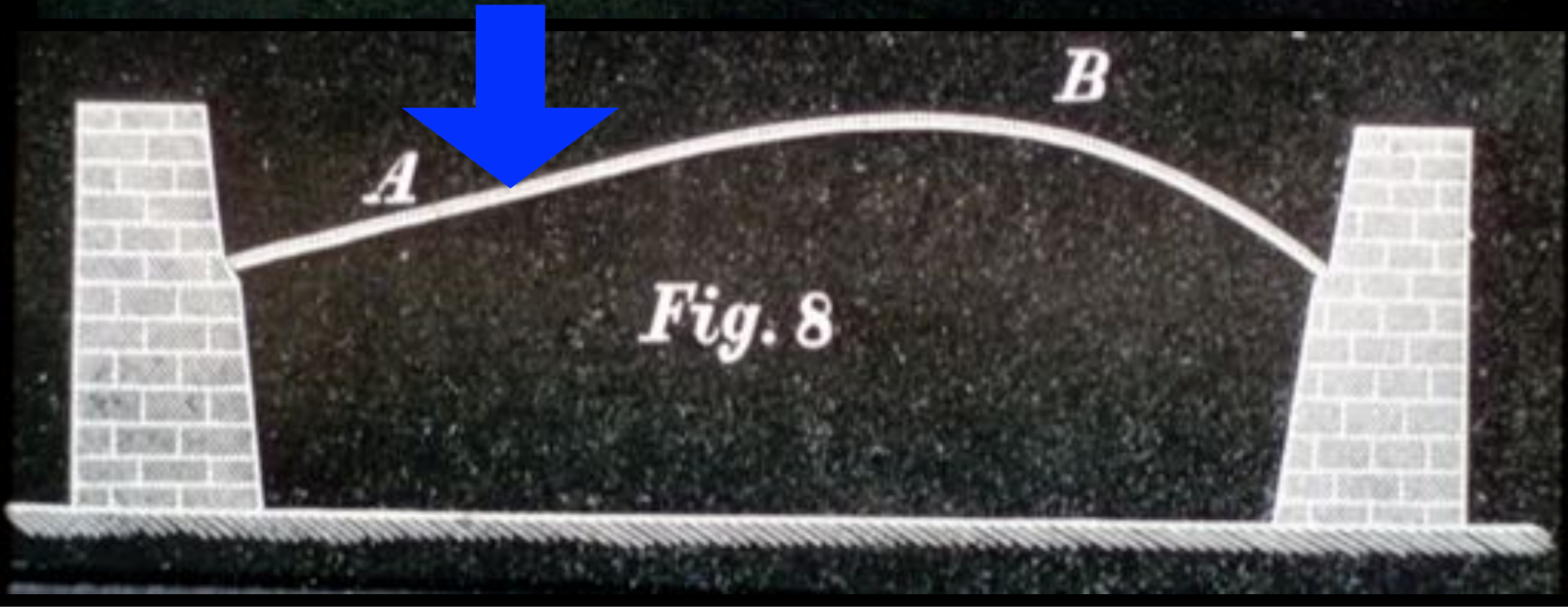

A
B
Fig. 8

Fig. 9

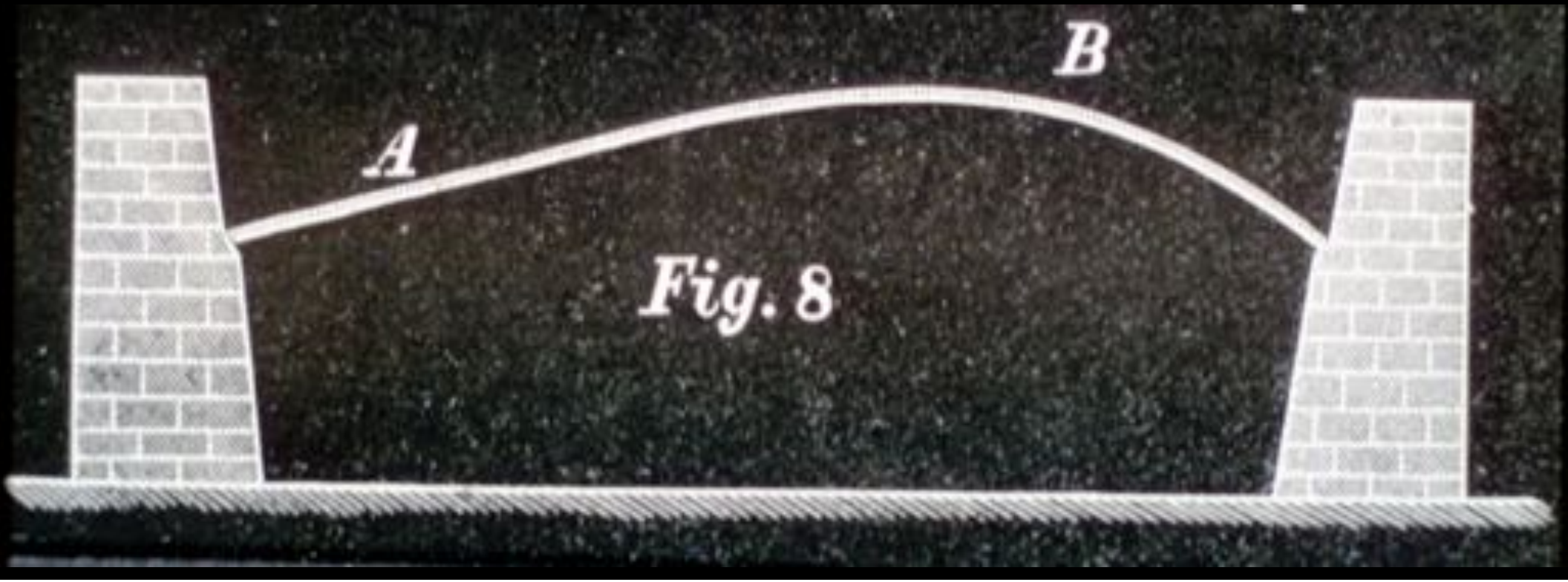
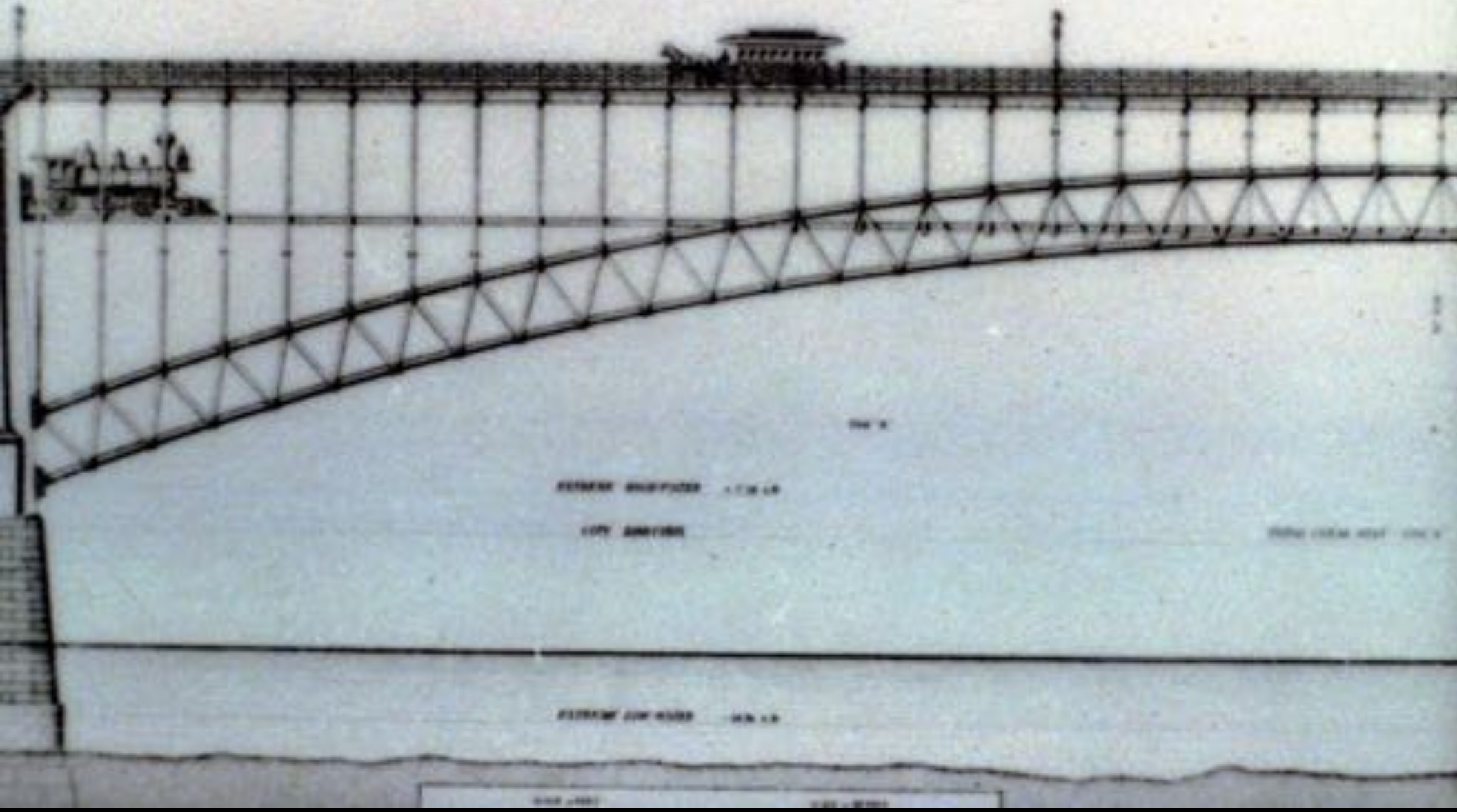


Fig. 8

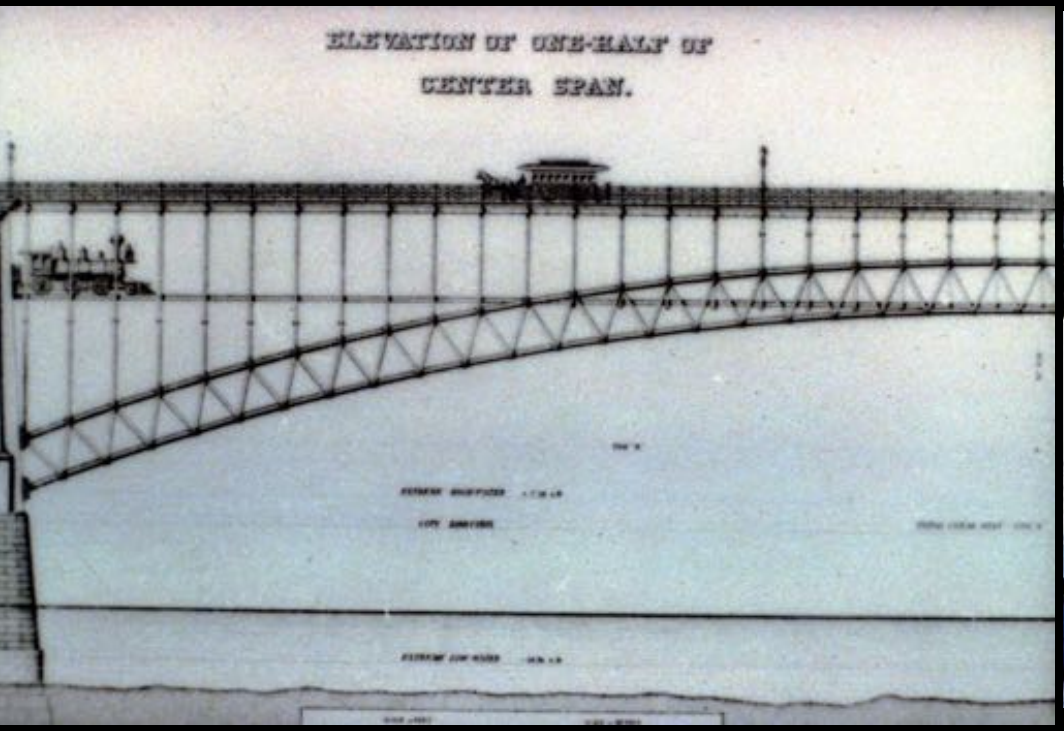
Fig.9

Fig.10.

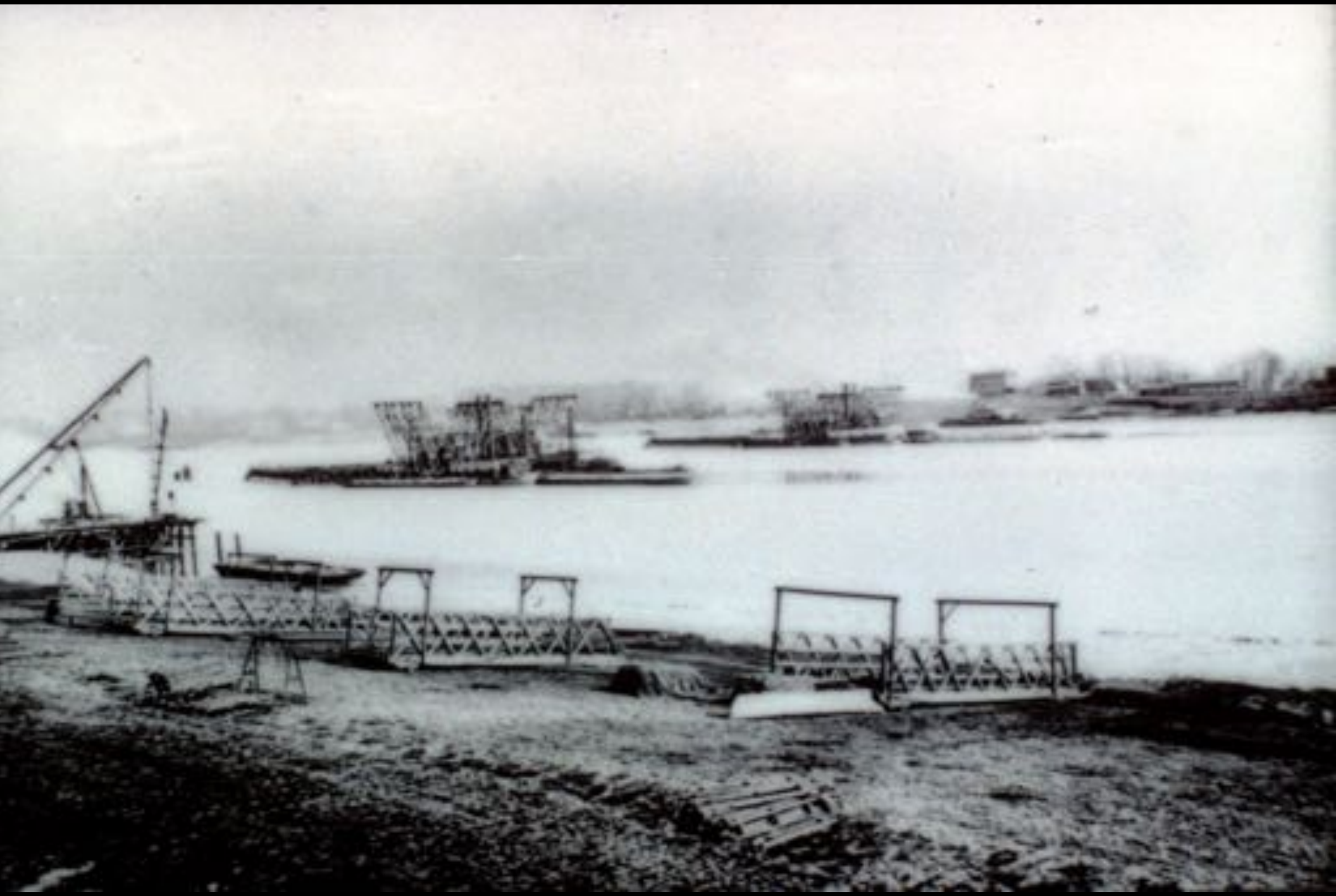
ELEVATION OF ONE-HALF OF CENTER SPAN.

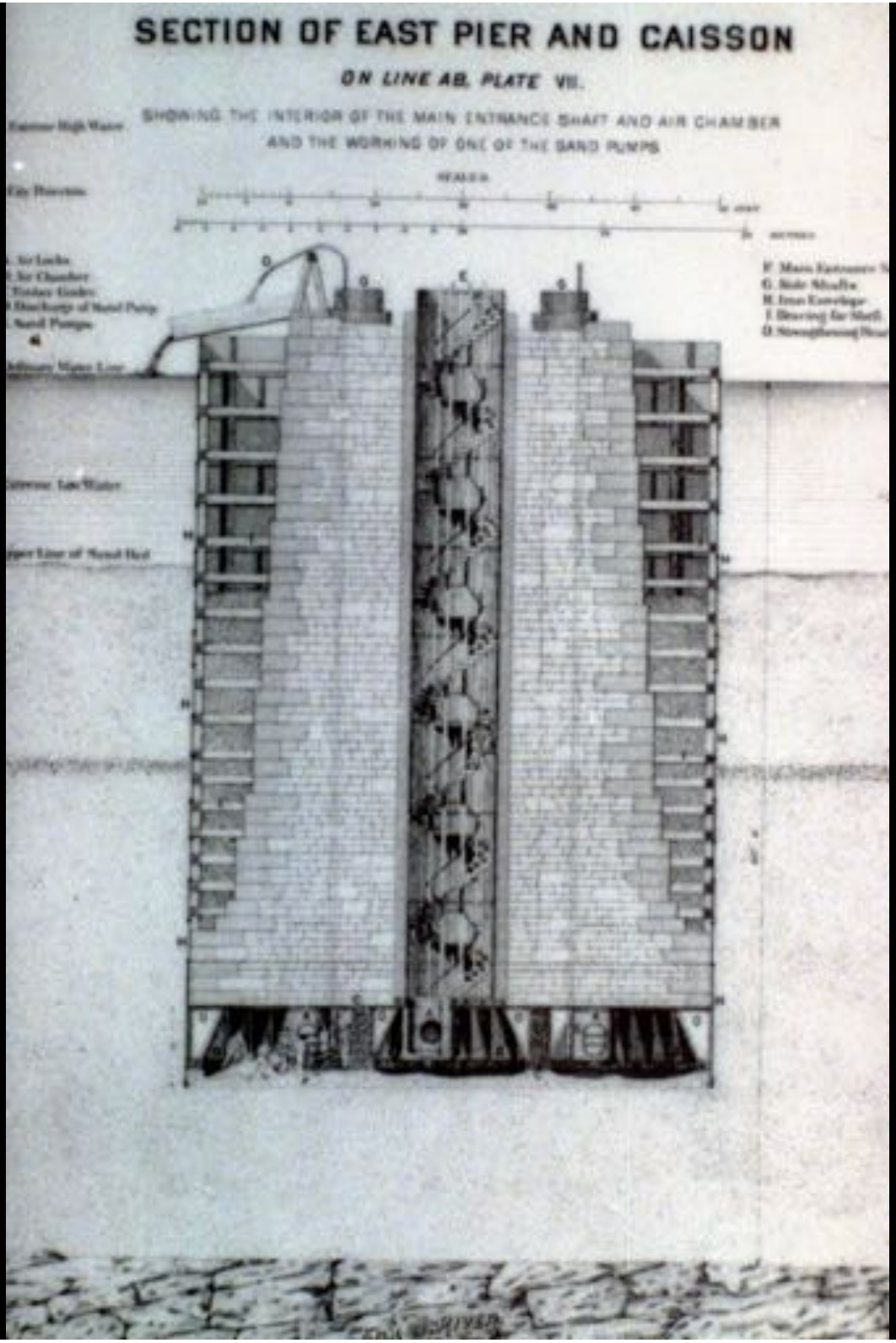


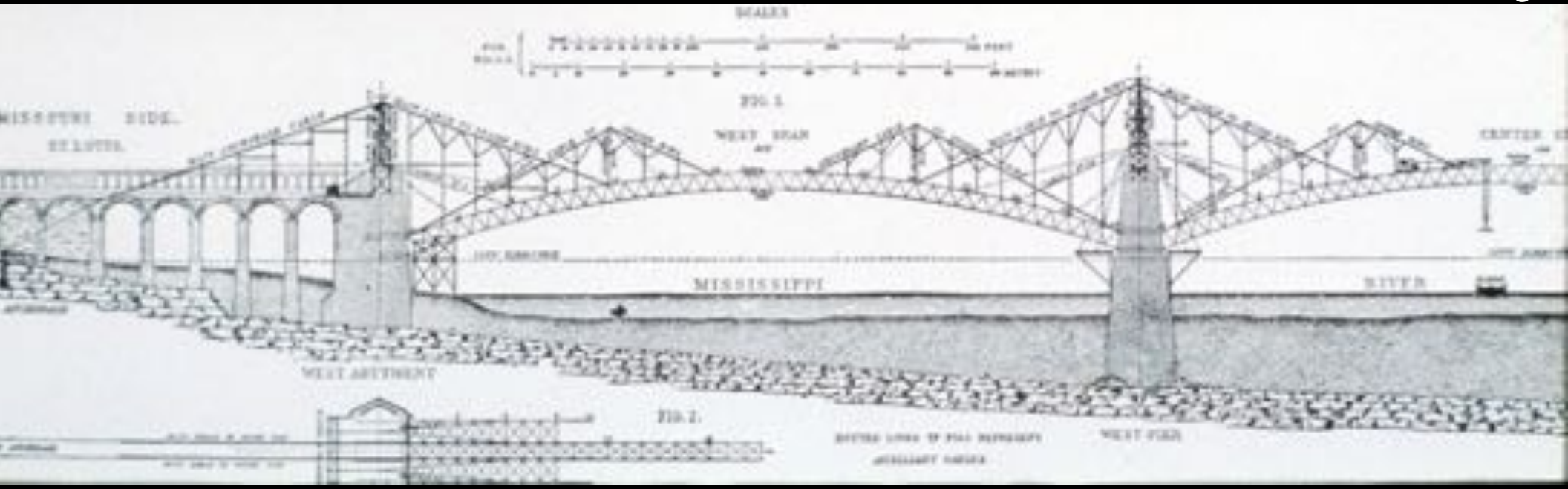

EJ&E

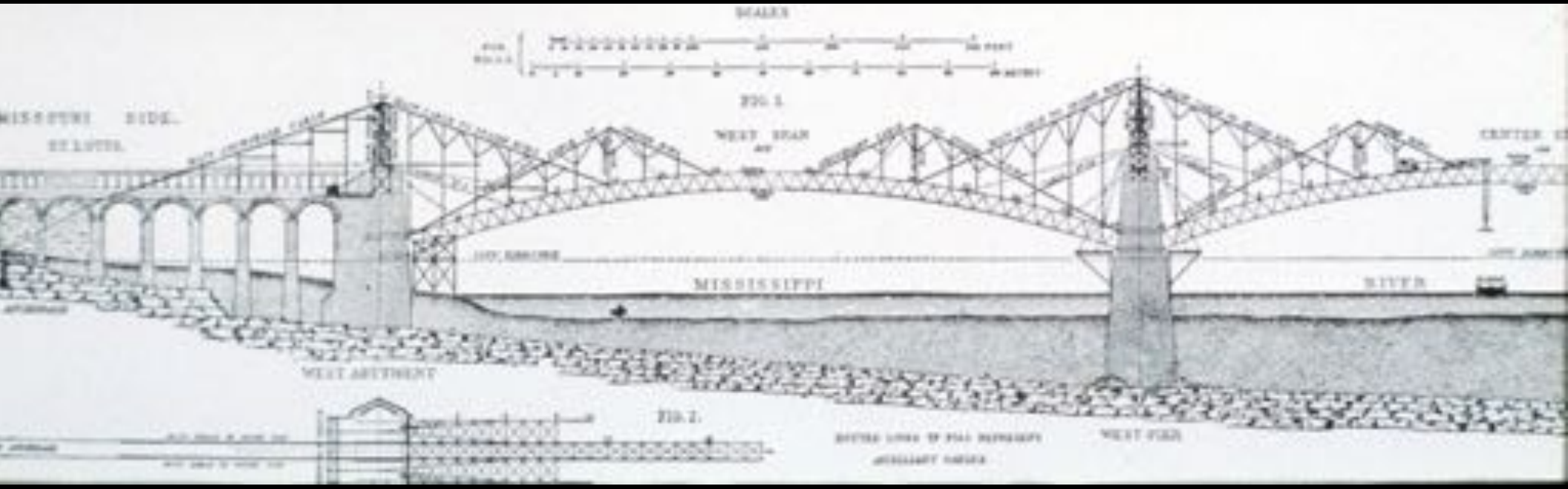

ELEVATION OF ONE-HALF OF
CENTER SPAN.

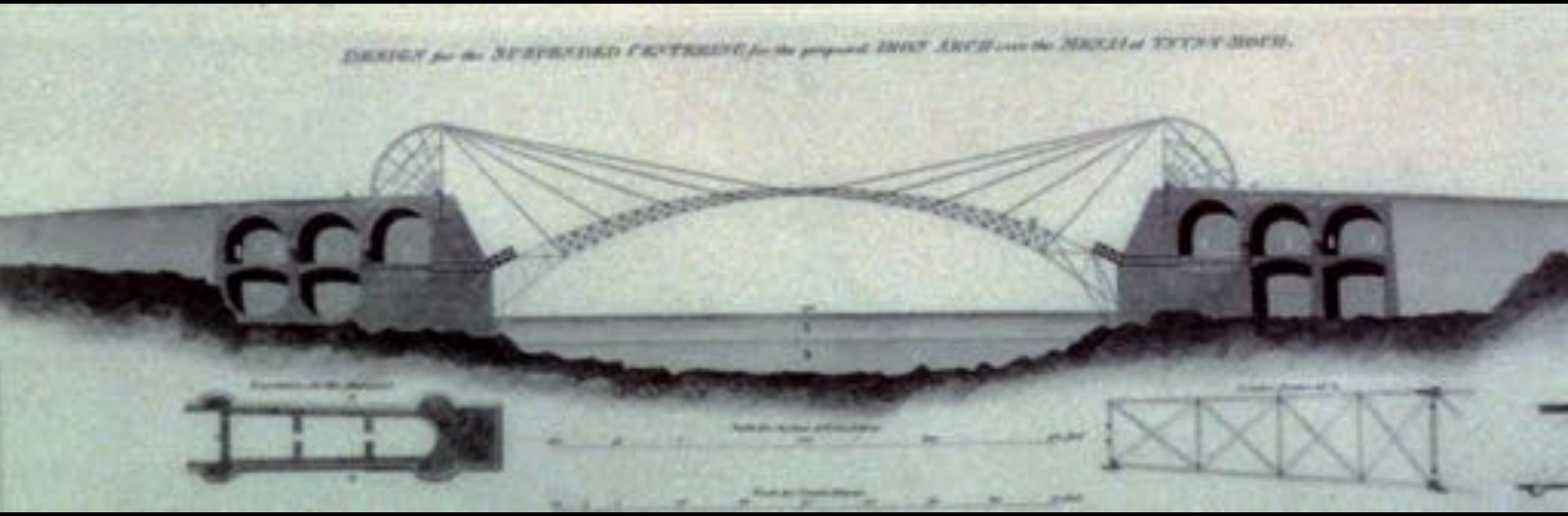

EJ&E

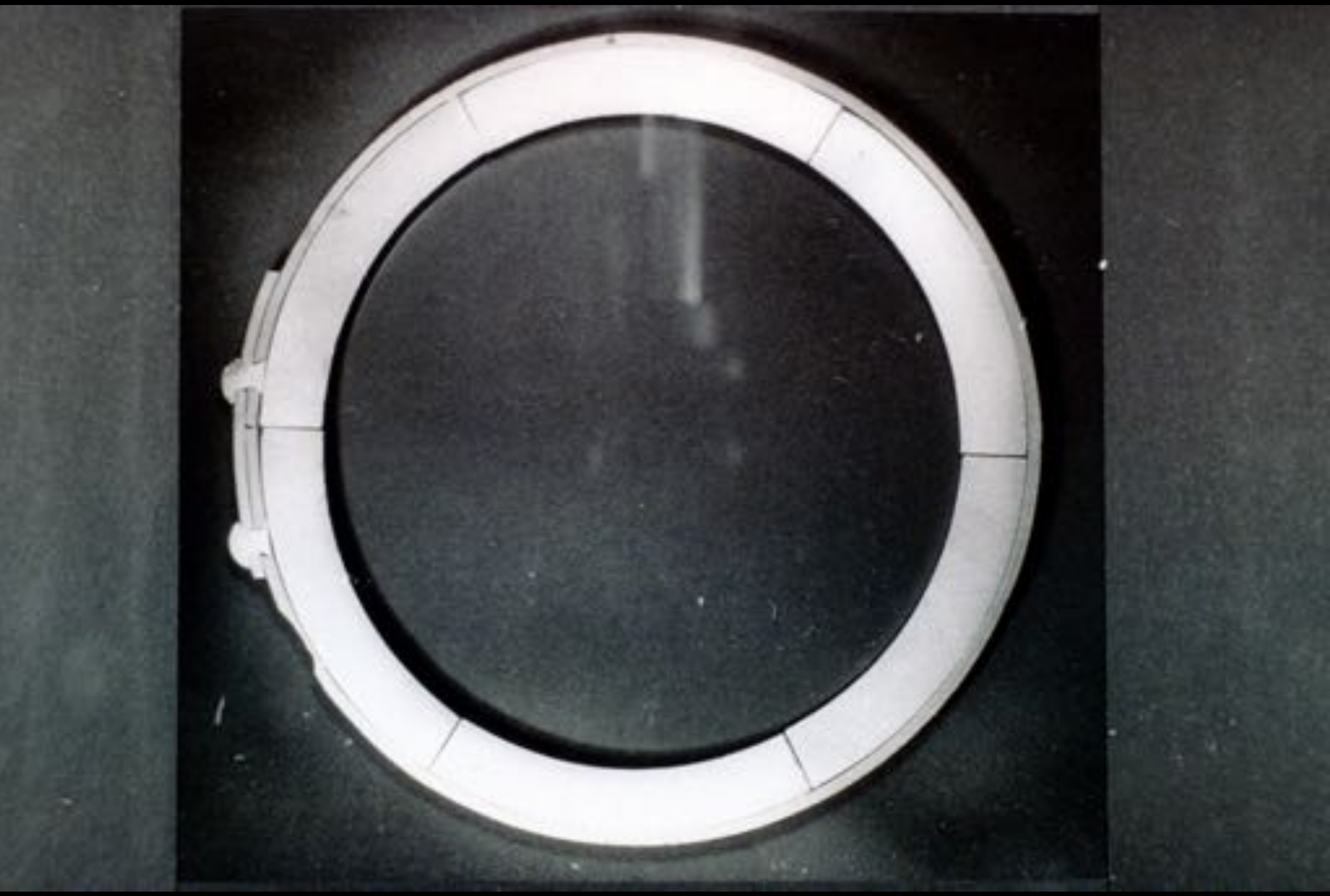



SECTION OF EAST PIER AND CAISSON
ON LINE AB. PLATE VII.
SHOWING THE INTERIOR OF THE MAIN ENTRANCE SHAFT AND AIR CHAMBER
AND THE WORKING OF ONE OF THE SAND PUMPS
122 feet to bedrock

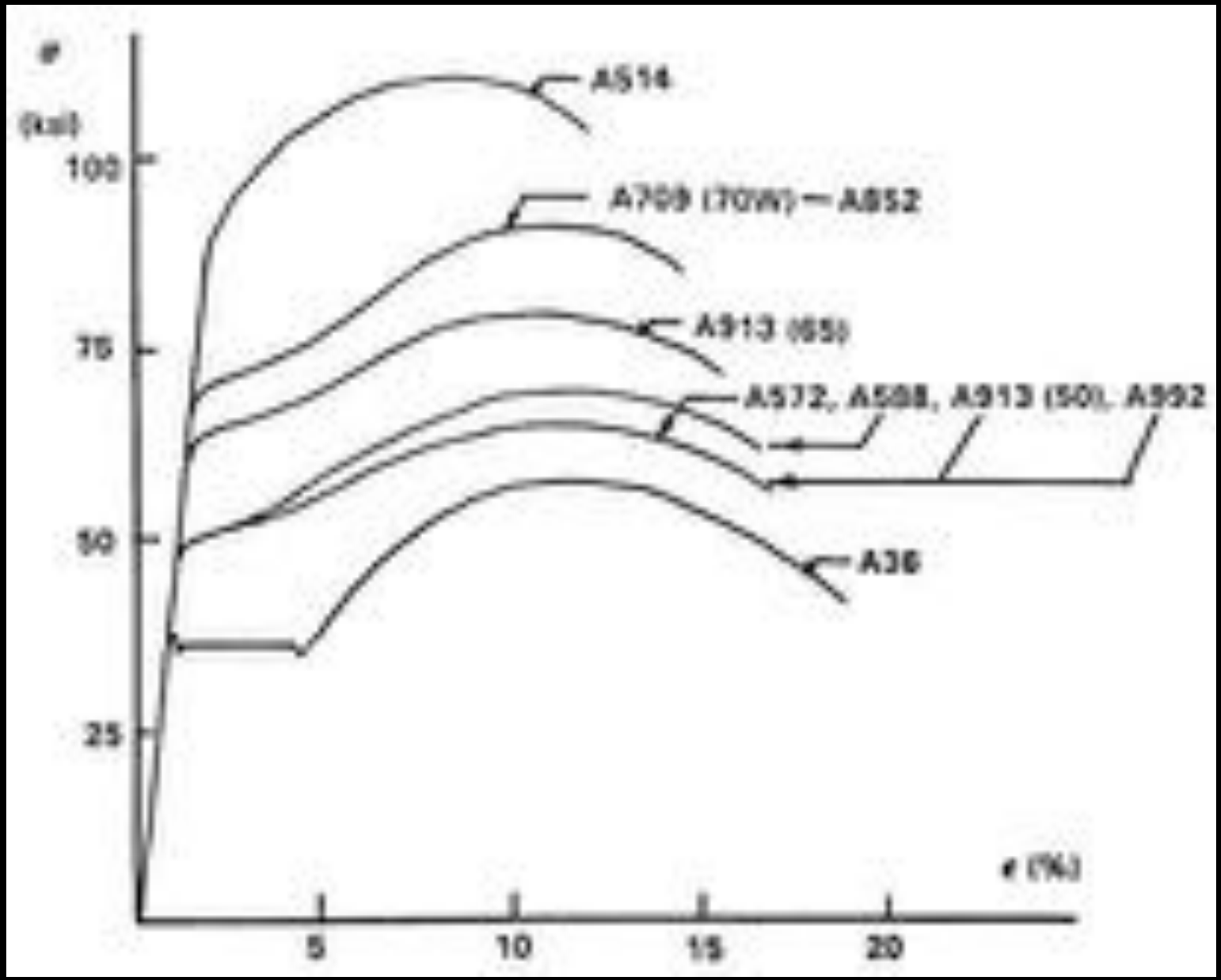

SCALES
FIG. 1.
WEST SPAN
MISSISSIPPI
RIVER
WEST ABUTMENT
FIG. 2.


SCALES
FIG. 1.
WEST SPAN
MISSISSIPPI
RIVER
WEST ABUTMENT
FIG. 2.



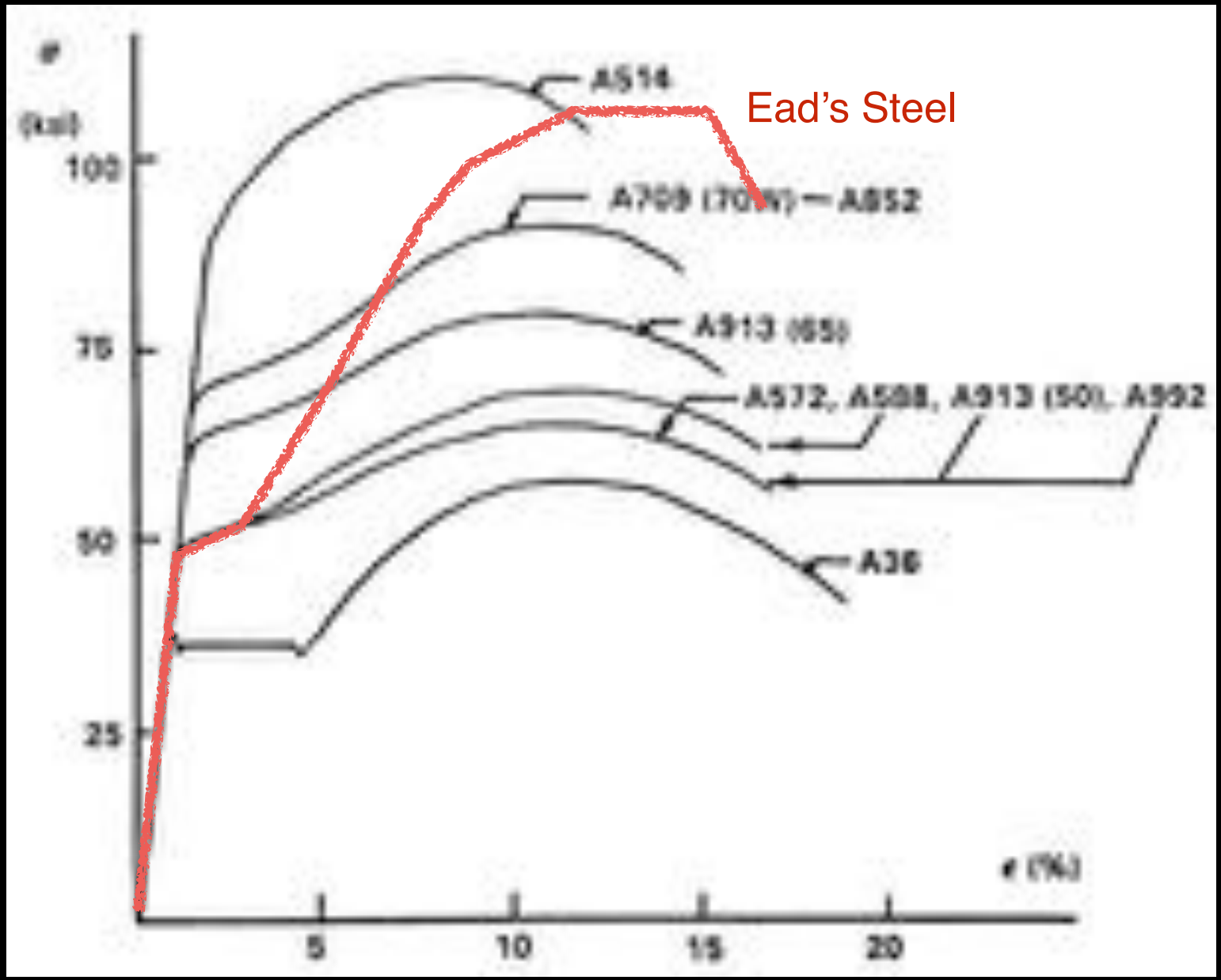


related to force when pulled

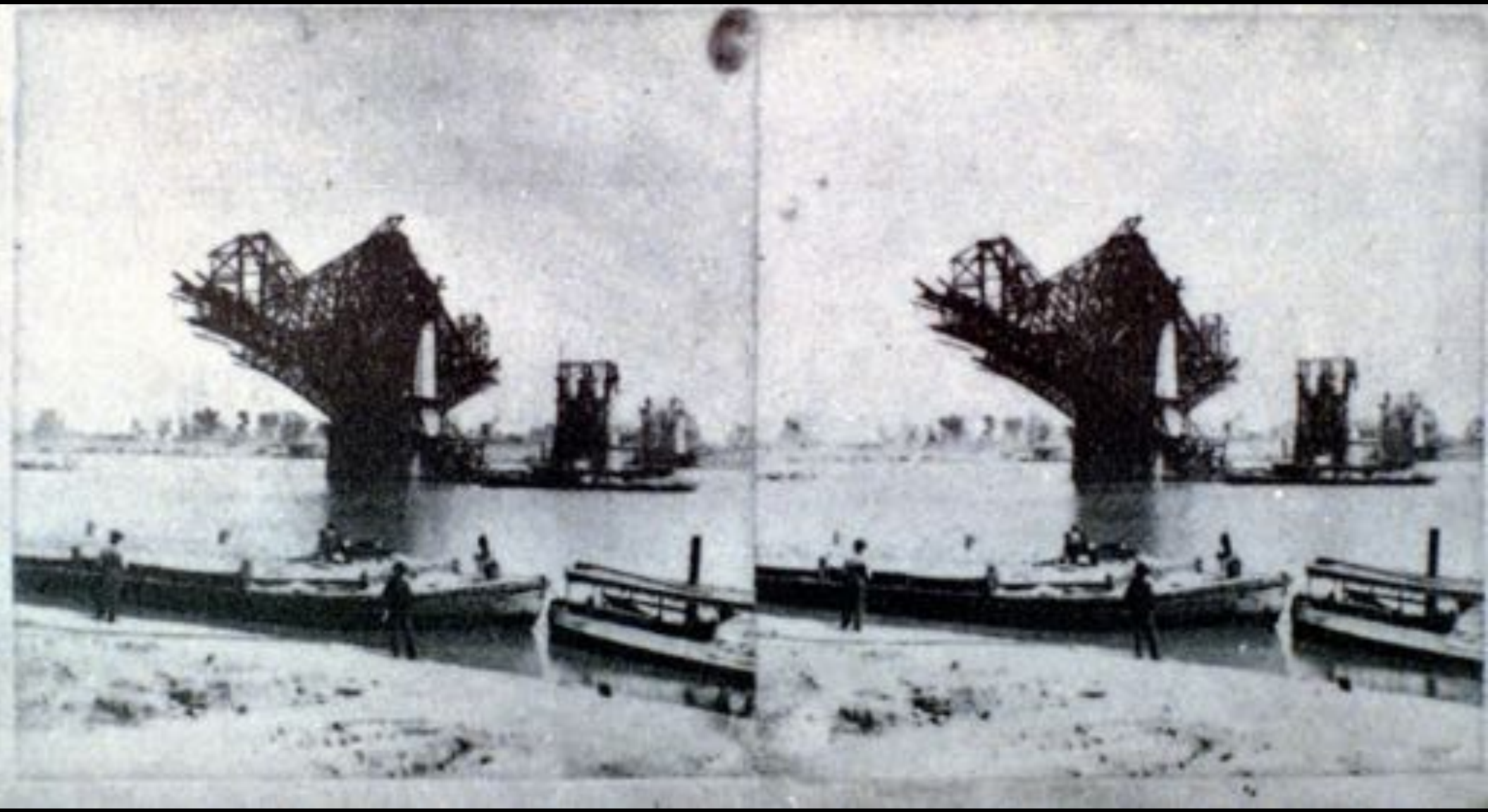


related to amount stretched

related to force when pulled

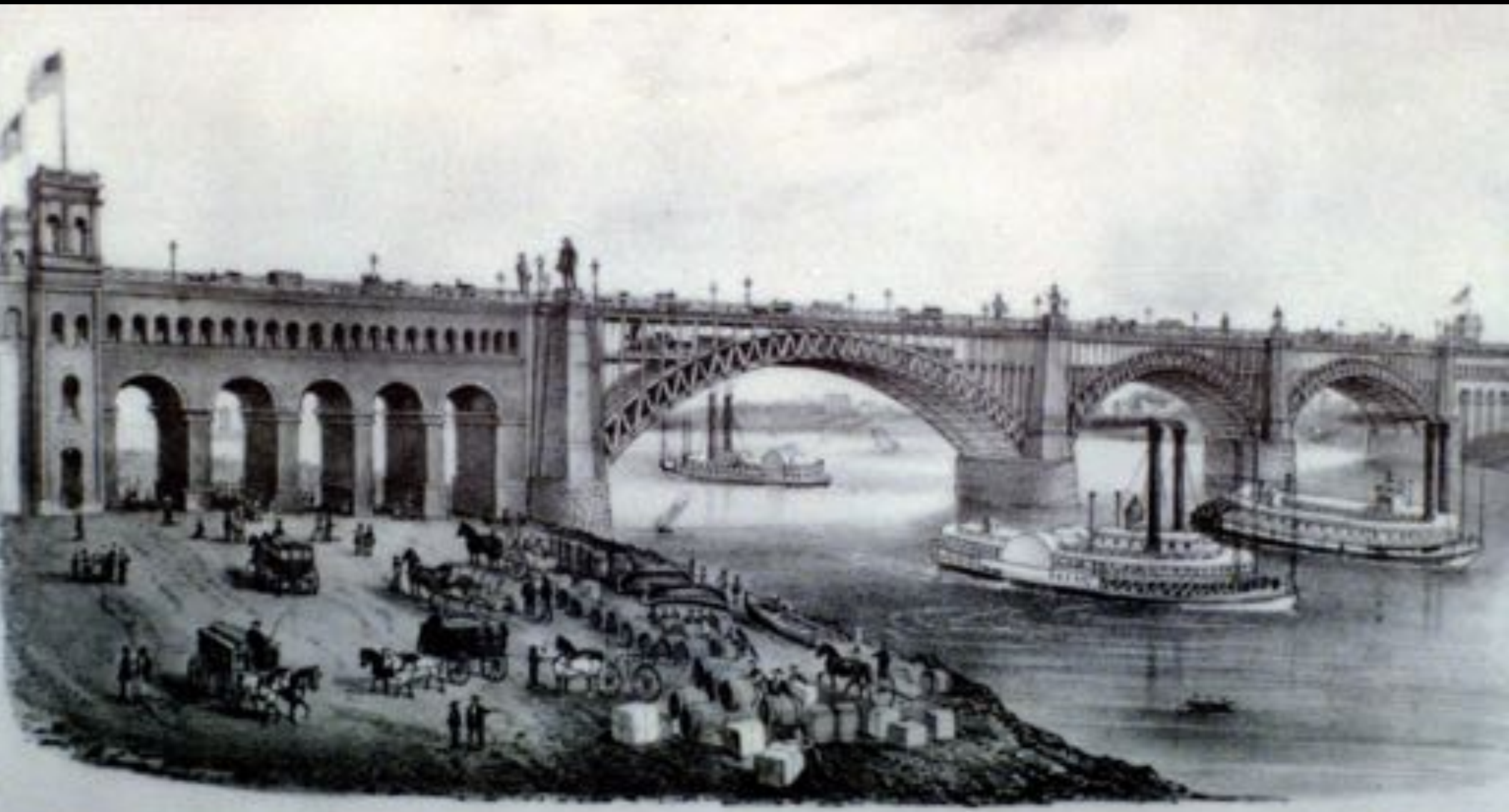


related to amount stretched




Eads Bridge - Dec. 1873

Eads Bridge. ~~June~~ 1874



THE GREAT ST LOUIS BRIDGE.

ACROSS THE MISSISSIPPI RIVER.

SAINT LOUIS

—THE—

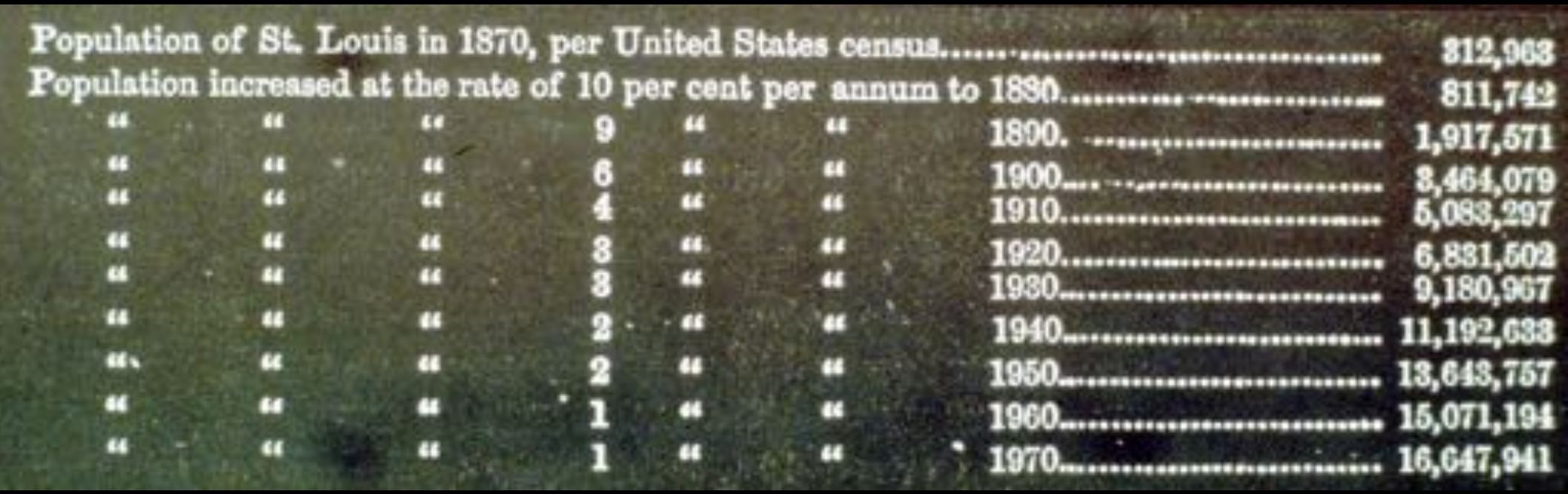
Future Great City

OF THE

WORLD.

THIRD EDITION.

1871



2002 population of the metropolitan area is 2,600,000

Dedication.

TO JAMES B. EADS,

THE MAN OF REAL GENIUS AND MARKED FIDELITY TO HIS FRIENDS,

THE CITIZEN OF GENUINE PATRIOTISM AND RARE PUBLIC

SPIRIT, THE MAN WORTHY OF HONOR

BECAUSE SELF-MADE,

THIS WORK,

DEVOTED TO THE FUTURE OF A CITY WHOSE

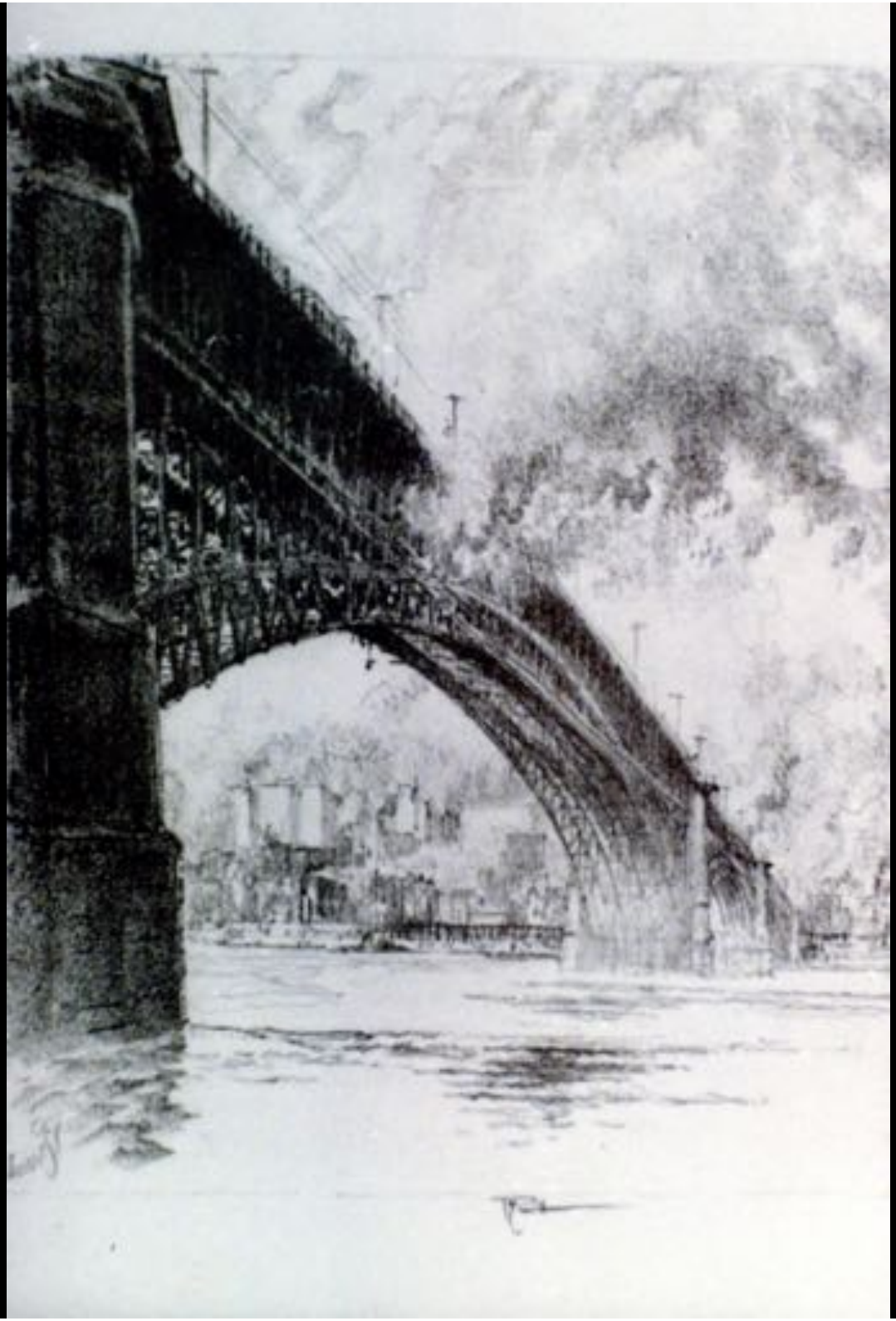
BEST HOPE IS IN SUCH MEN, IS

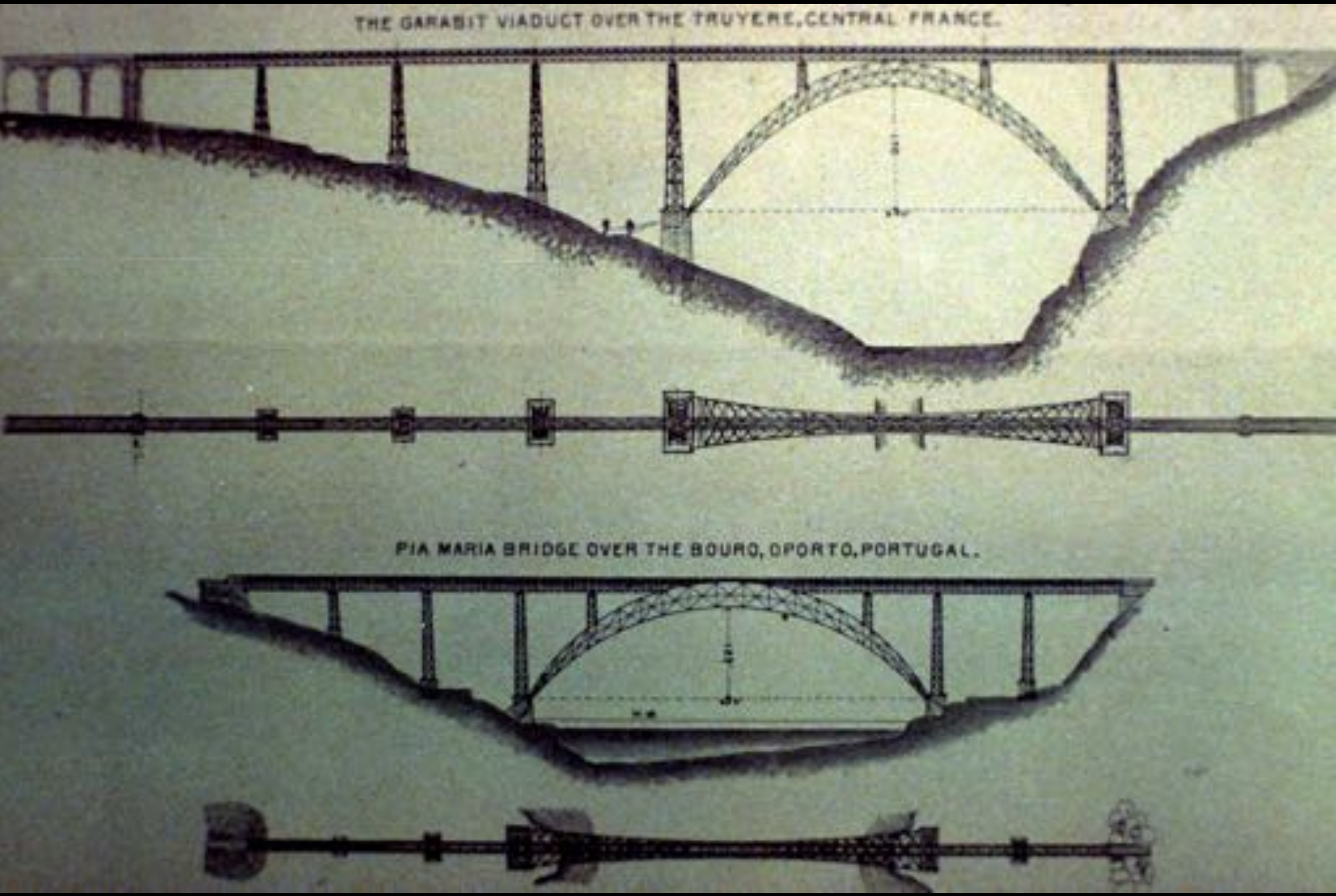
DEDICATED BY

THE AUTHOR.

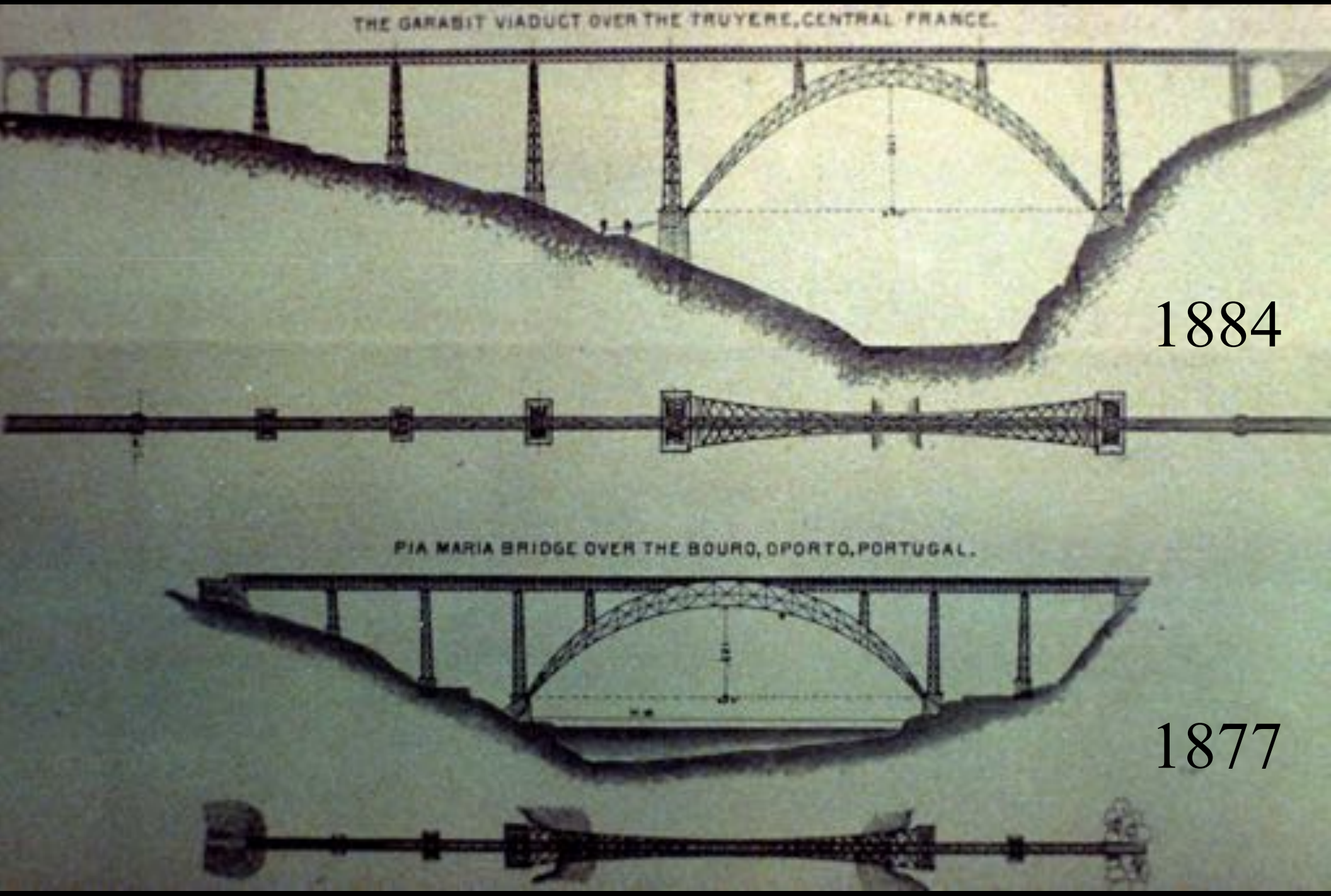
July 4, 1874

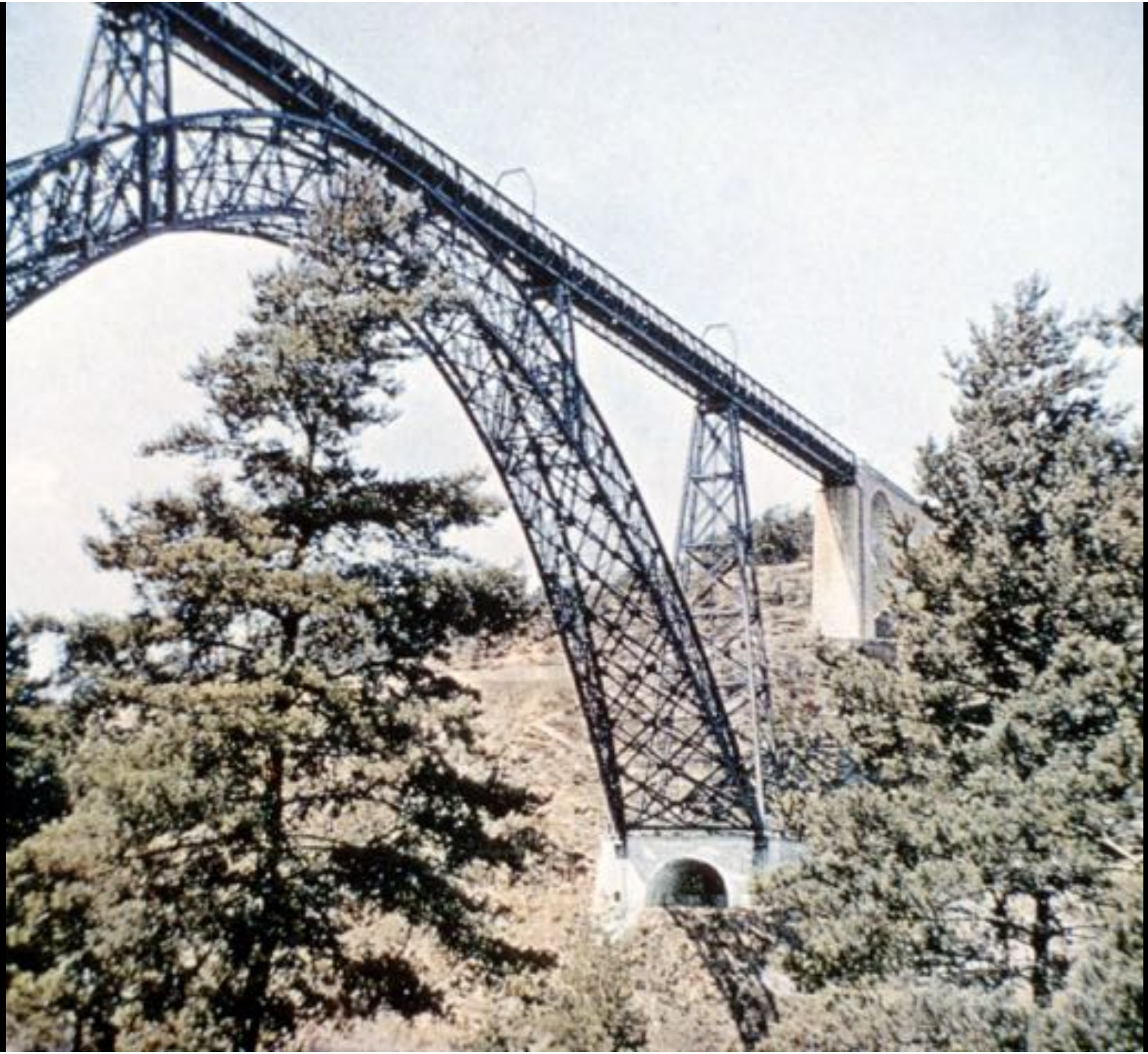

ILLINOIS



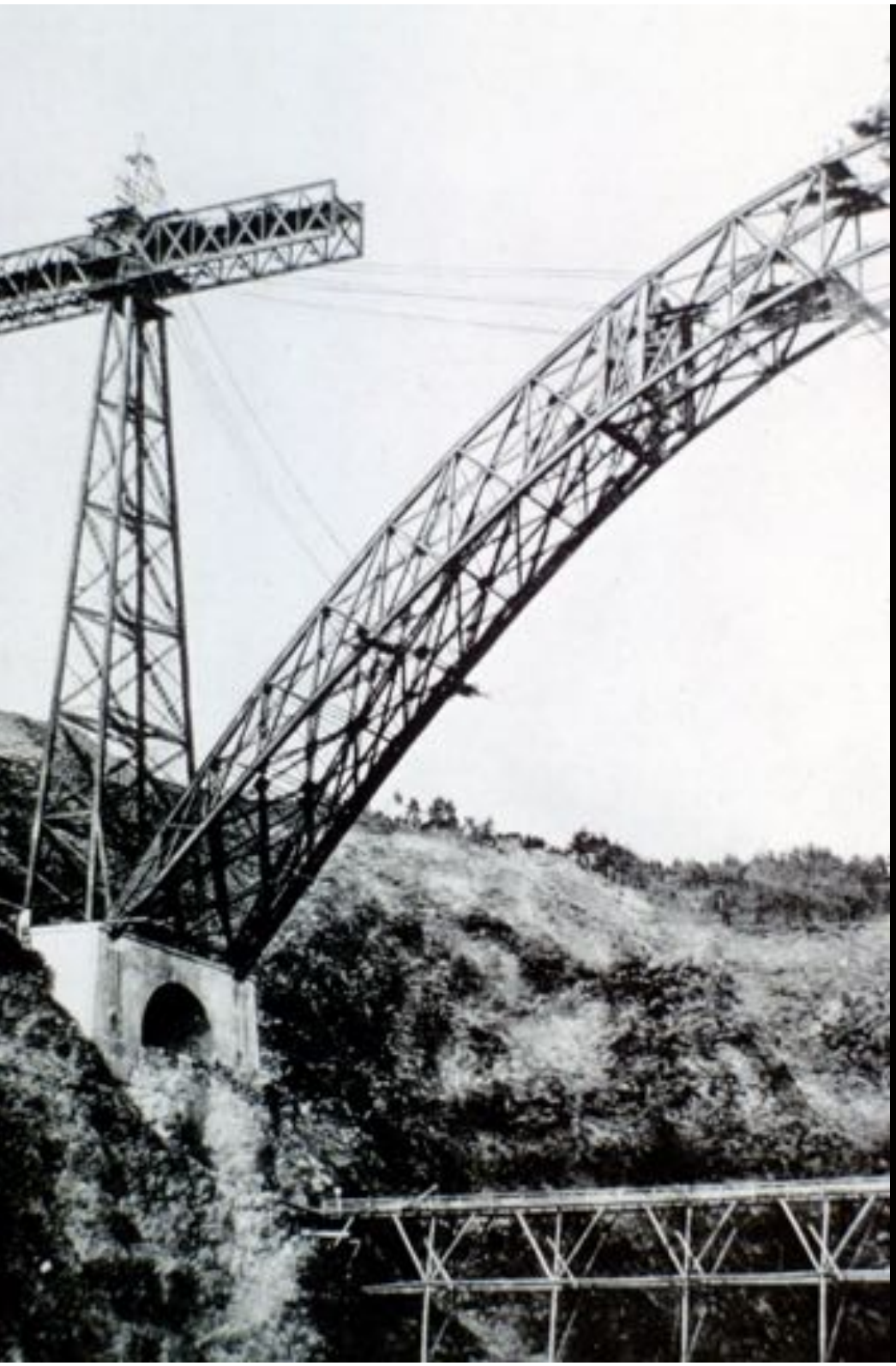


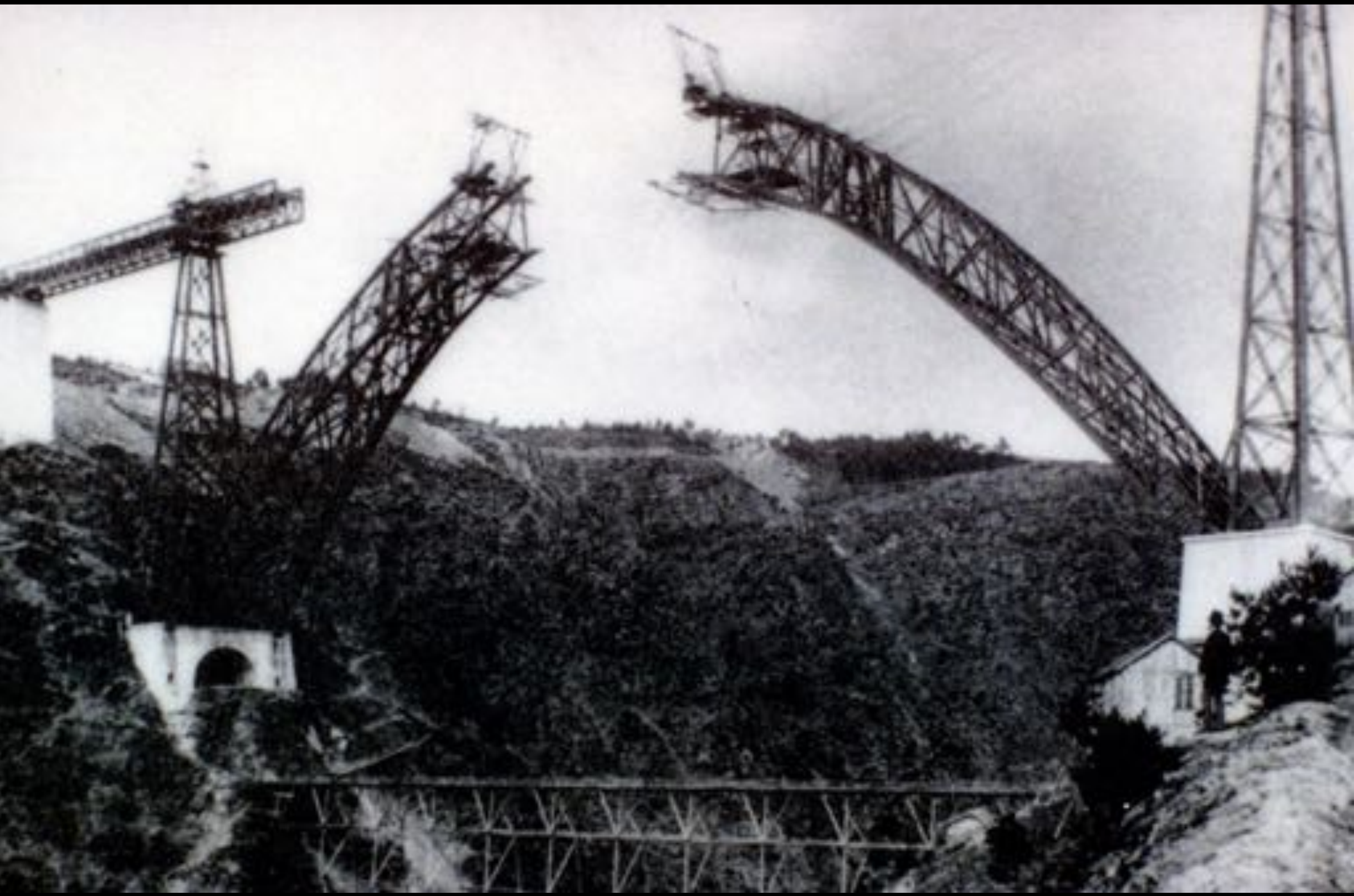
Can you identify differences?


THE GARABIT VIADUCT OVER THE TRUYERE, CENTRAL FRANCE.
1884
PIA MARIA BRIDGE OVER THE DOURO, OPORTO, PORTUGAL.
1877



Garabit
Viaduct
1884
540 feet





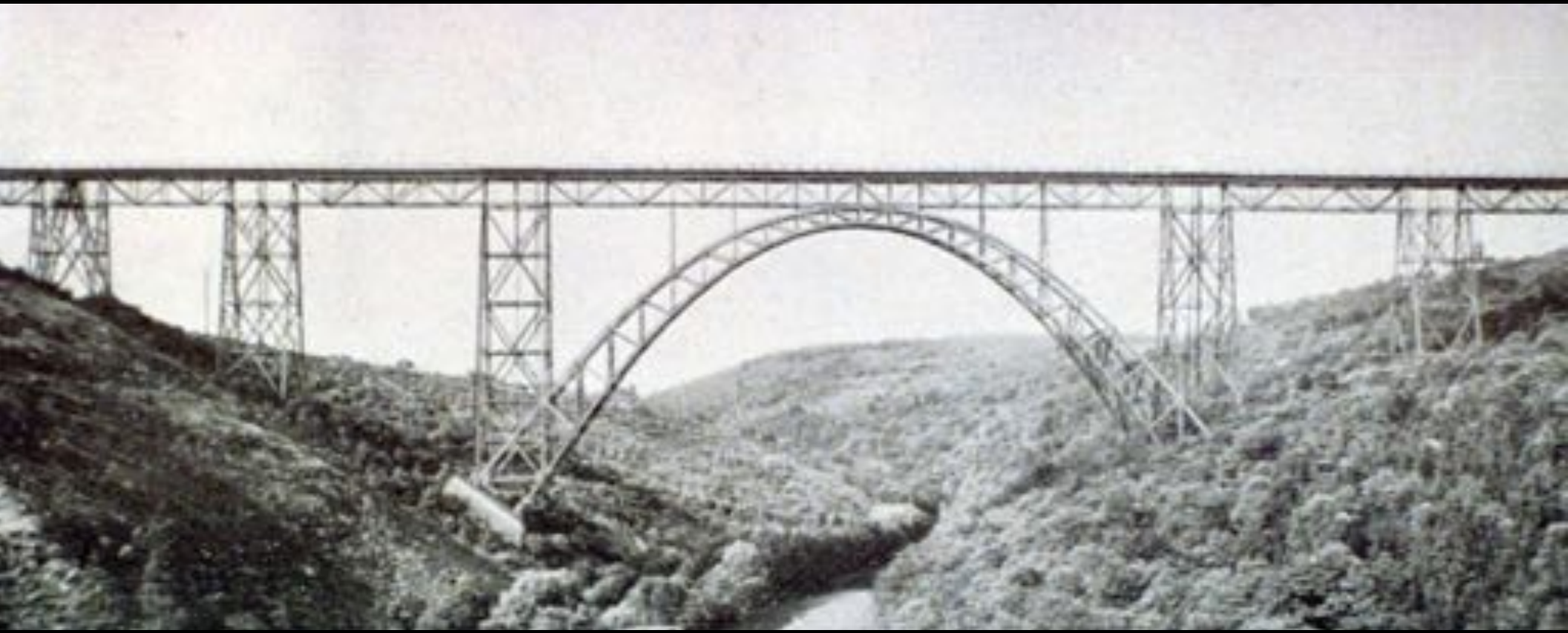
Koblenz

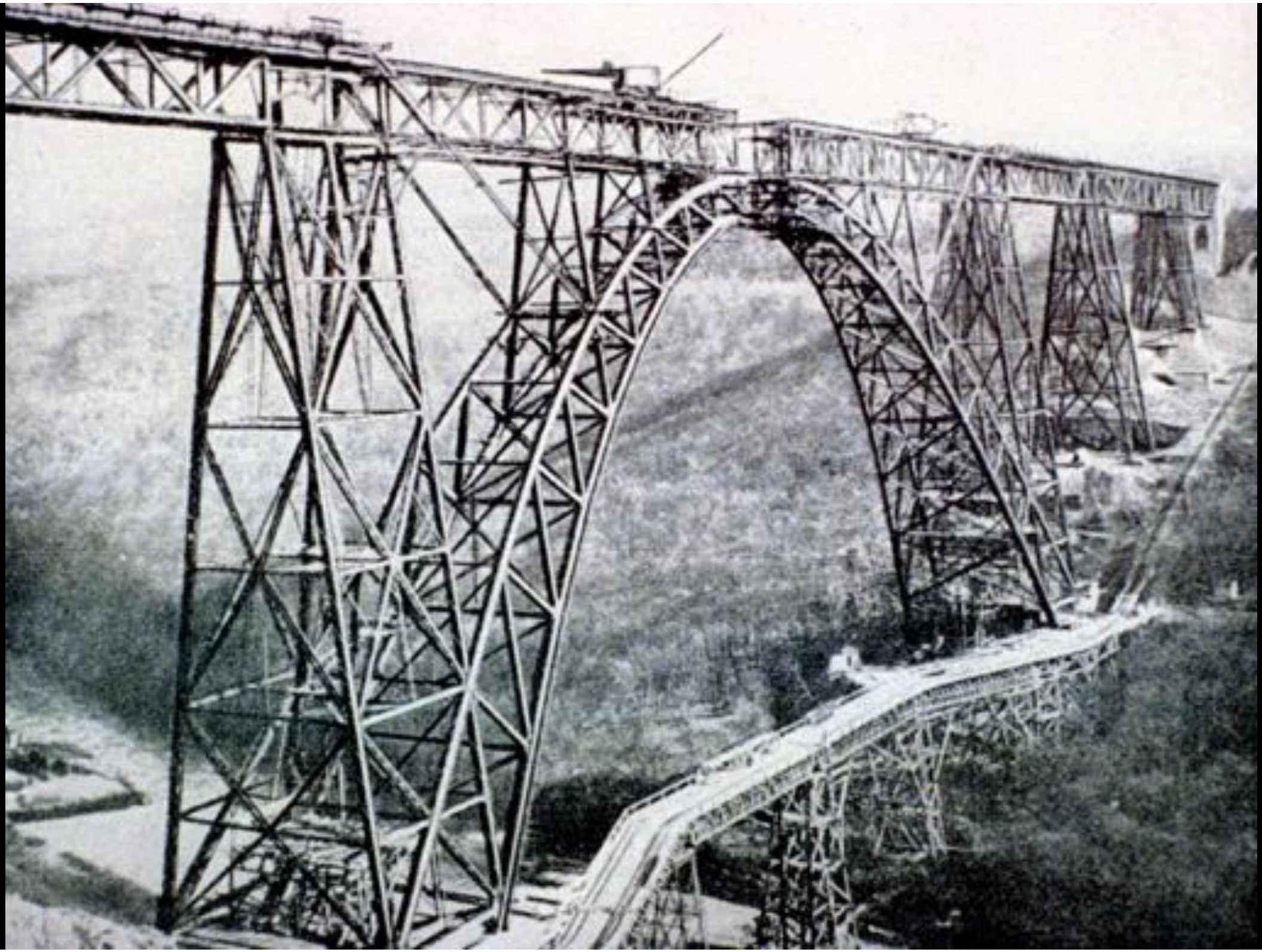
Eads

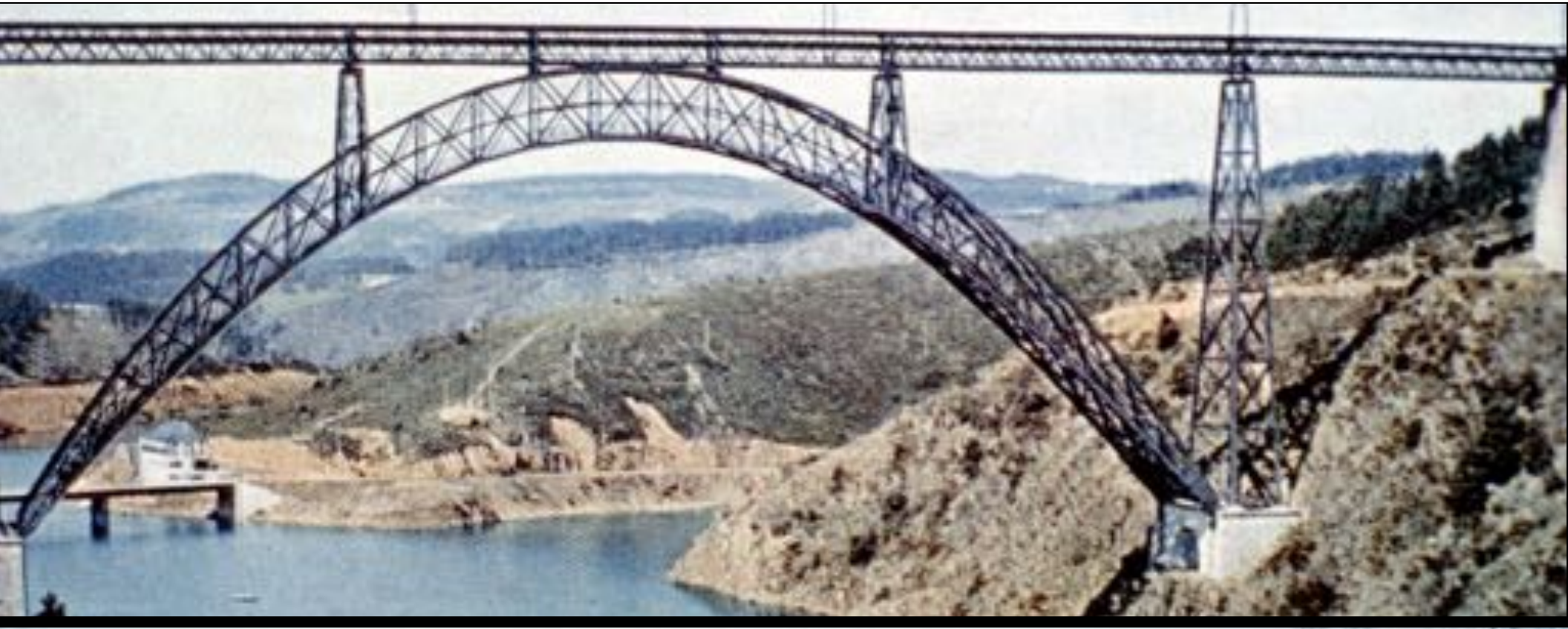
Pia Maria

Garabit

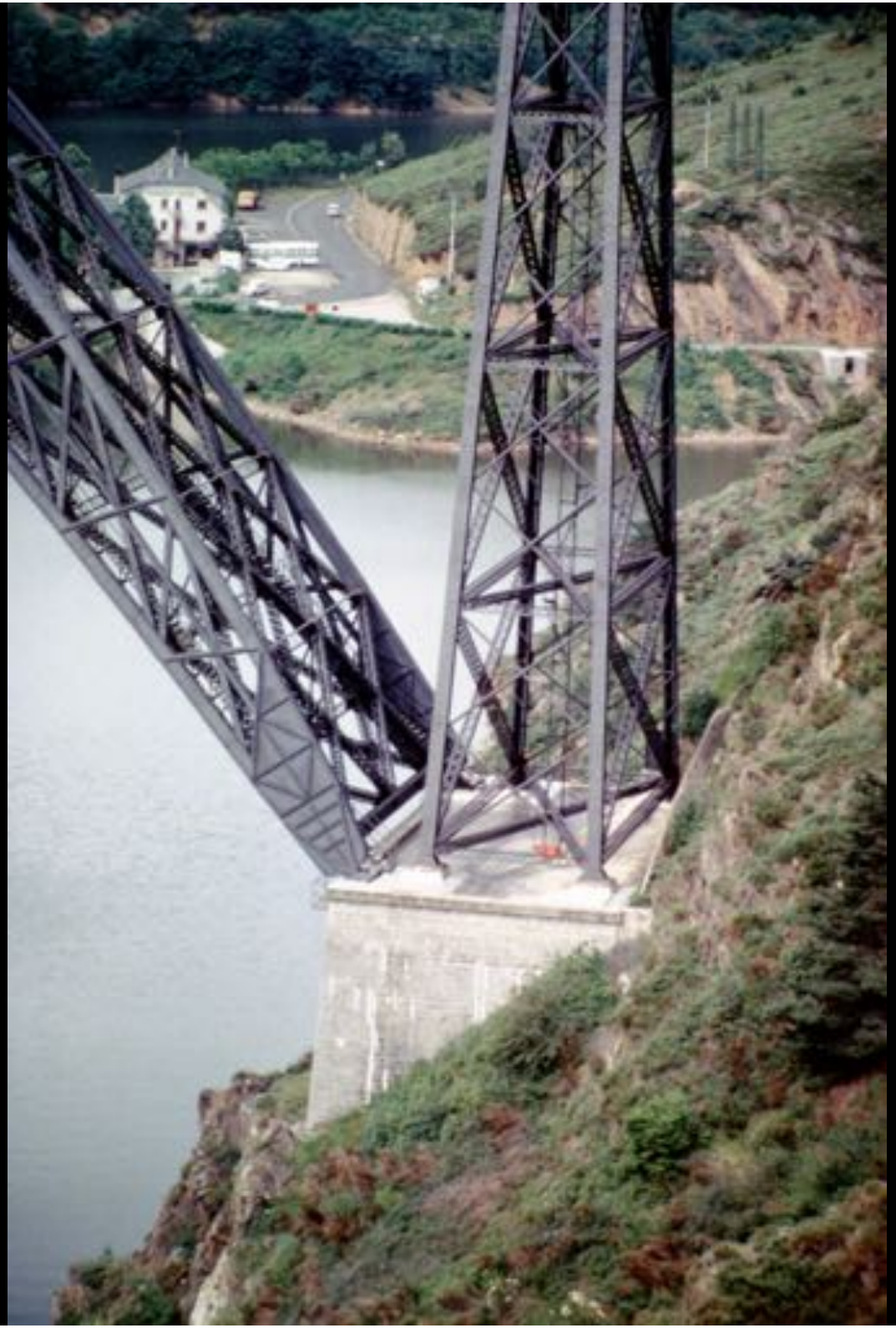
http://www.structurae.de/en/photos/img3815.php
Garabit Viaduct.
Photo by Jacques Mossot








Garabit



PONT DE GARABIT
Designed by Eiffel the engineer.

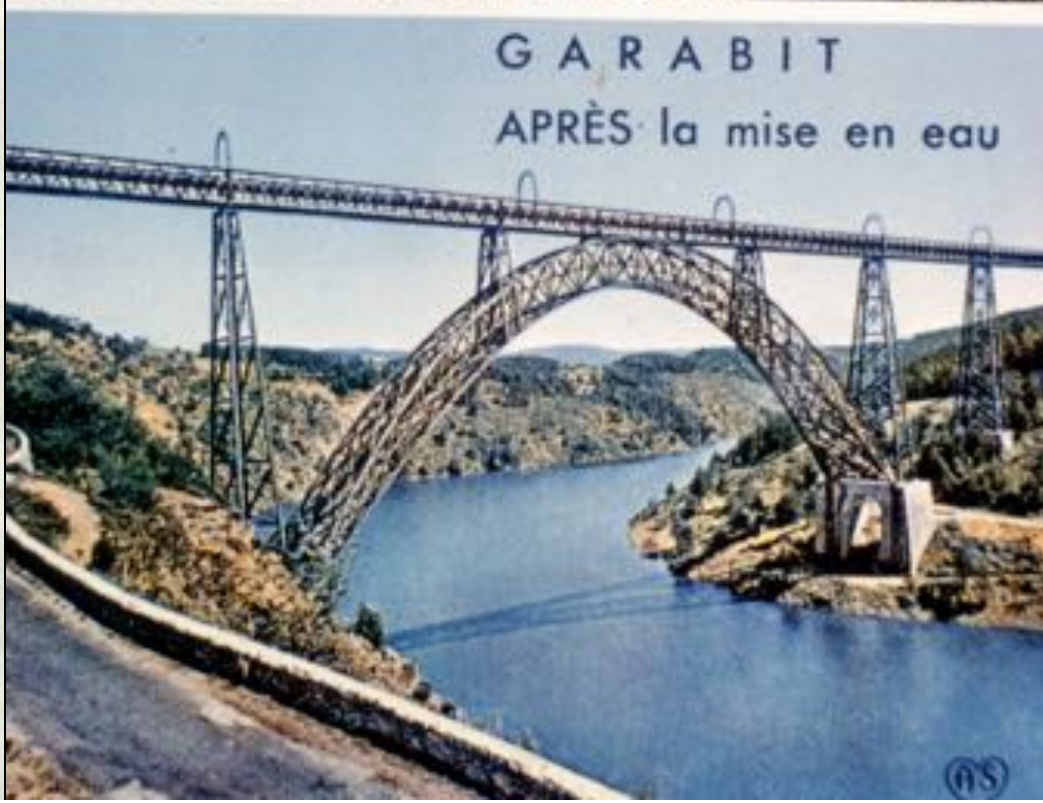
THE ENGINEER'S ÆSTHETIC AND ARCHITECTURE

Le Corbusier

PONT DE GARABIT

Designed by Eiffel the engineer.

THE ENGINEER'S ÆSTHETIC AND ARCHITECTURE




United Kingdom
Ireland
Netherlands
Belgium
Aberdeen
Glasgow
Edinburgh
Belfast
Isle of Man
Dublin
Cork
Manchester
Liverpool
Leeds
Hull
Sheffield
Nottingham
Coventry
Birmingham
Bristol
Cardiff
London
Southampton
Portsmouth
Brighton
Rotterdam
Amsterdam
Eindhoven
Ghent
Bruges


Firth of Tay
Firth of Forth
Dundee
Perth
Dunfermline
Falkirk
Edinburgh
Glasgow
East Kilbride

1879, 75 people perished

Court of inquiry proceedings, for Sir Thomas Bouch

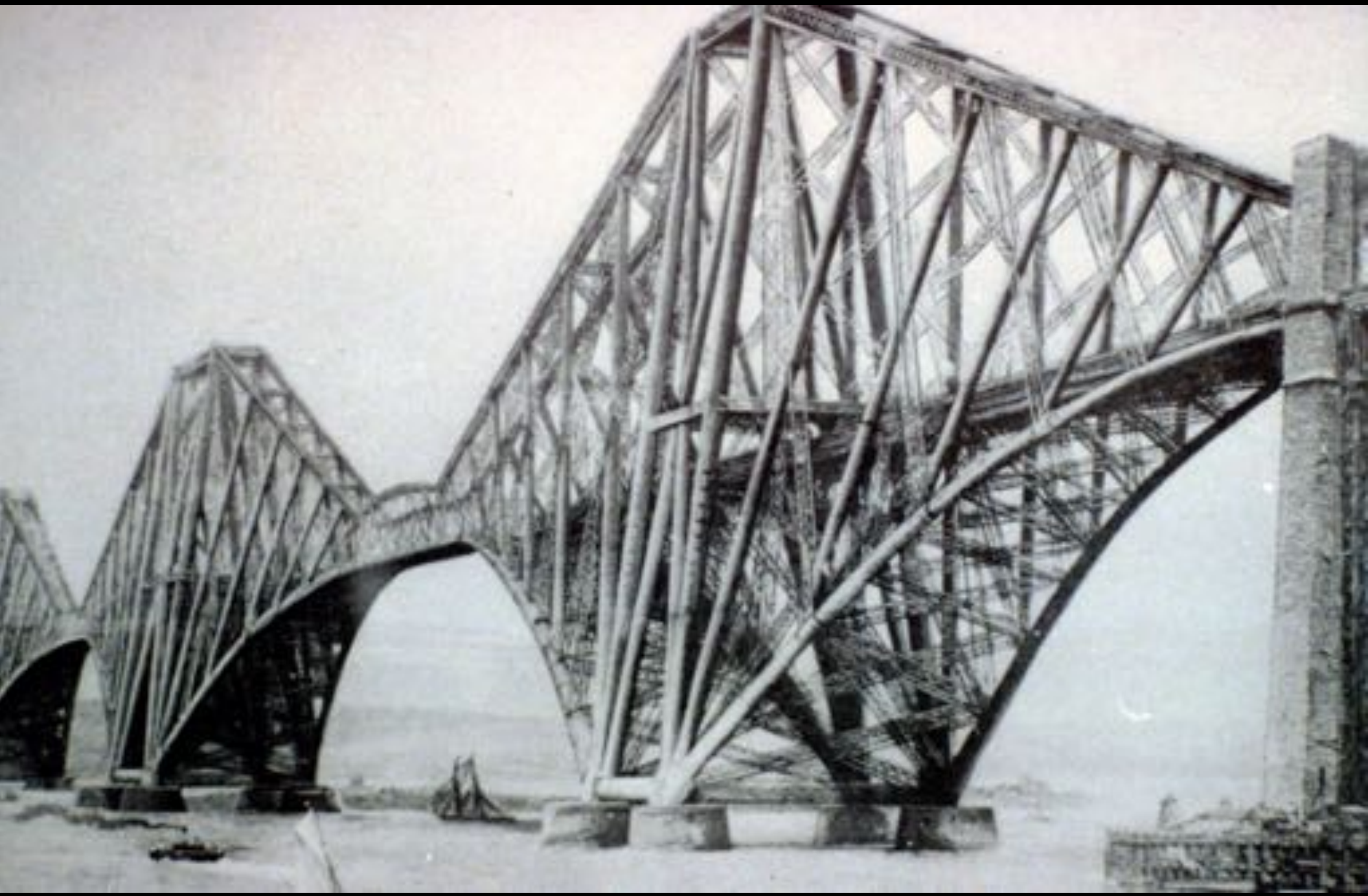
re: collapse of the Firth of Tay Br.

Q: Sir Thomas, did you in designing this bridge, make any allowance at all for wind pressure?

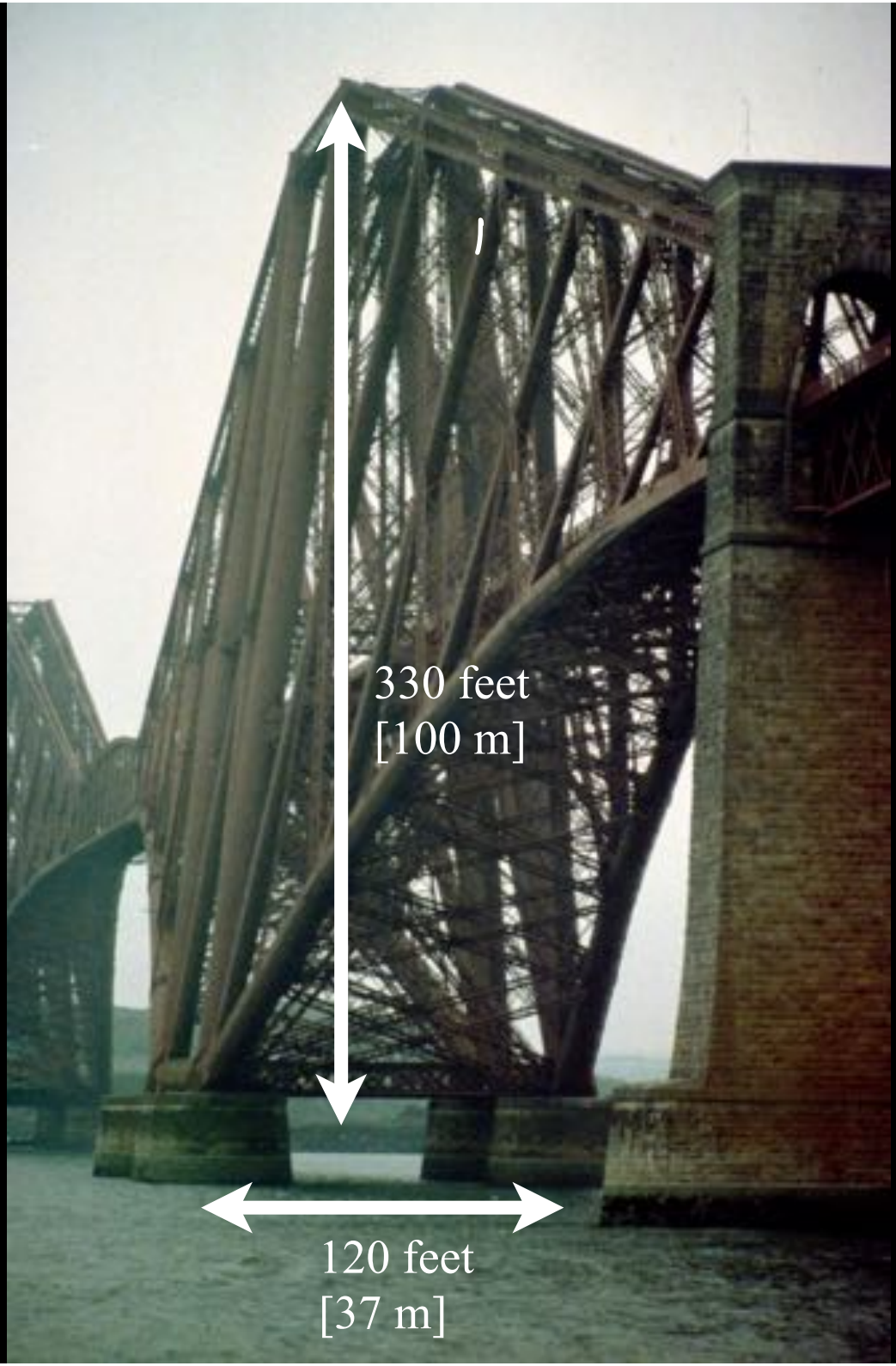
A: Not specially.

Q: You made no allowance?

A: Not specially.



Firth of Forth Bridge - Benjamin Baker - 1890 - 1710 ft [521 m]


330 feet
[100 m]
120 feet
[37 m]

SCANNING THE FORTH BRIDGE

Poems by Robin Bell

PETERLOO POETS

Scanning the Forth Bridge

The bridge is wide. The Forth is deep.
Iambic trains are made for sleep.

Trochee trains are bright achievers,
sparkling through the cantilevers.

Dactylic trains cross the bridge very speedily,
passengers munching their sandwiches greedily.

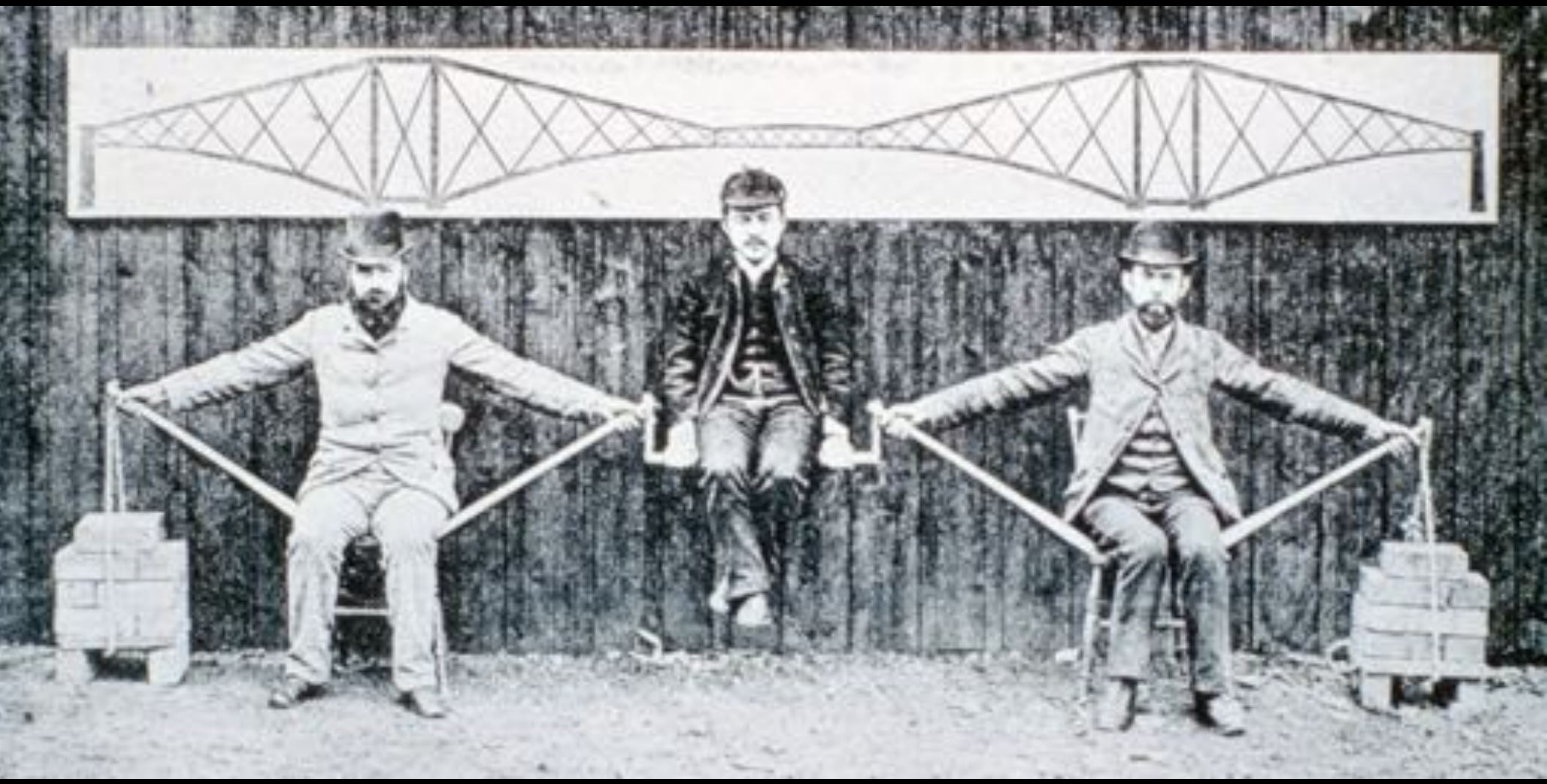
All the girders and seagulls and Anapaest trains
can expect to get wet every time that it rains.

Spondee trains plod on, on, on, on.
Dusk, dawn, dusk, dawn, yawn, yawn, yawn, yawn.

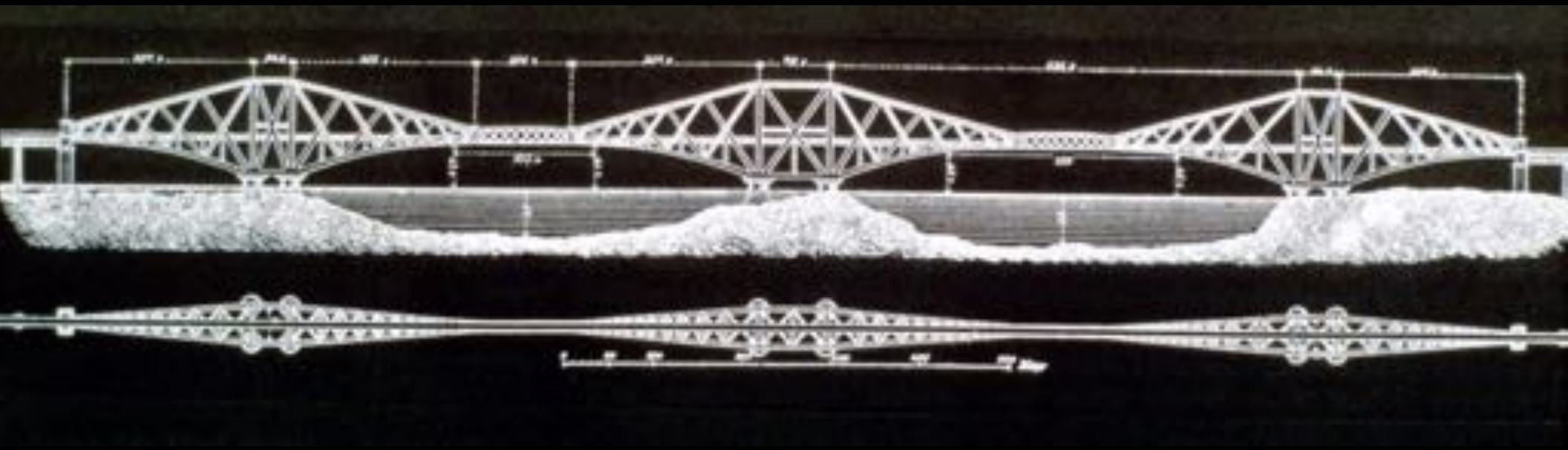
Workers work all year round: pots of paint, nuts and bolts.
Cretic trains shake you up: nasty jars, sudden jolts.

The Amphibrach trains travel swiftly but rarely,
and say that the Dactyl's competing unfairly.

Of timid Pyrrhic trains
not one remains.



can you identify tension and compression?



Social-Scientific-Symbolic

Eads Br.
Garabit Br.
Forth Br.

Economy-Efficiency-Elegance

Eiffel Tower Structural Study

introduction to statics

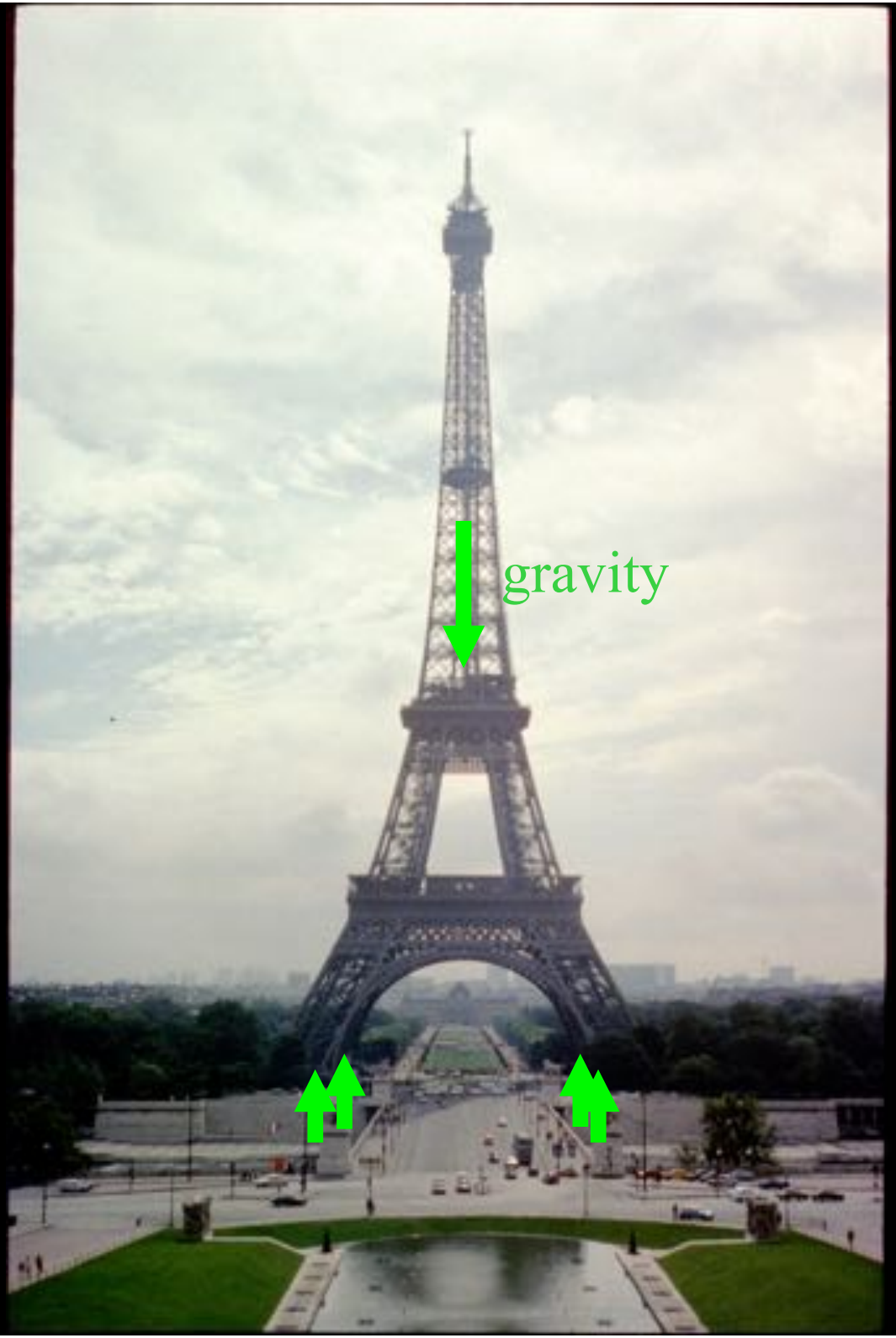
Tools and methods for structural analysis

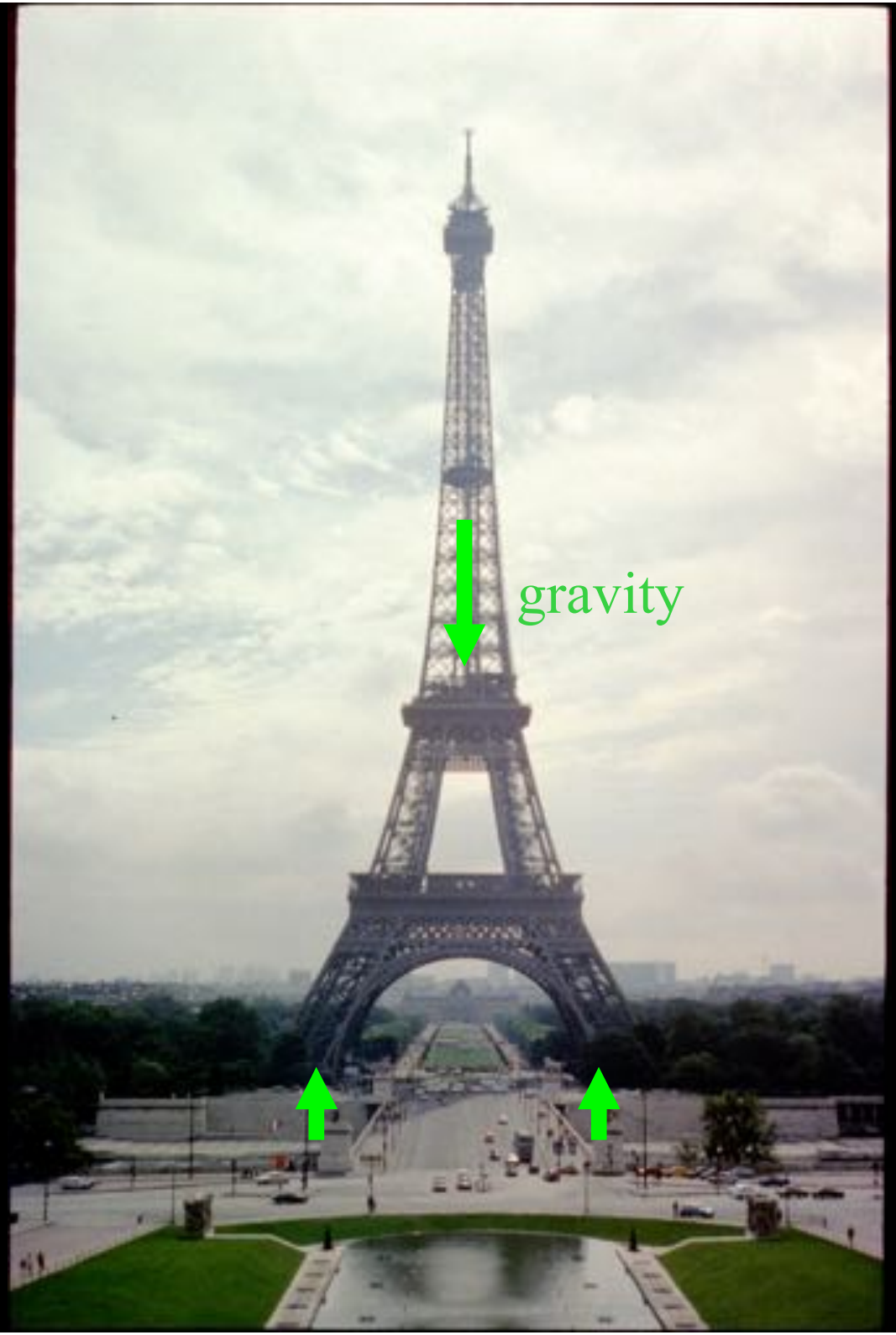
Free body diagrams

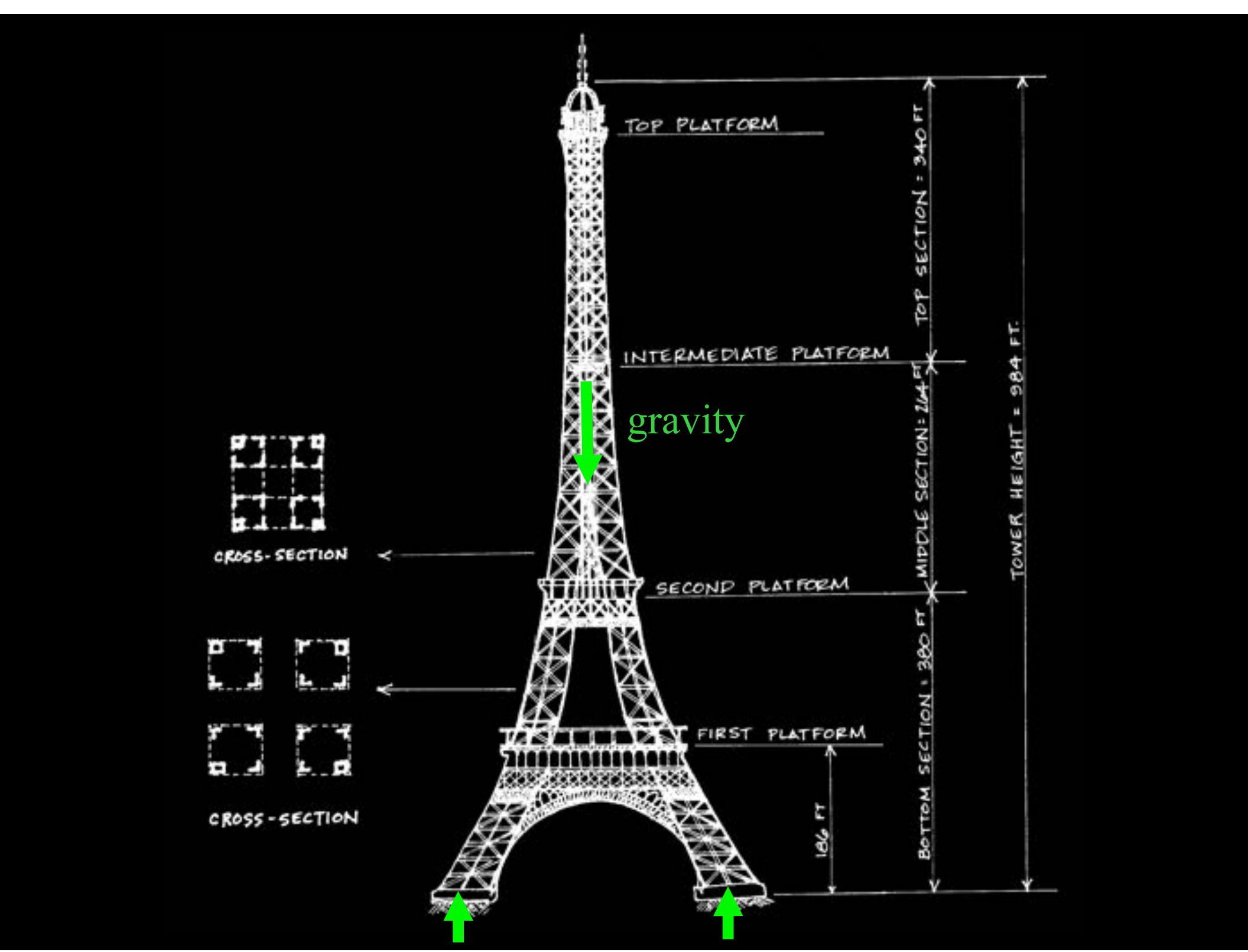
Equilibrium

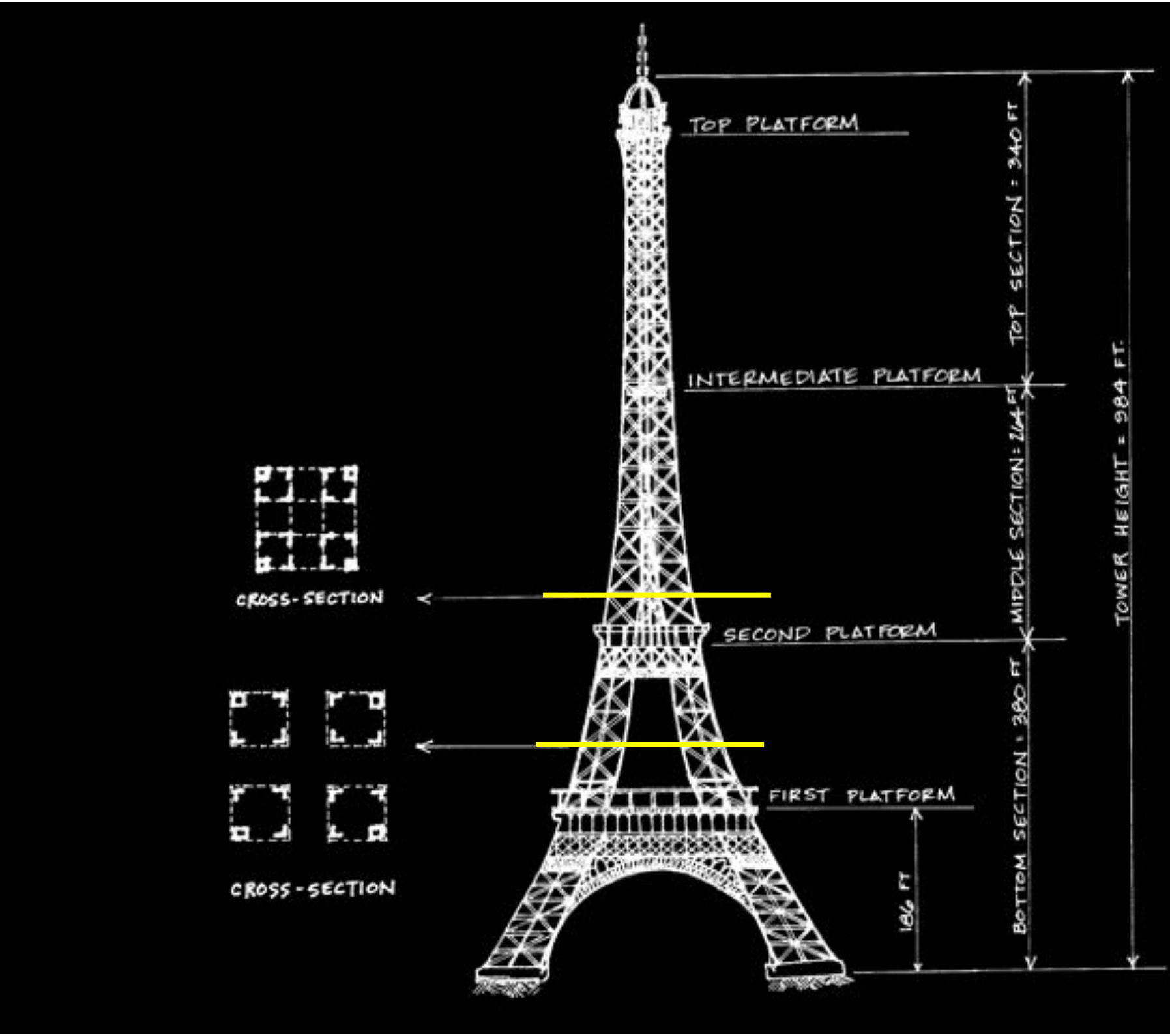
Load path

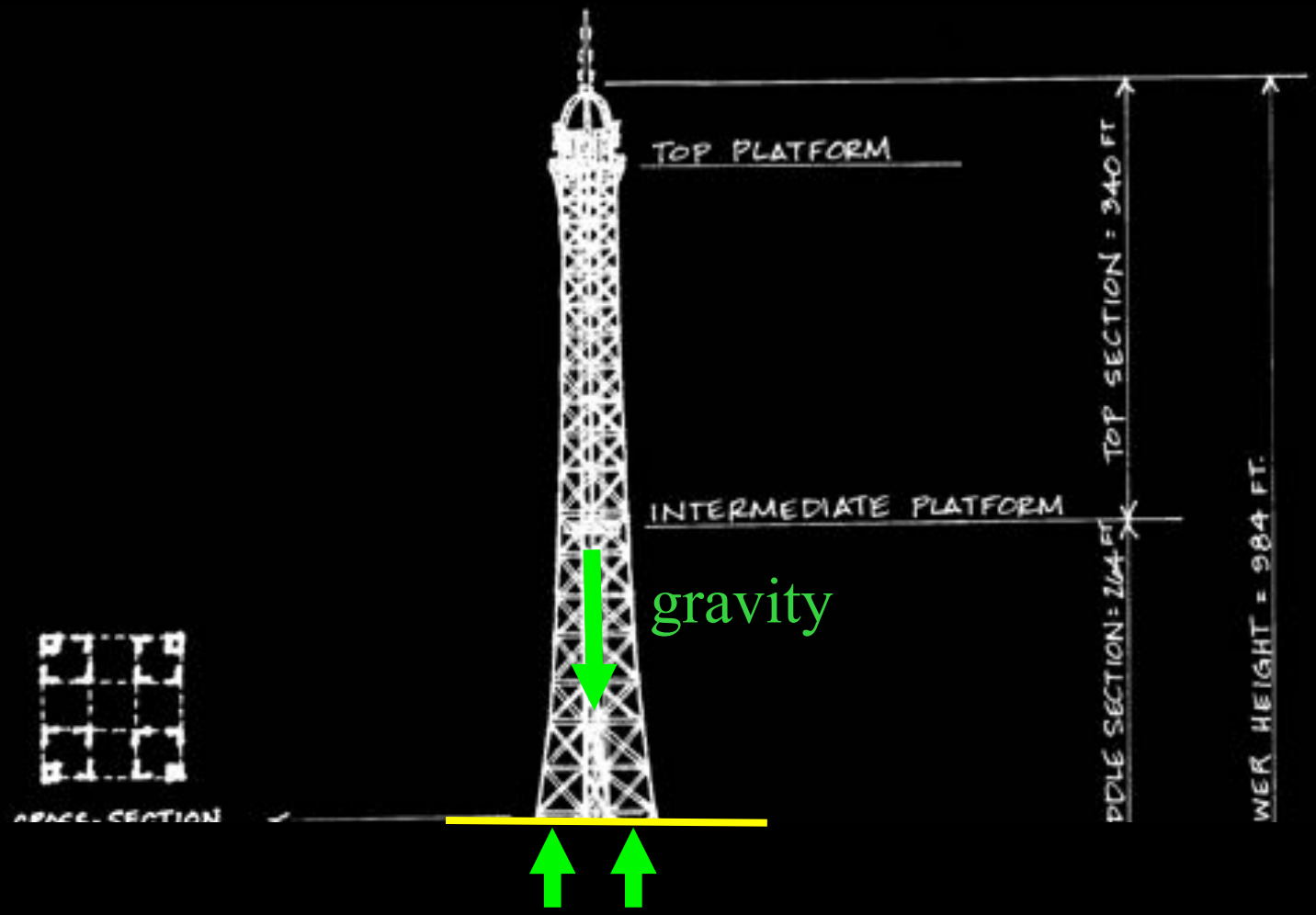
Free Body Diagrams

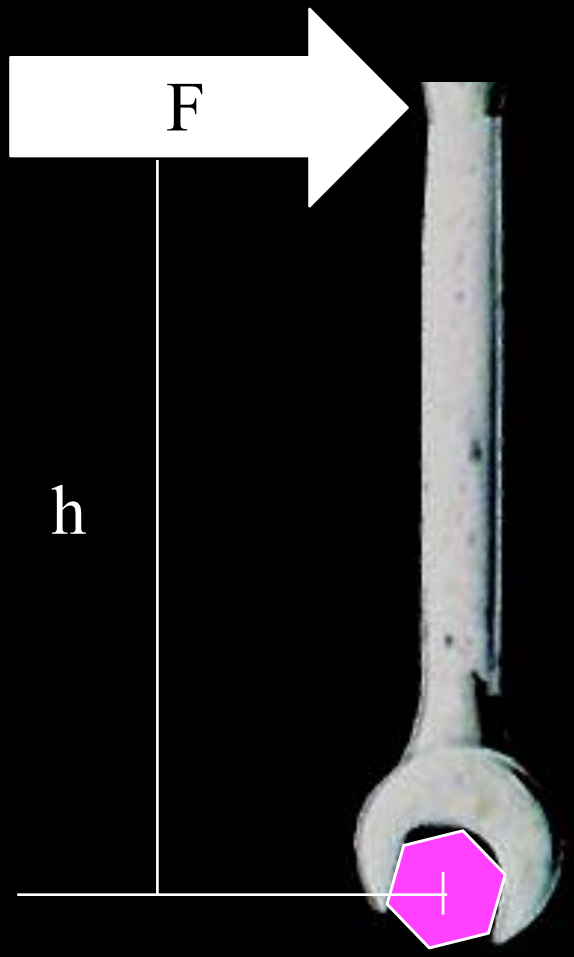

gravity


gravity


TOP PLATFORM
INTERMEDIATE PLATFORM
SECOND PLATFORM
FIRST PLATFORM
gravity
CROSS-SECTION
CROSS-SECTION
TOP SECTION = 340 FT
MIDDLE SECTION = 104 FT
BOTTOM SECTION = 380 FT
186 FT
TOWER HEIGHT = 984 FT.

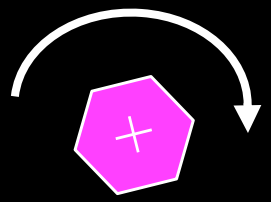

TOP PLATFORM
INTERMEDIATE PLATFORM
SECOND PLATFORM
FIRST PLATFORM
CROSS-SECTION
CROSS-SECTION
TOP SECTION = 340 FT
MIDDLE SECTION = 344 FT
BOTTOM SECTION = 380 FT
186 FT
TOWER HEIGHT = 984 FT.

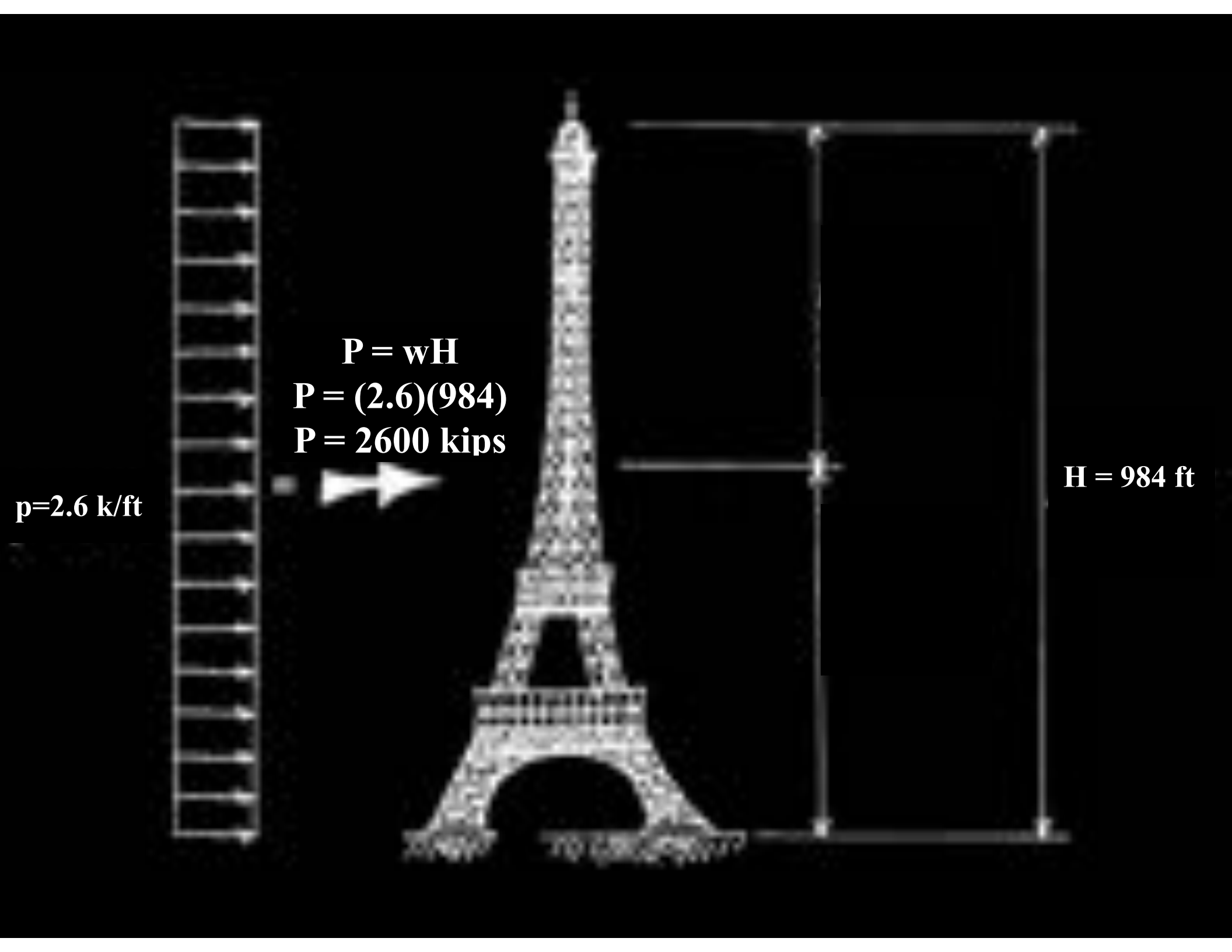

TOP PLATFORM
INTERMEDIATE PLATFORM
gravity
TOP SECTION = 340 FT
MIDDLE SECTION = 164 FT
TOWER HEIGHT = 984 FT.

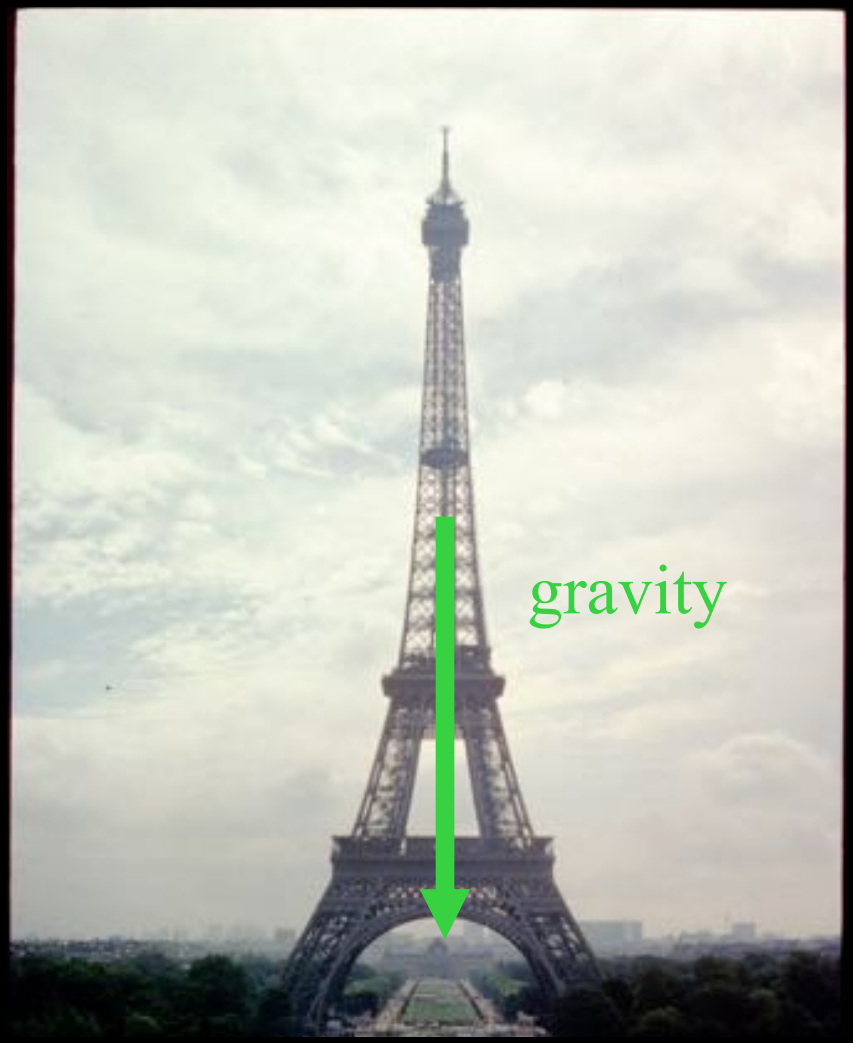


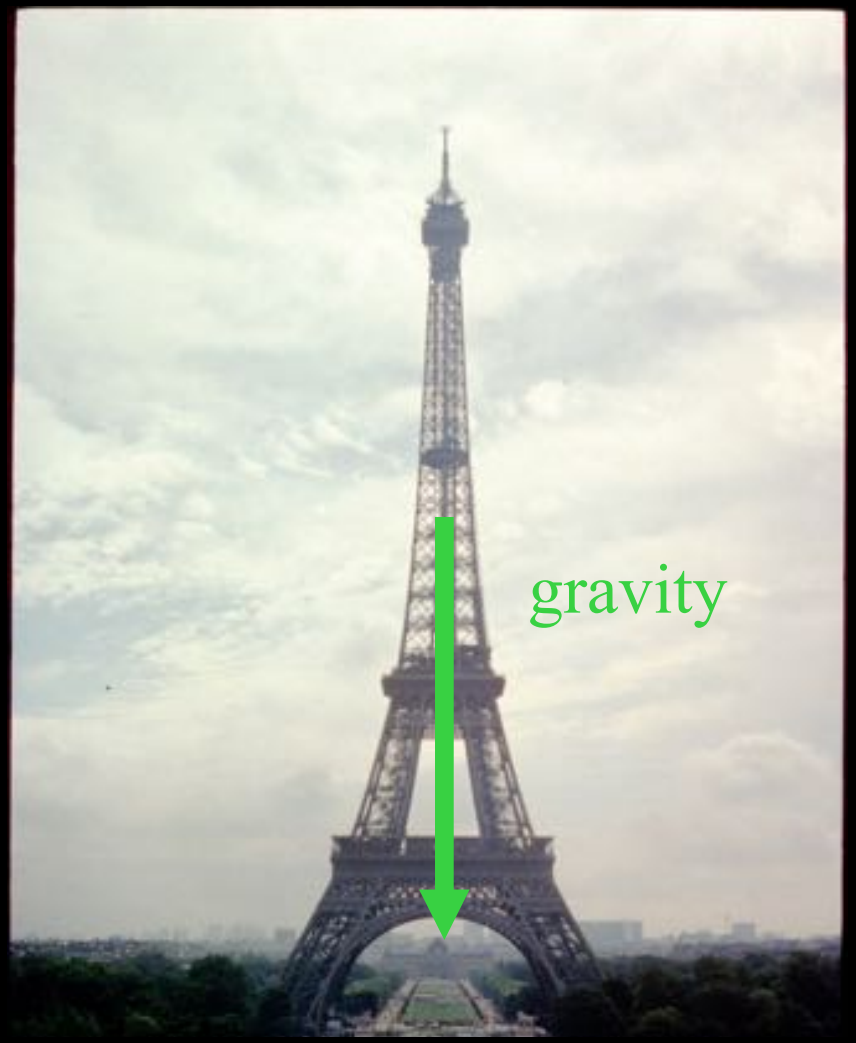
=

M=Fh

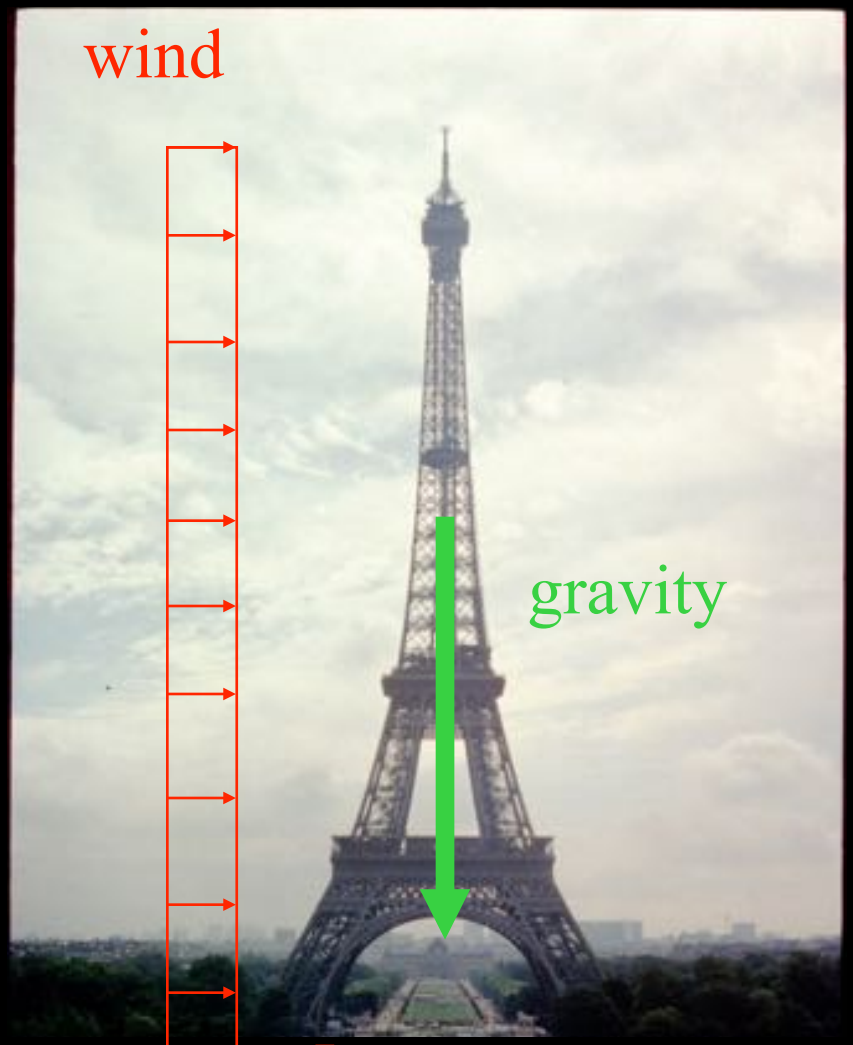



P = wH
P = (2.6)(984)
P = 2600 kips
p=2.6 k/ft
H = 984 ft


gravity
reactions

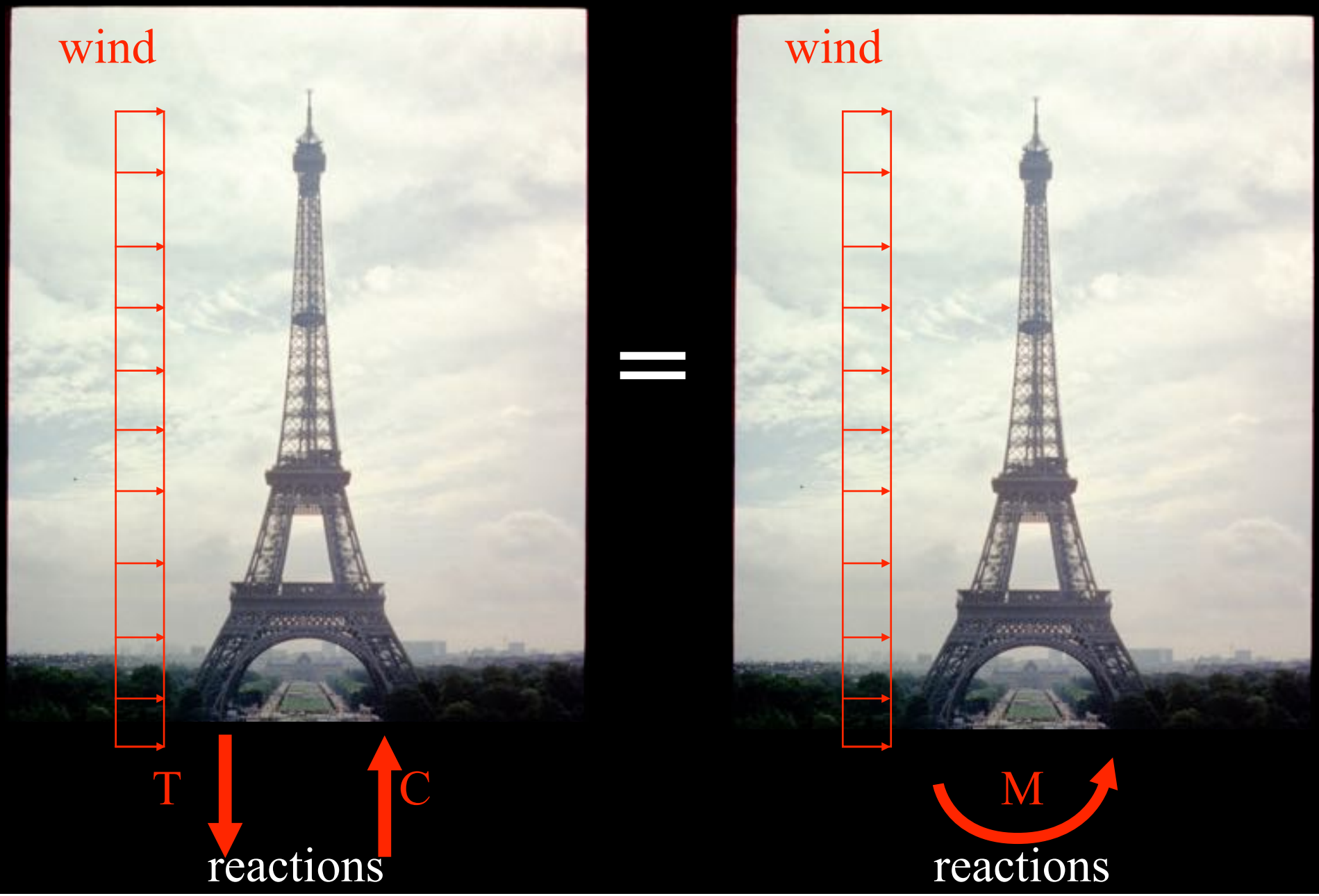


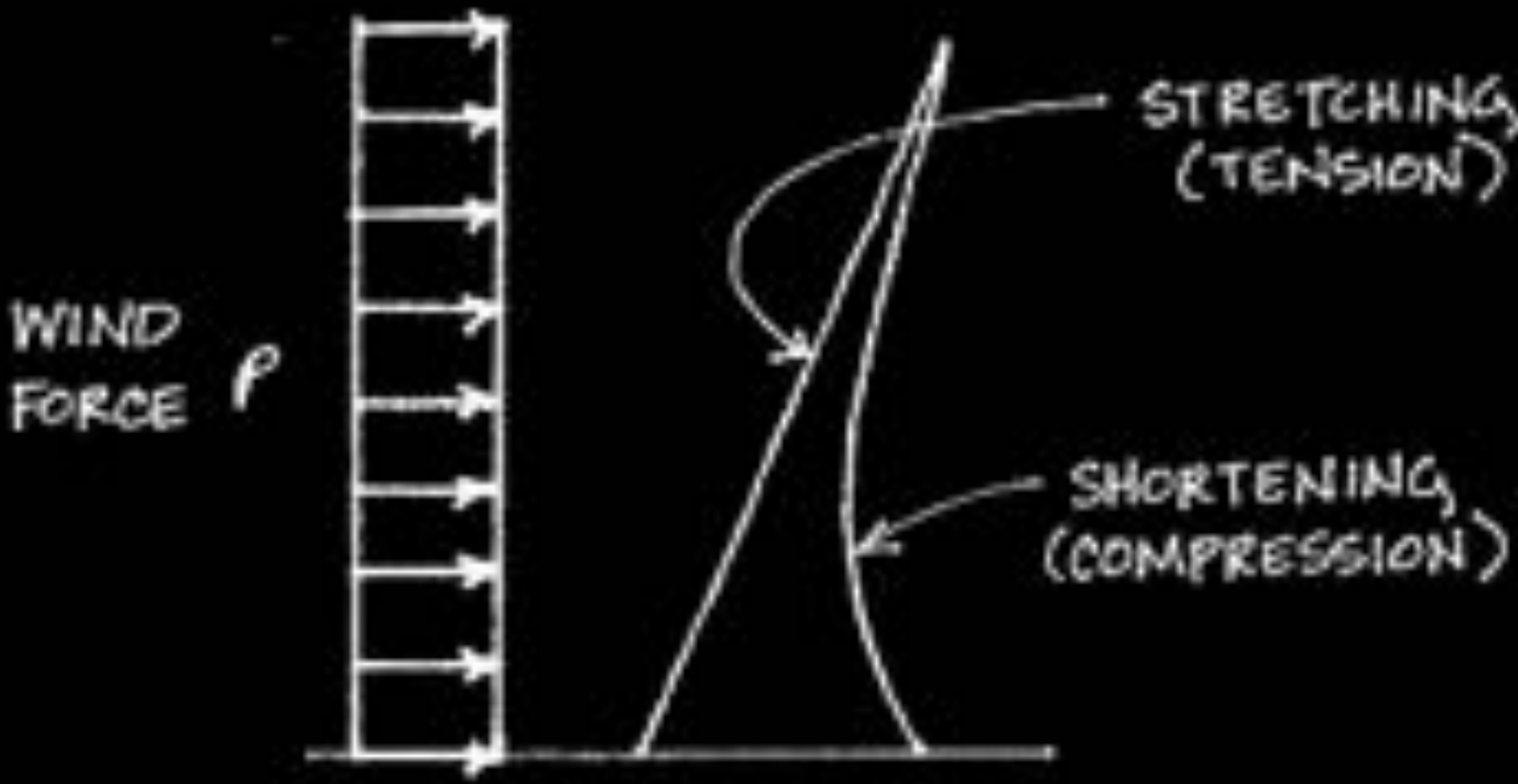
reactions

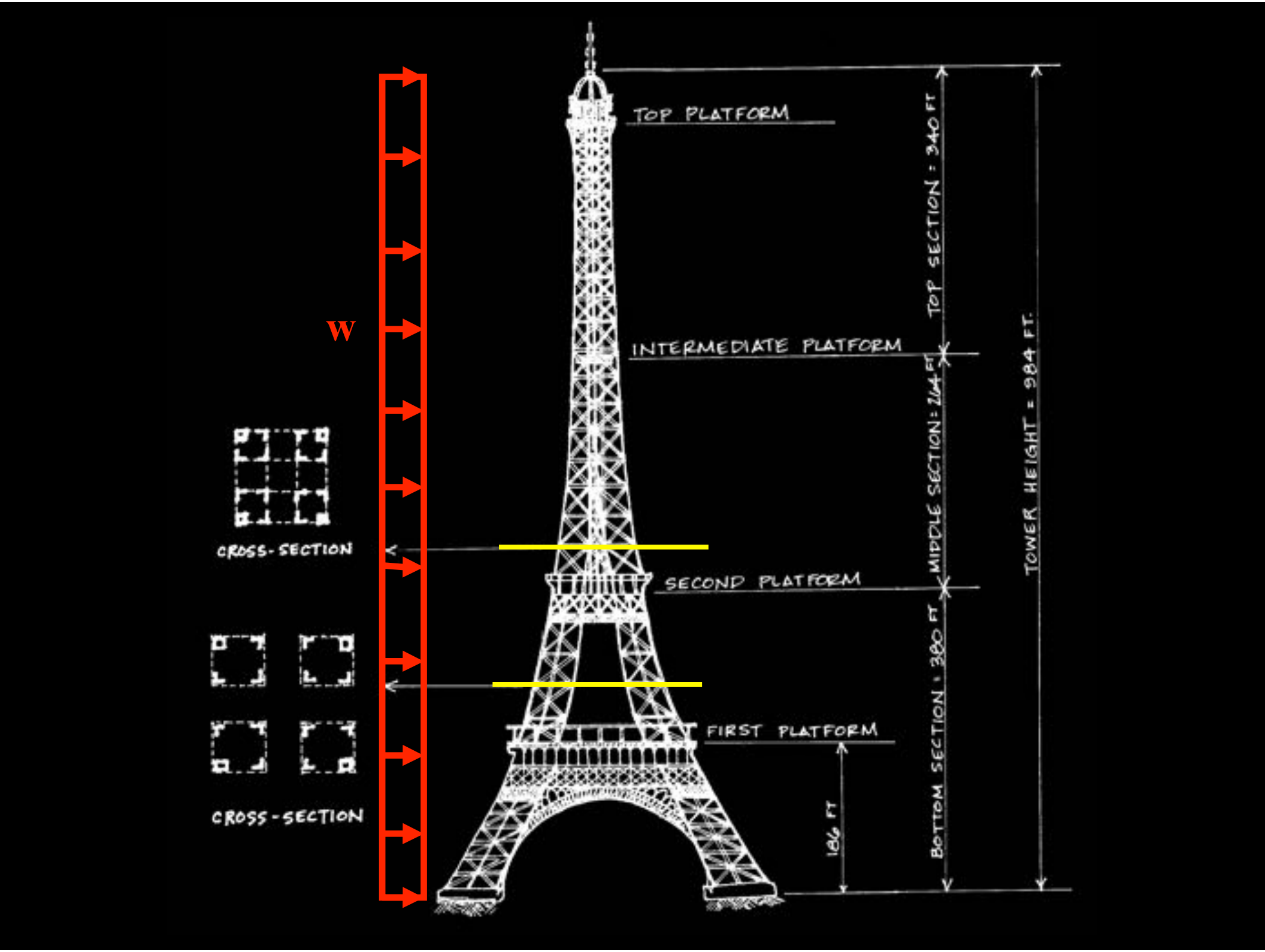


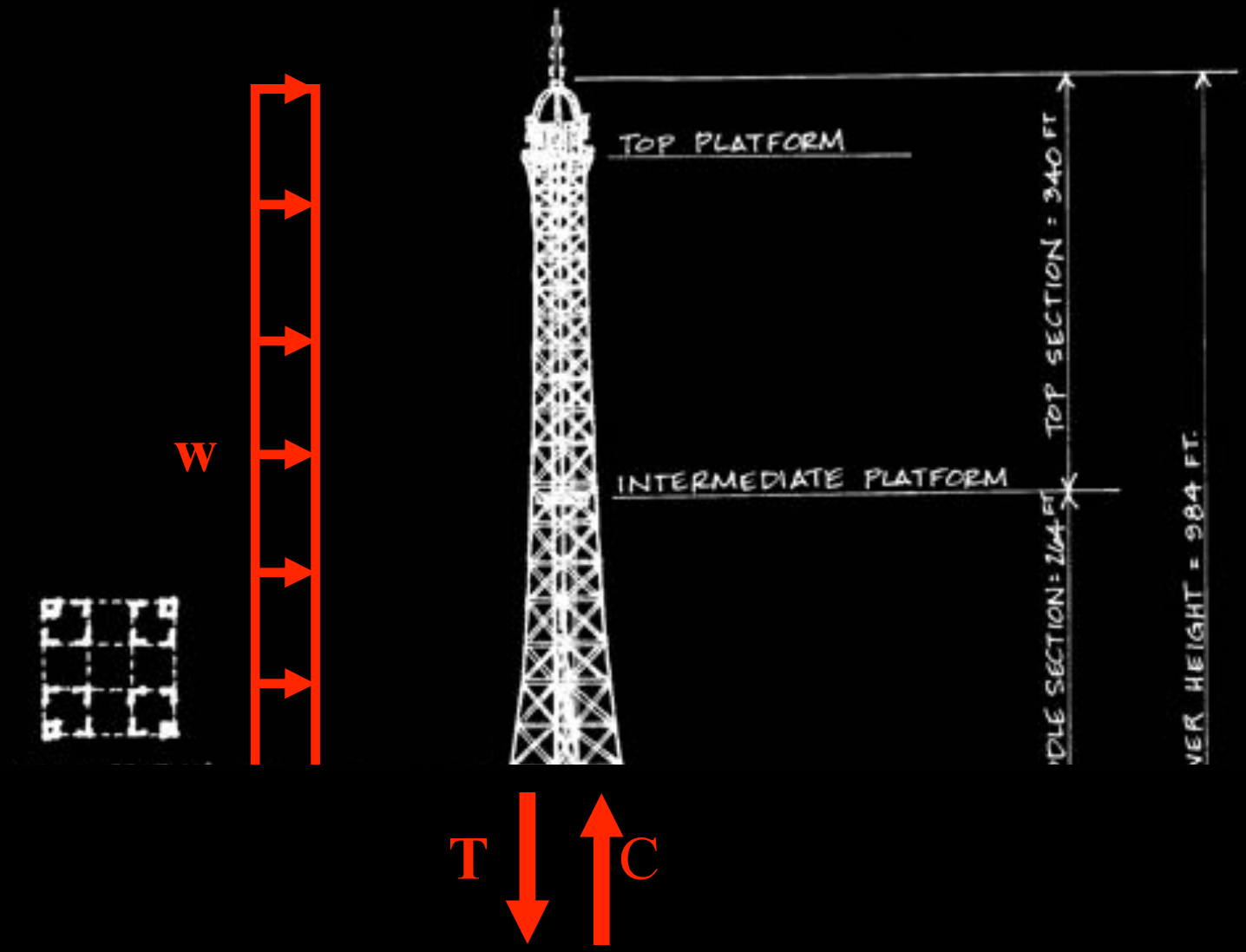
C T C C

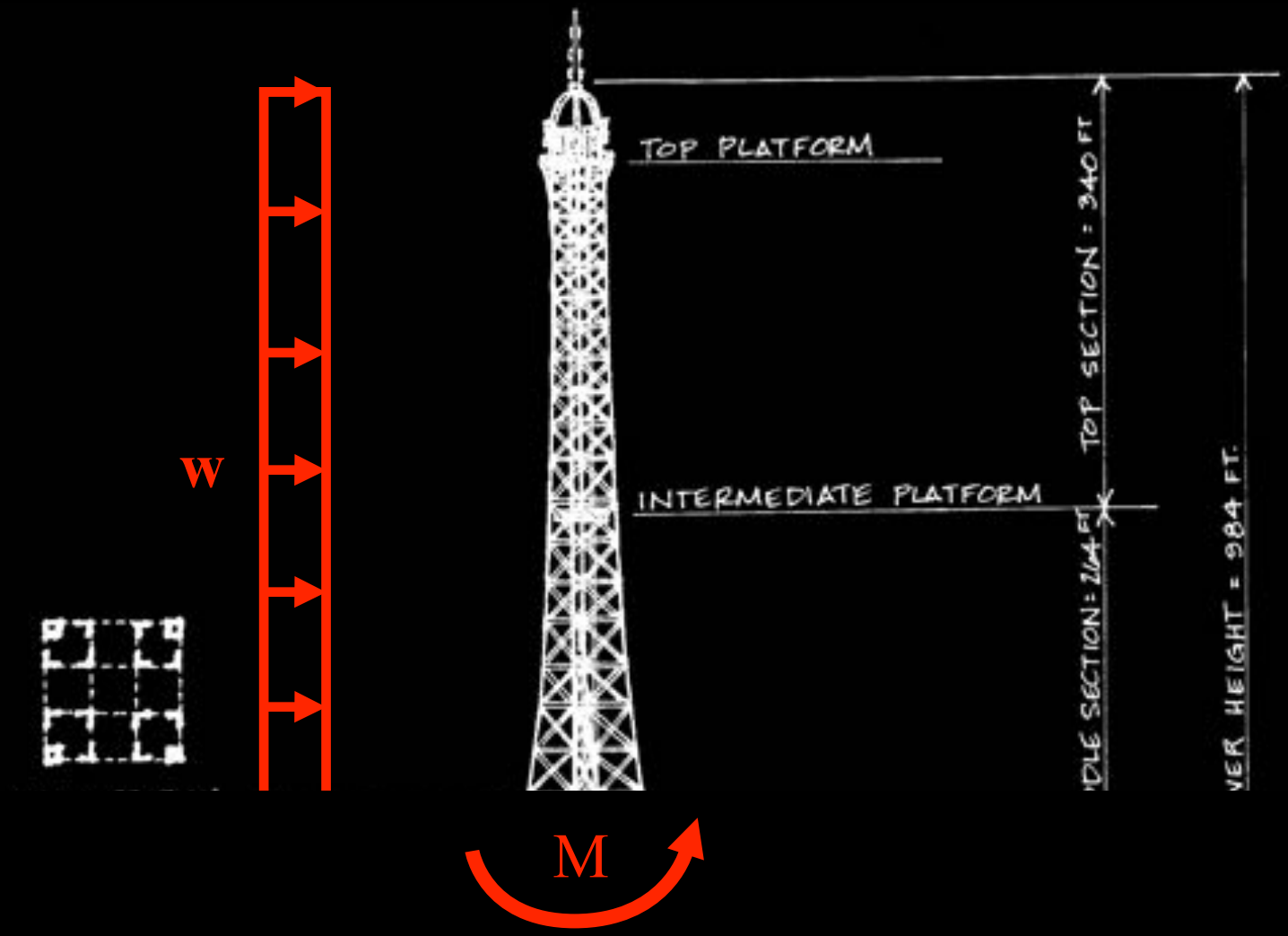
reactions


wind
T
C
reactions
=
wind
M
reactions


WIND
FORCE
p
STRETCHING
(TENSION)
SHORTENING
(COMPRESSION)


w
CROSS-SECTION
CROSS-SECTION
TOP PLATFORM
INTERMEDIATE PLATFORM
SECOND PLATFORM
FIRST PLATFORM
TOP SECTION = 340 FT
MIDDLE SECTION = 344 FT
BOTTOM SECTION = 380 FT
186 FT
TOWER HEIGHT = 984 FT.

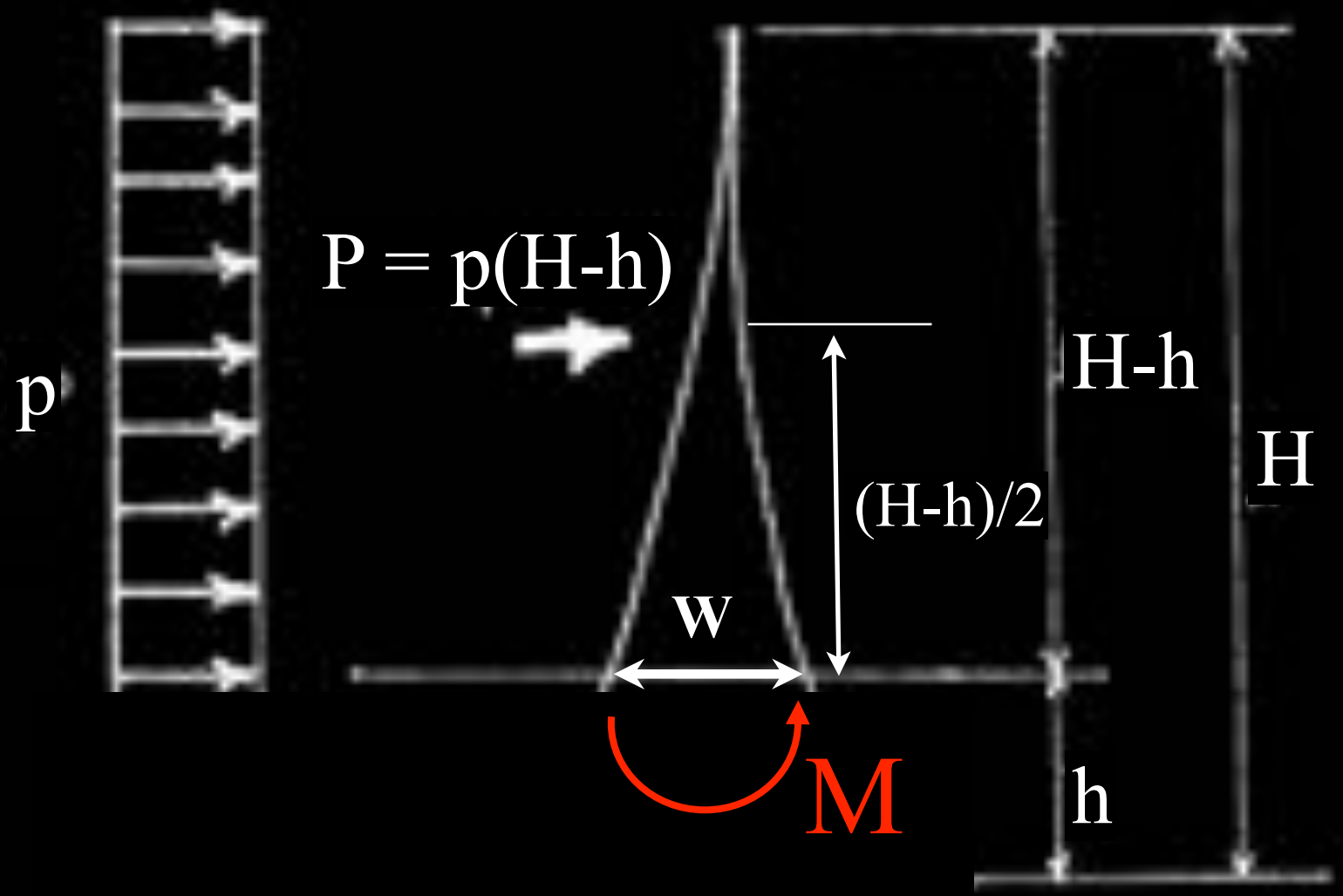

W
TOP PLATFORM
INTERMEDIATE PLATFORM
TOP SECTION = 340 FT
VER HEIGHT = 984 FT.
T
C


w
TOP PLATFORM
INTERMEDIATE PLATFORM
TOP SECTION = 340 FT
VER HEIGHT = 984 FT.
M

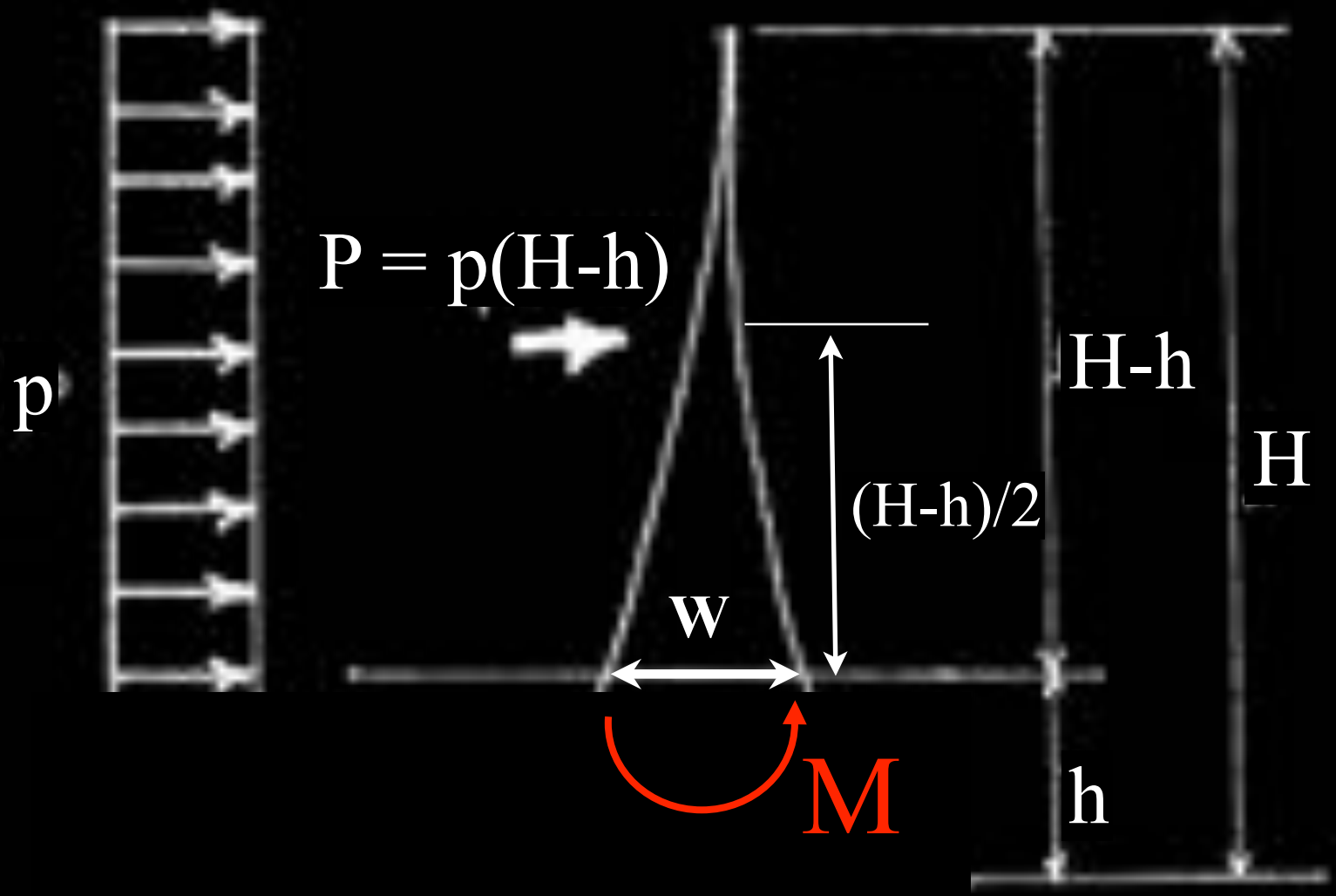
Civil Engineering Units

- Lots of imperial units..
- The kip? kip = kilopound = 1000 lb
- The psf? a pound per square foot
  - say you weigh 150 lb and are standing on a part of the floor which is 1ft x 1ft, you are = 150psf
  - other way – say a constant wind of 40 psf is blowing on a building which is 100ft x 100ft across – the force is 40psf X 100ft X 100ft = 40,000 lb
  - 40,000 lb = 40 kips
- Also… psi and ksi, pound/sq. in, and kip/sq. in
  - Materials may be described as having limit stresses in psi or ksi, e.g., typical yield stress of steel = 50 ksi

Equilibrium

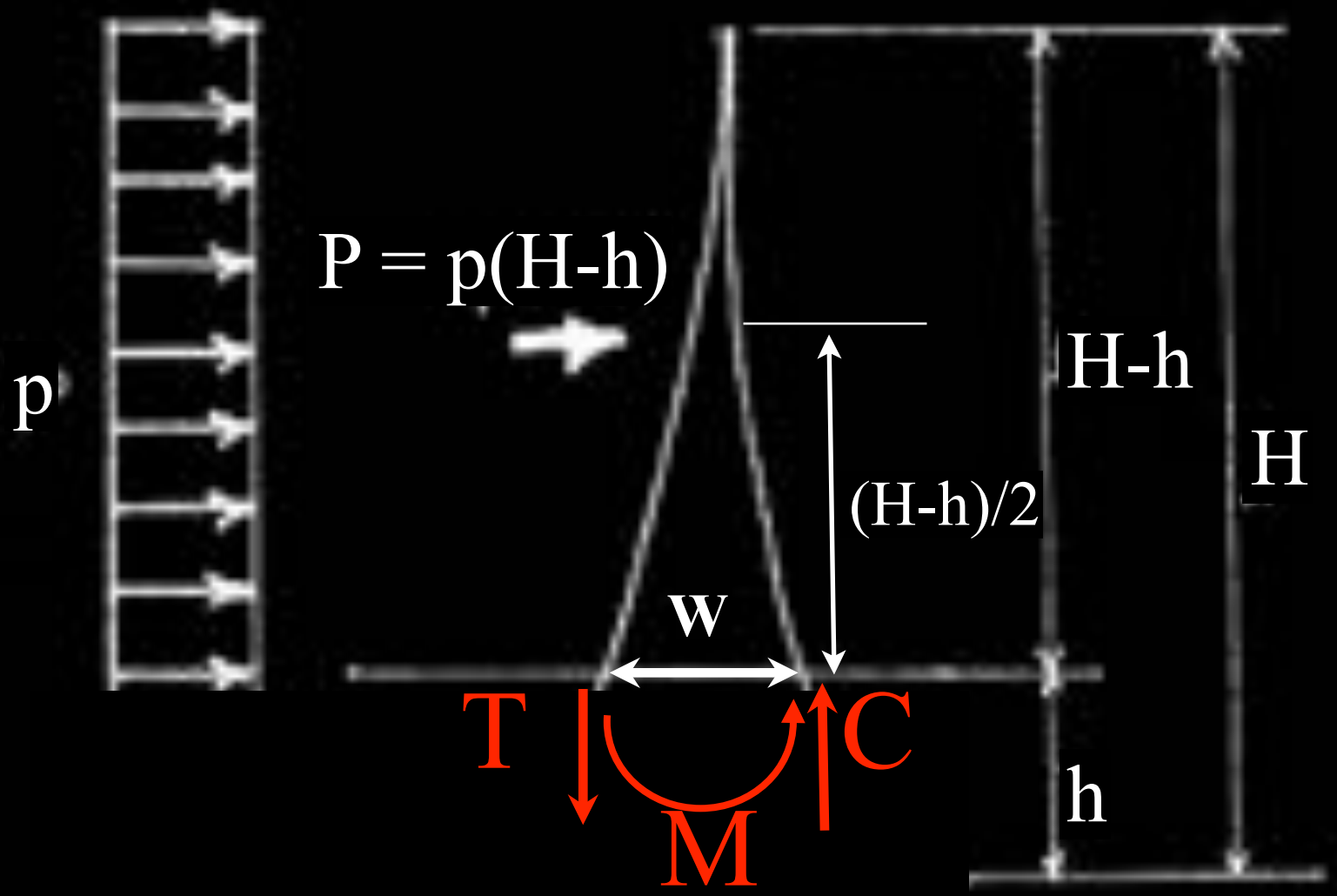


$\Sigma M_{section} = 0 \rightarrow M - p(H-h)(H-h)/2 = 0$



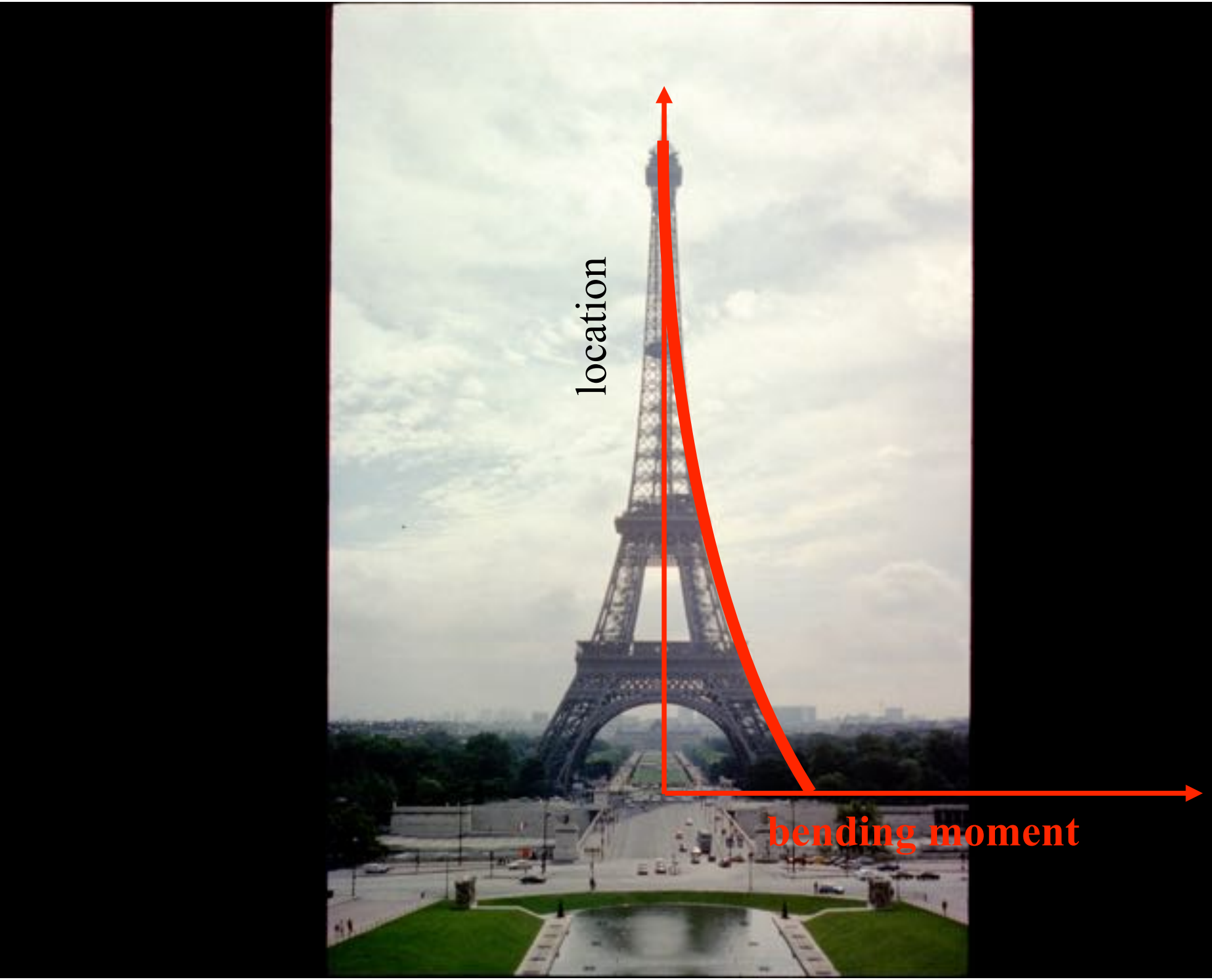
$\Sigma M_{section} = 0 \rightarrow M - p(H-h)(H-h)/2 = 0$

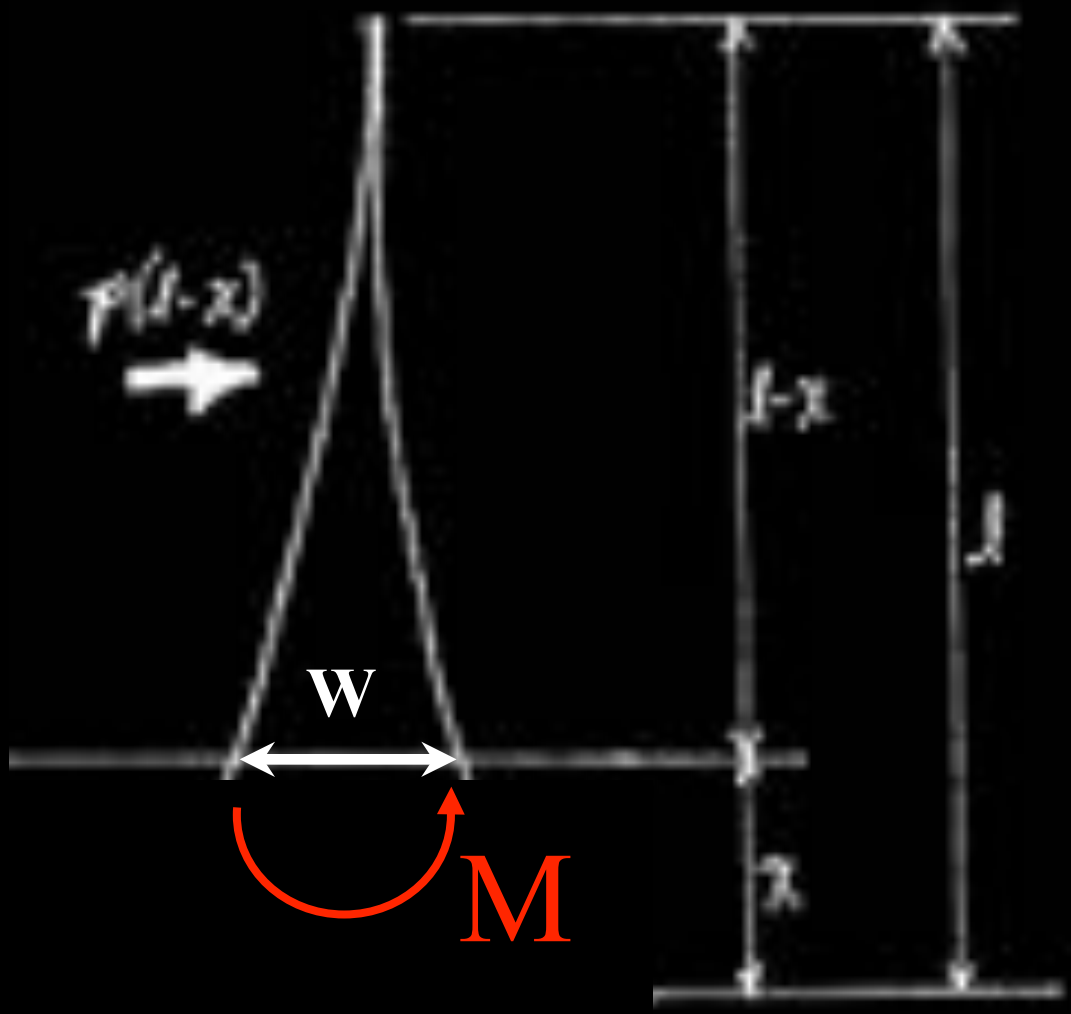
$M = [p(H-h)][(H-h)/2] = P(H-h)/2$

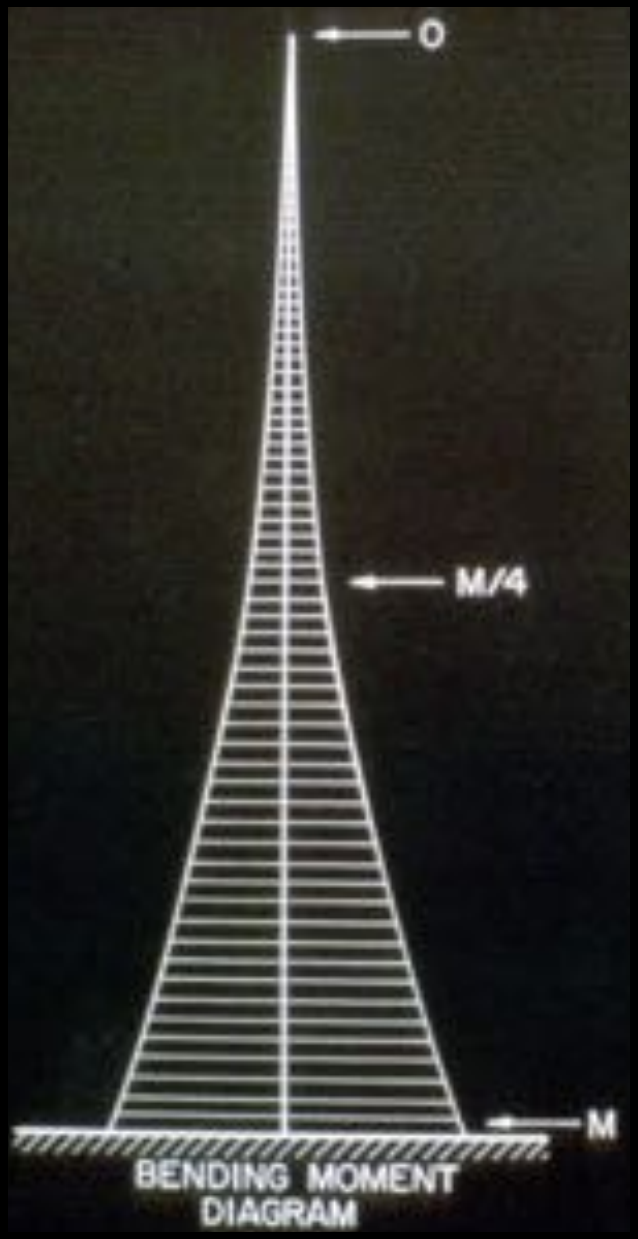


$$M=[p(H-h)][(H-h)/2]=P(H-h)/2$$

$$C = -T = M/w$$


location
bending moment





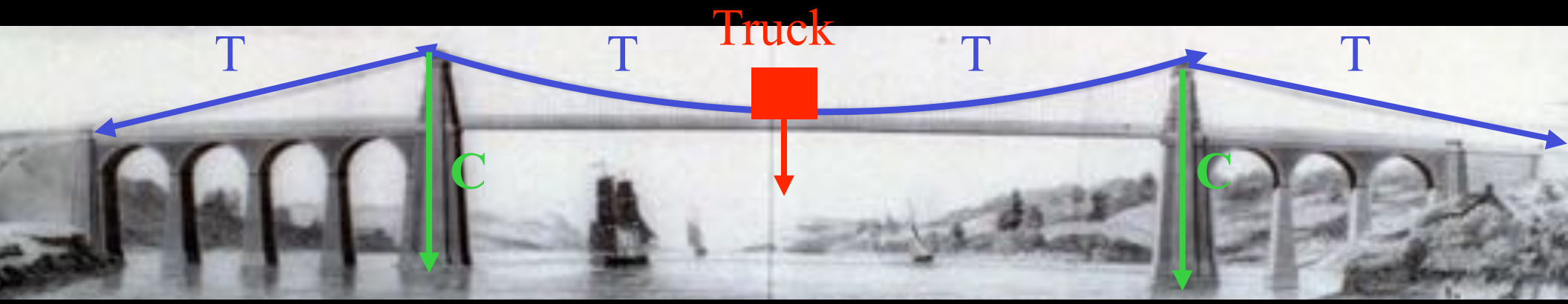
$$M=[p(H-h)][(H-h)/2]=p(H-h)^2/2$$

Load path

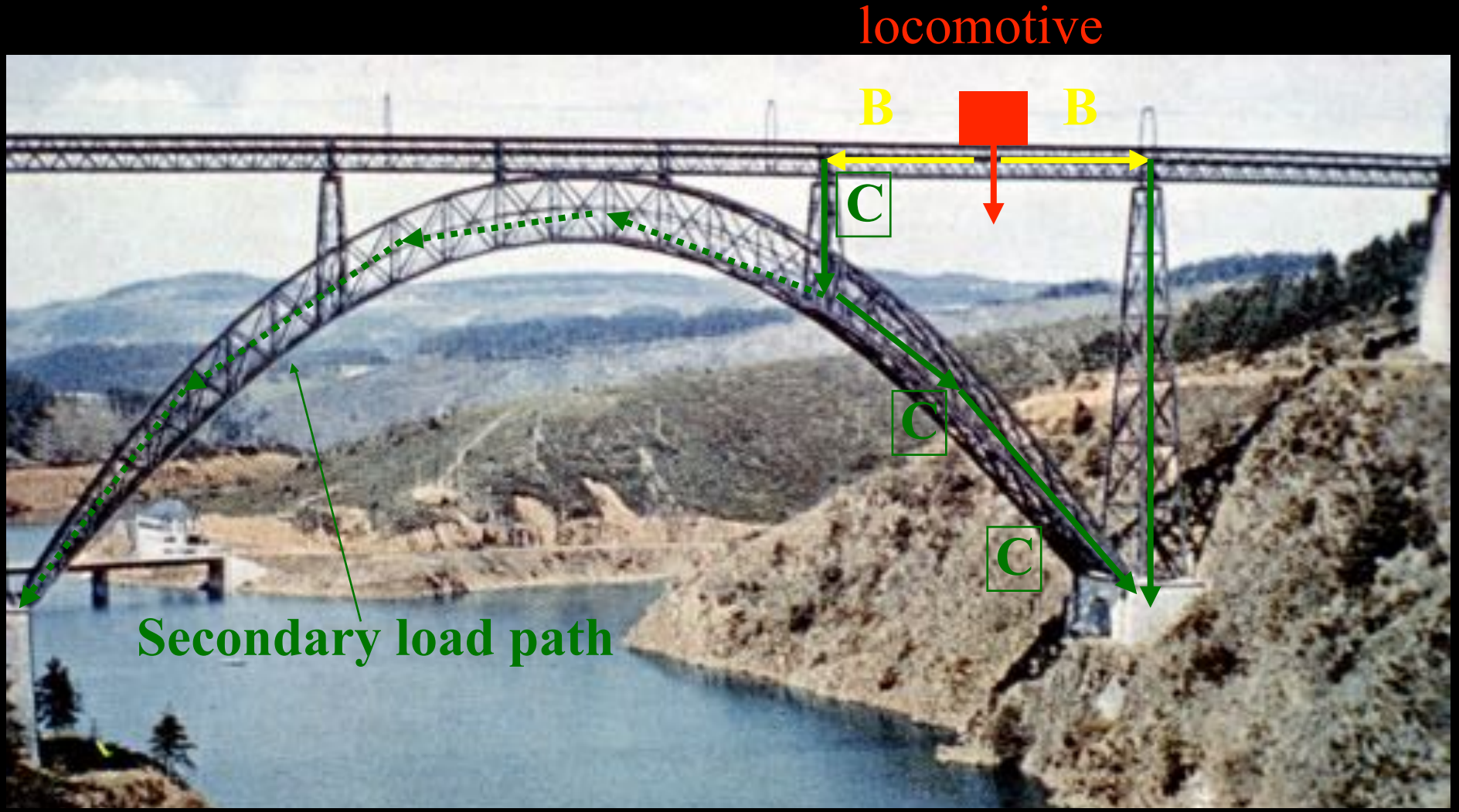
or, how the load travels to the ground

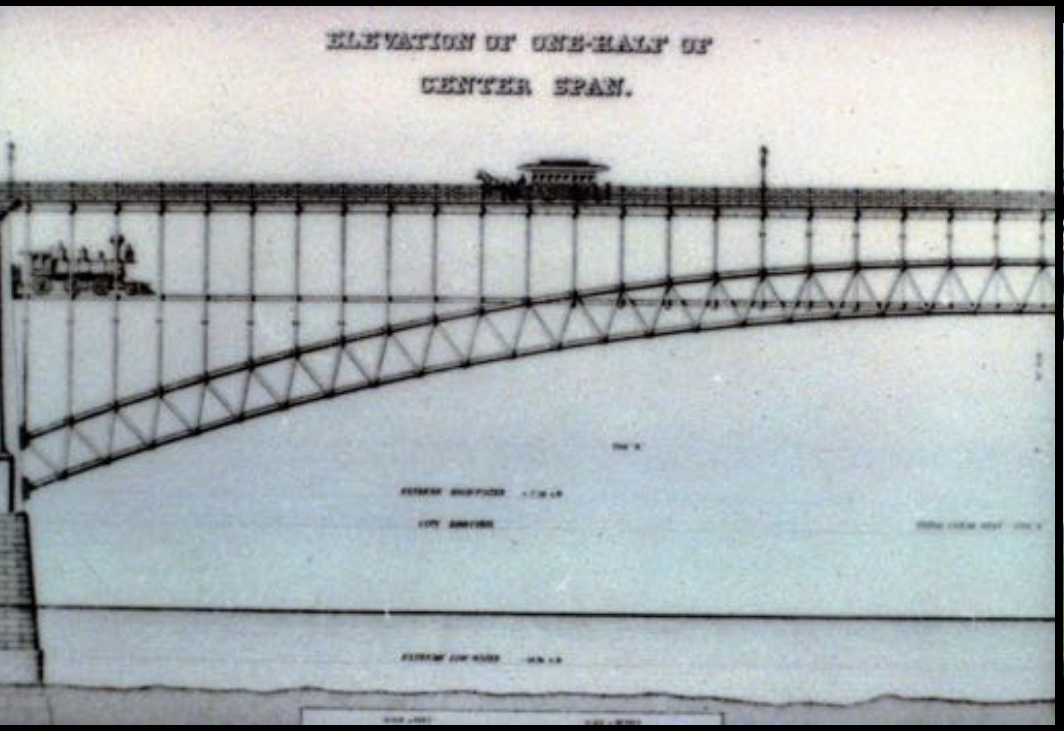
All forces or loads must eventually get to the ground.
Can we trace the path of tension of compression?

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



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





Pick the person on the railing, the carriage, or the locomotive - describe the load path for the force you have selected...