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

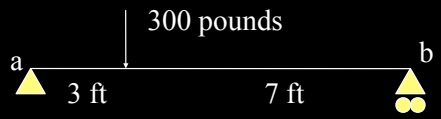
- In two dimensions what are the three equations of equilibrium?
  - (1)
  - (2)
  - (3)
- Give yourself a point if you know them.

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

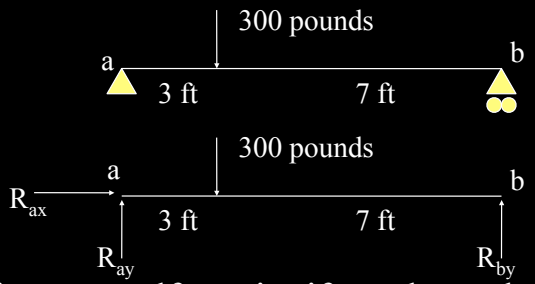
- Make a free body diagram of the following little bridge.



- Give yourself a point if you know how. ☺

Answer 2

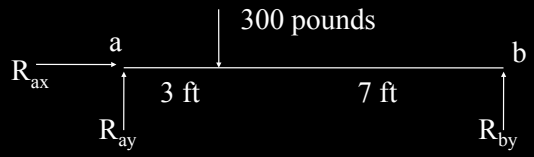
- Make a free body diagram of the following little bridge.



- Give yourself a point if you know how. ☺

Q3

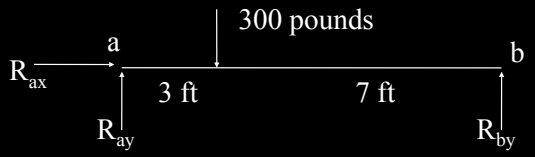
- Write the equation for sum of forces in the y



- Give yourself a point if you know how. ☺

Answer 3

- Write the equation for sum of forces in the y

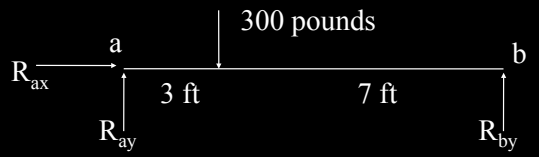


$\Sigma F_y=0 \quad R_{ay}-300+R_{by}=0 \quad R_{ay}+R_{by}=300$

- Give yourself a point if you know how. ☺

Q4

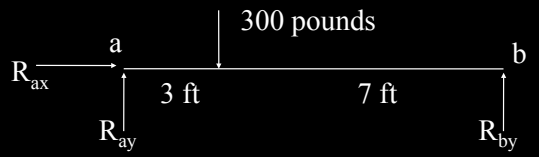
- Write the equation for sum of moments at a



- 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)

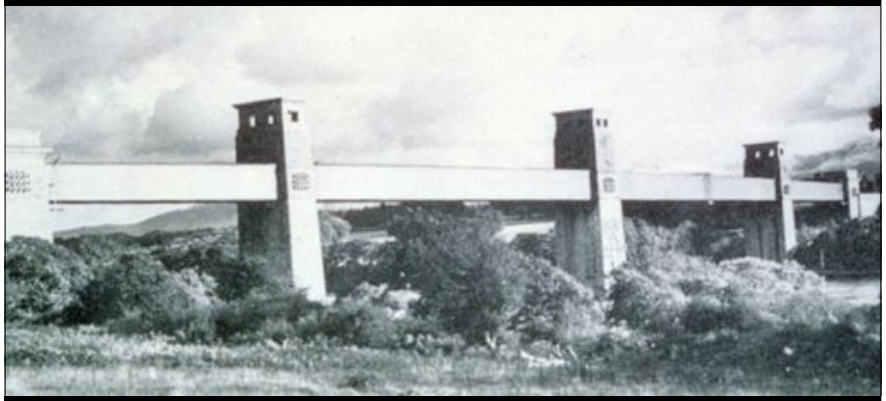
- Establish the 3's, 4's and 5's..
- Find our way into groups of 2 or 3 – these are not permanent groups, don't fret!
- Introduce yourself

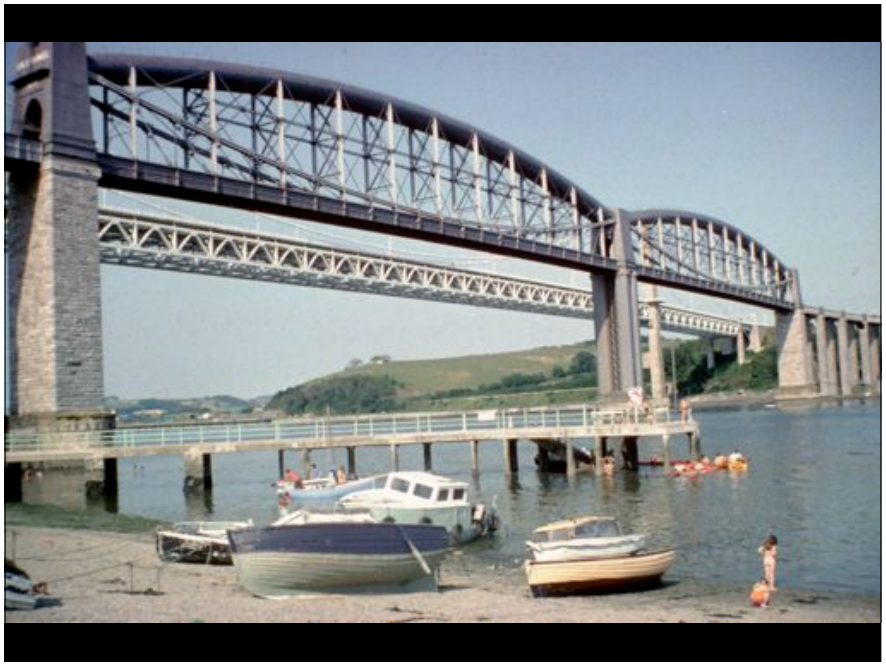
Moving time (just for today)

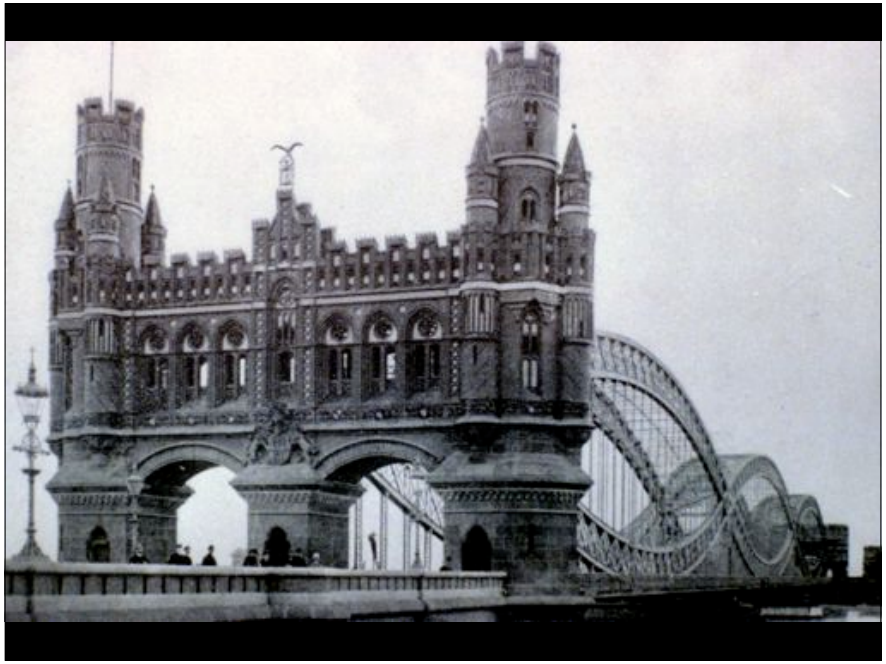
- Establish the 3's, 4's and 5's..
- Find our way into groups of 2 or 3 – these are not permanent groups, don't fret!
- Introduce yourself
- Please exchange contact information amongst your group (cell, email, whatever)
- Now we are ready!

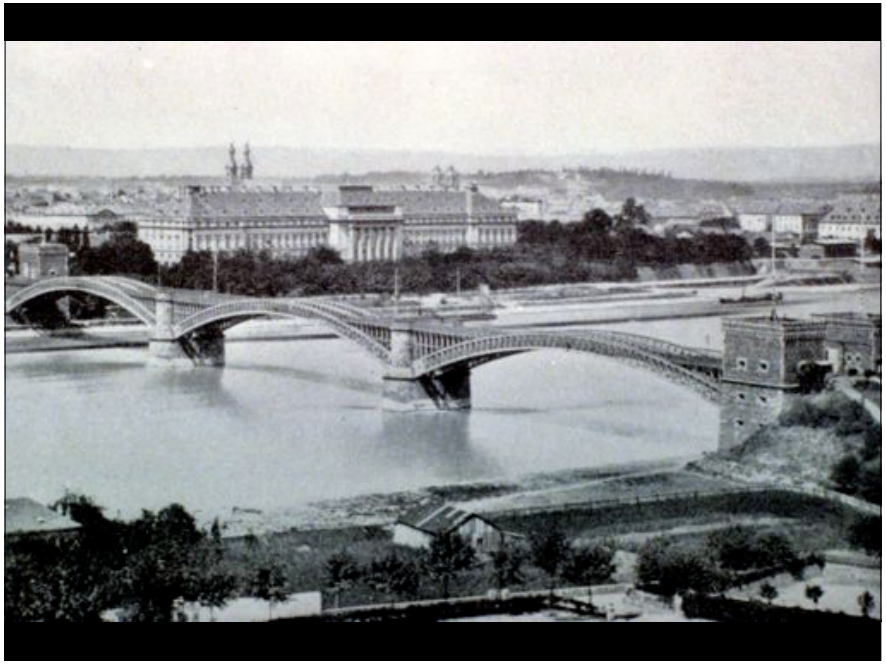
Eads, Eiffel and the Forth Bridge

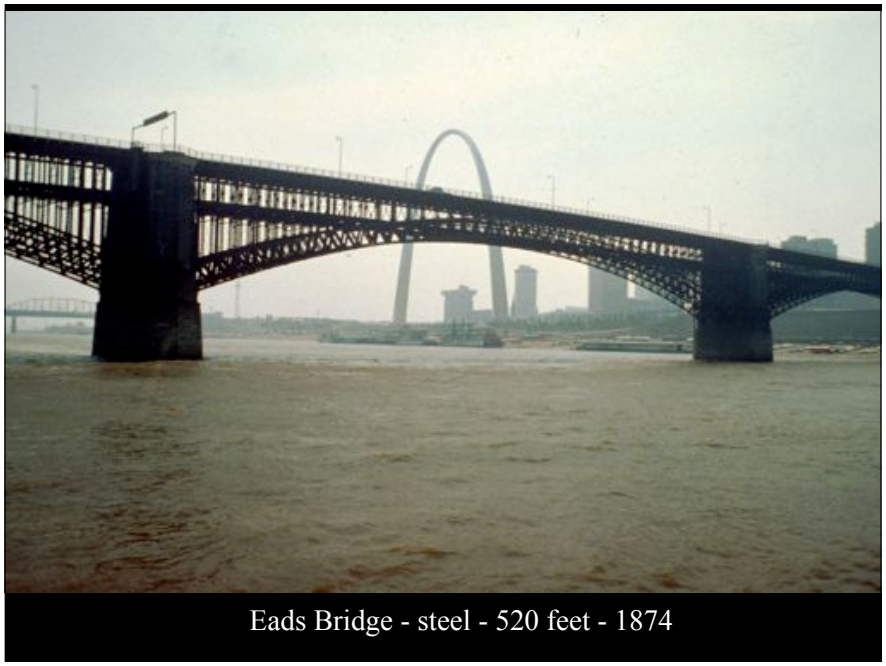
The big 19th century
iron and steel bridges



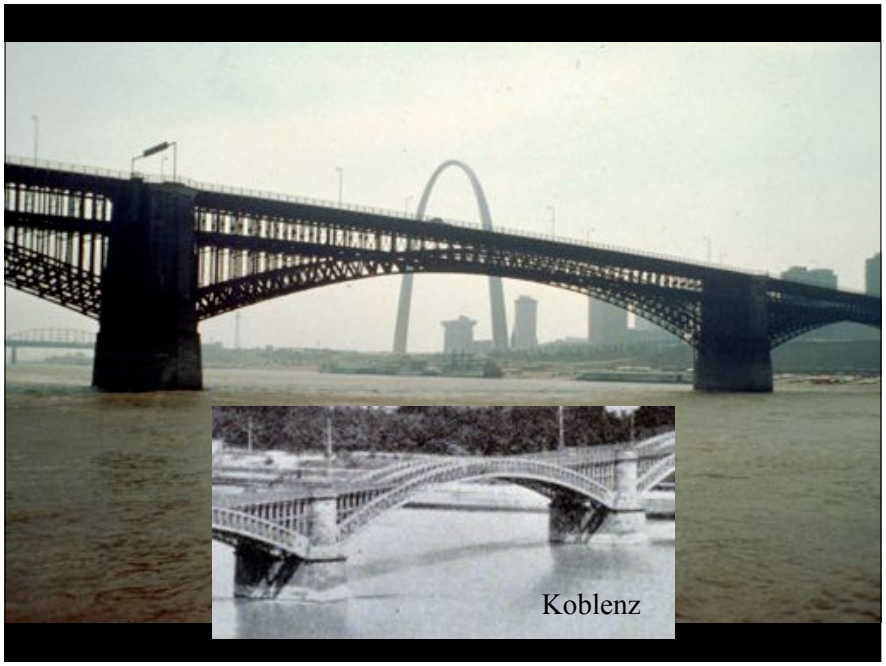




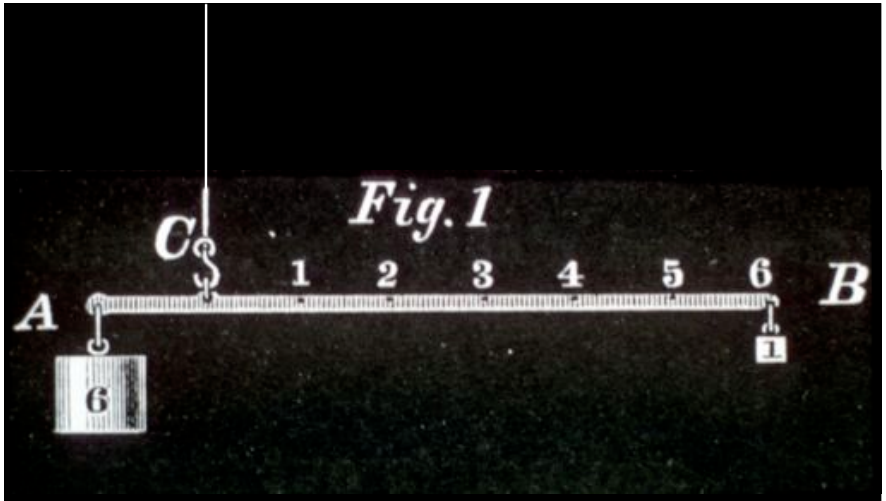




Eads Bridge - steel - 520 feet - 1874

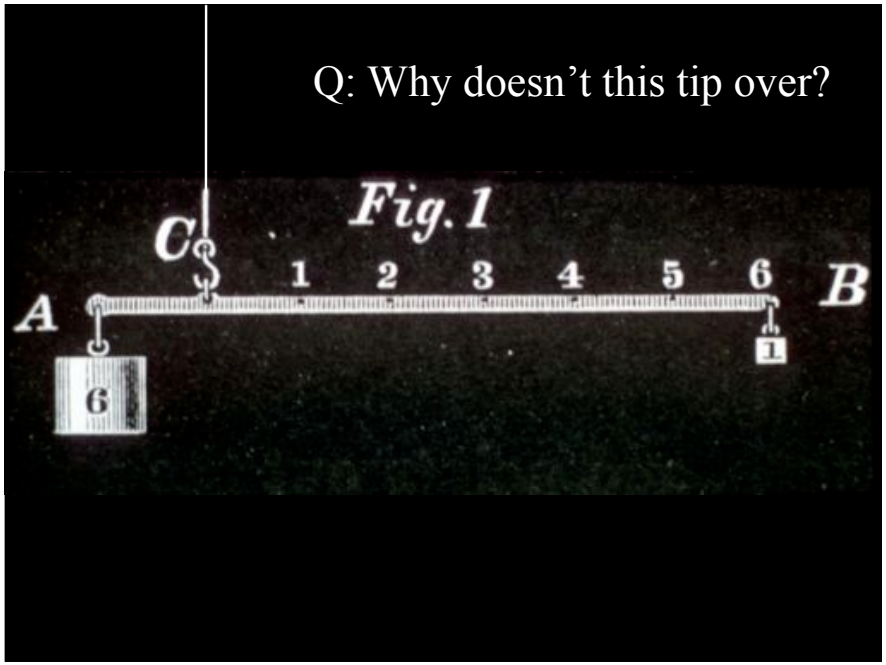


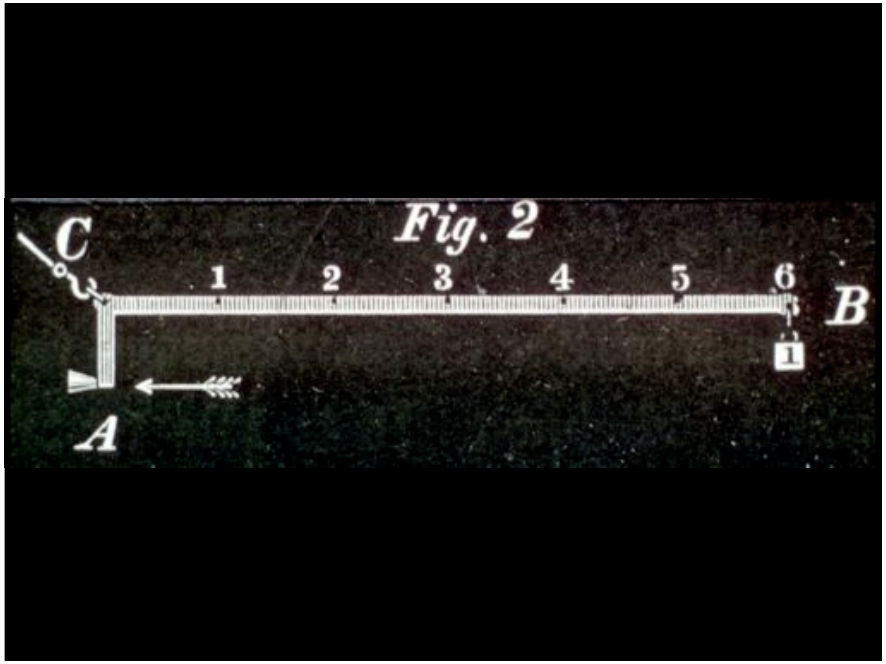
James Buchanan Eads
1820-1887

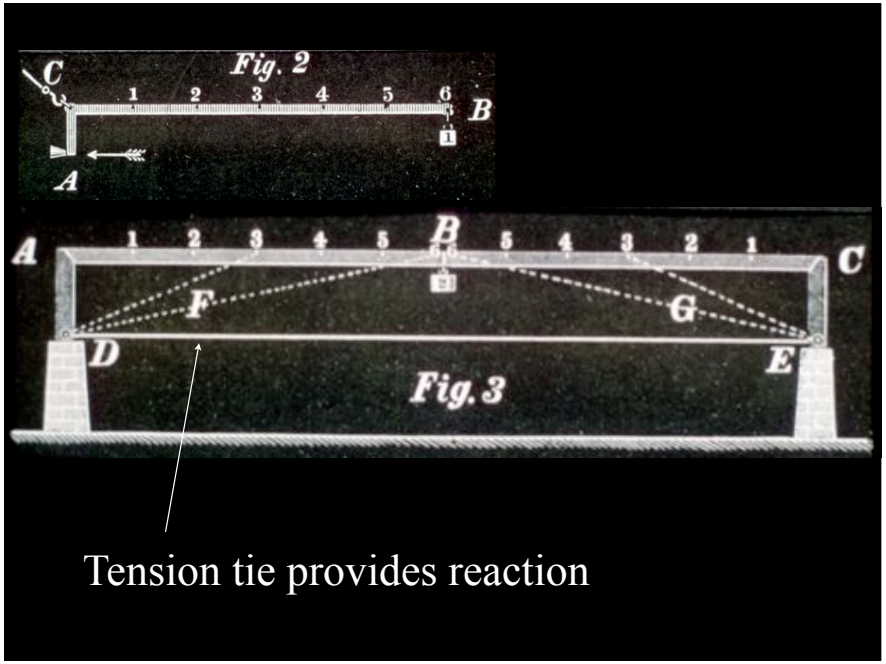


From a book written by Eads

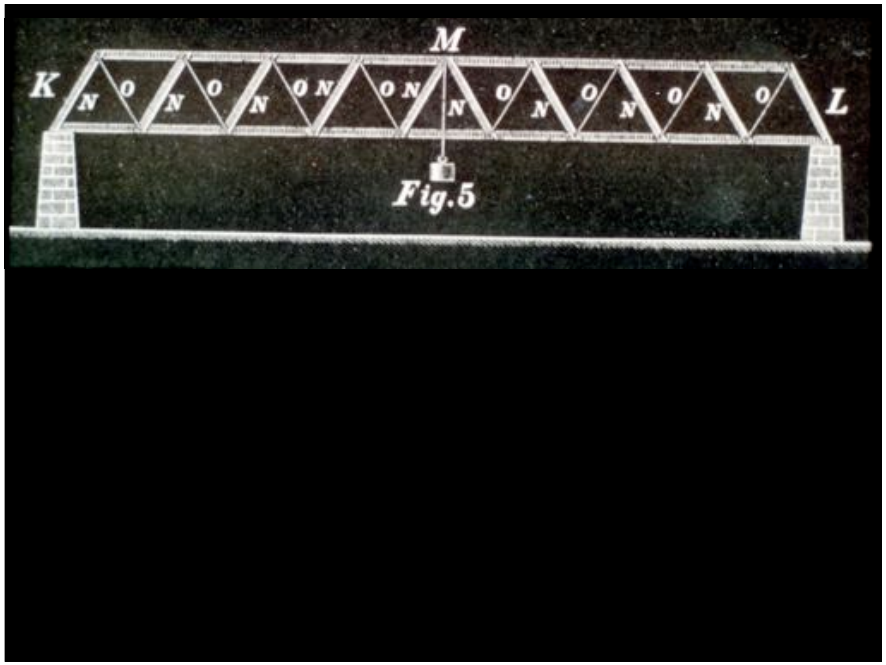
Q: Why doesn't this tip over?







Tension tie provides reaction


M
K
L
N O N O N ON ON N O N O N O N O
Fig.5

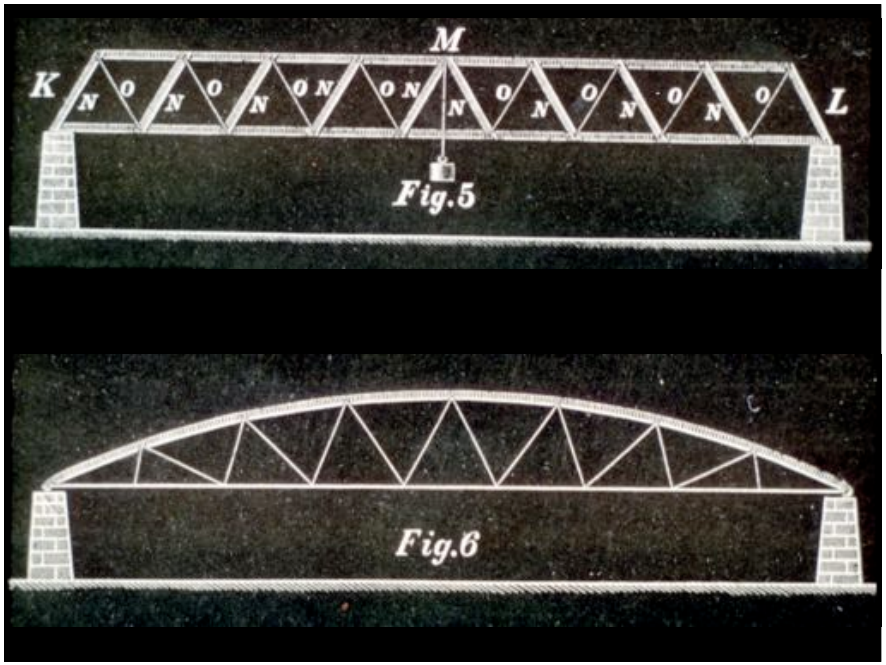

M
K
L
N O N O N ON ON N O N O N O N O
Fig.5

Fig.6

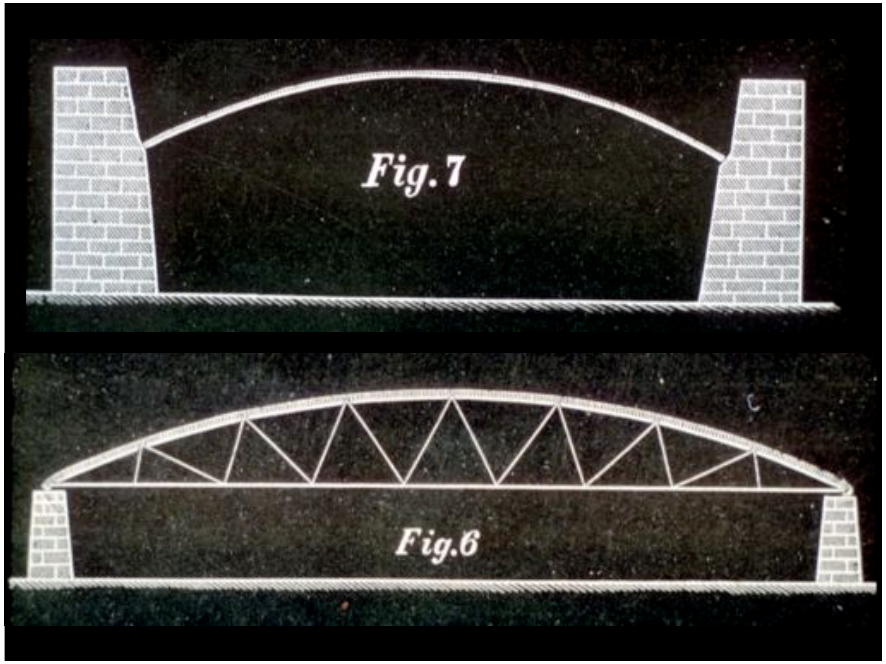


Fig.7
Fig.6

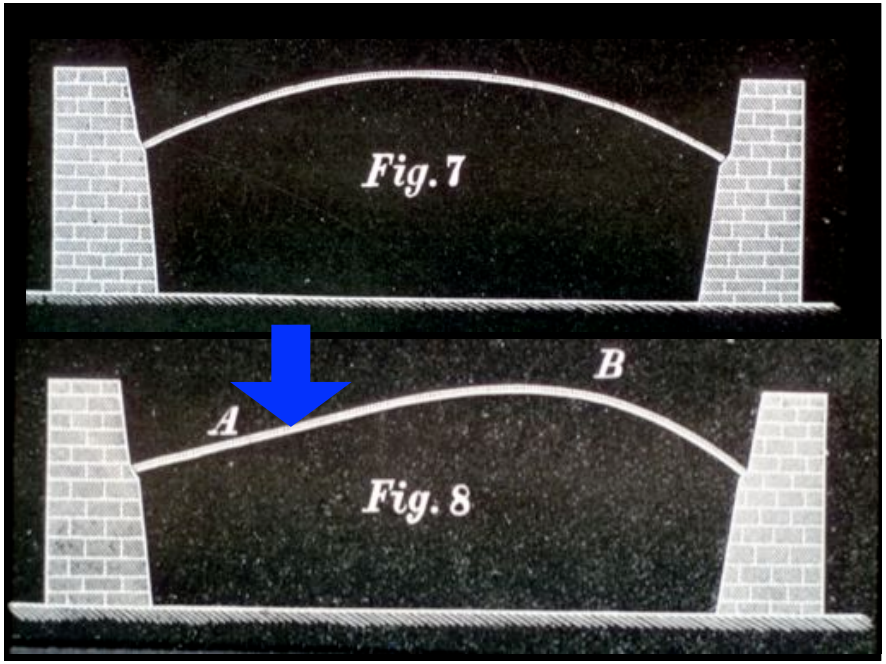


Fig.7
B
A
Fig. 8

Fig.9

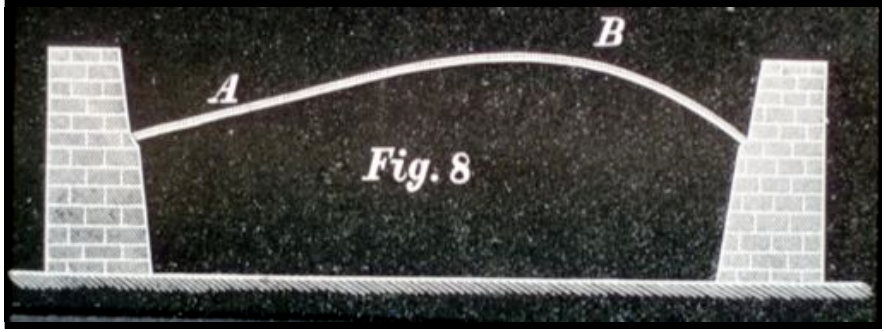


Fig. 8

Fig.9

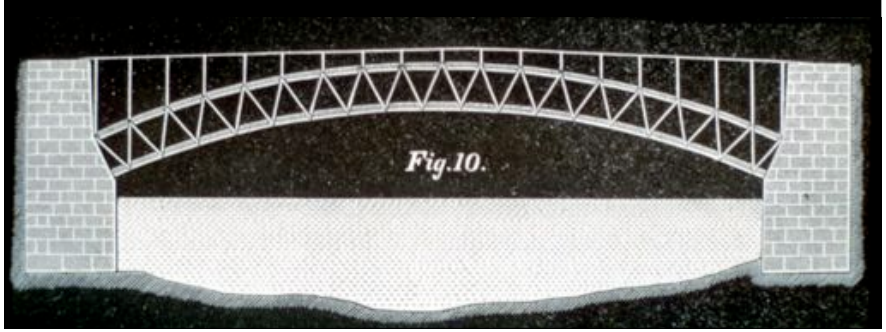
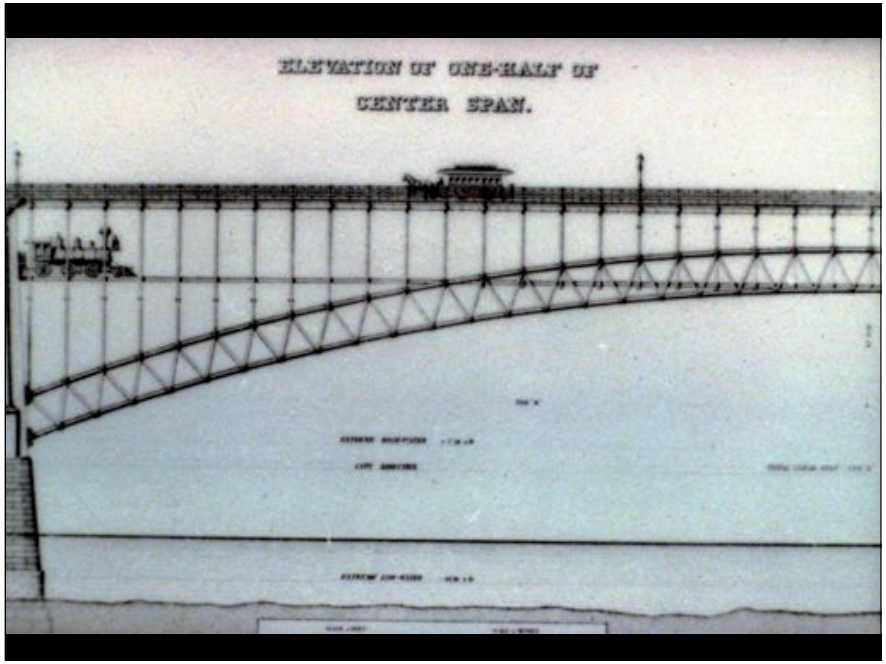
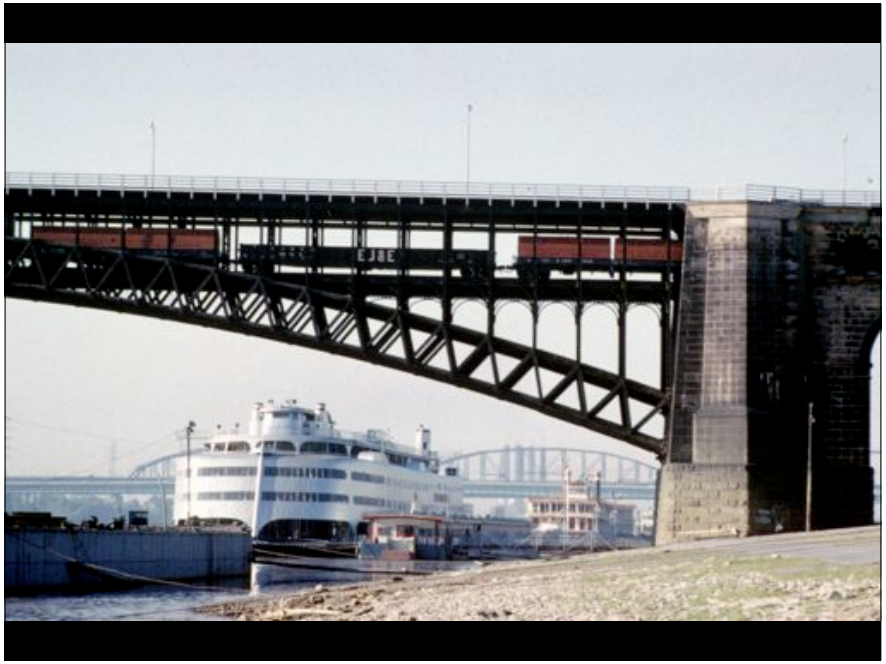
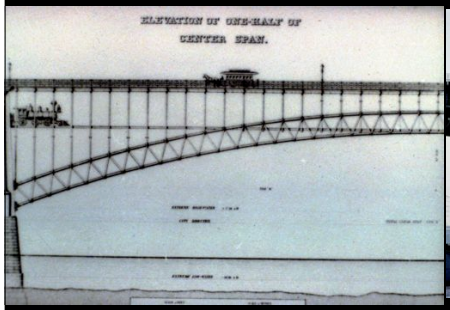
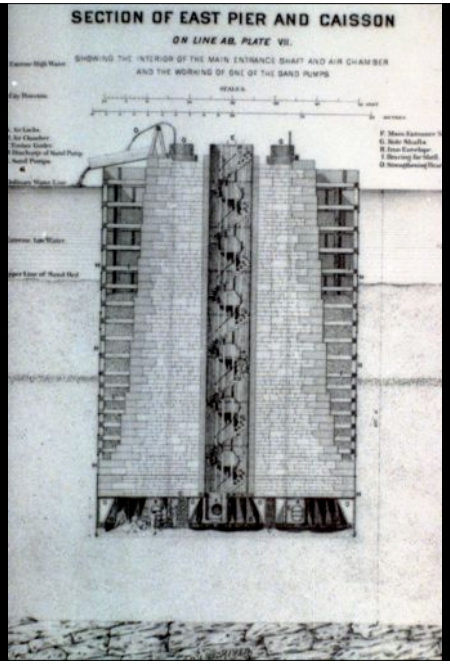


Fig.10.

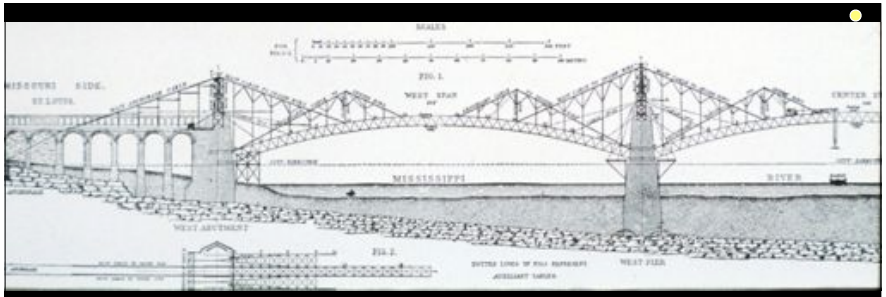


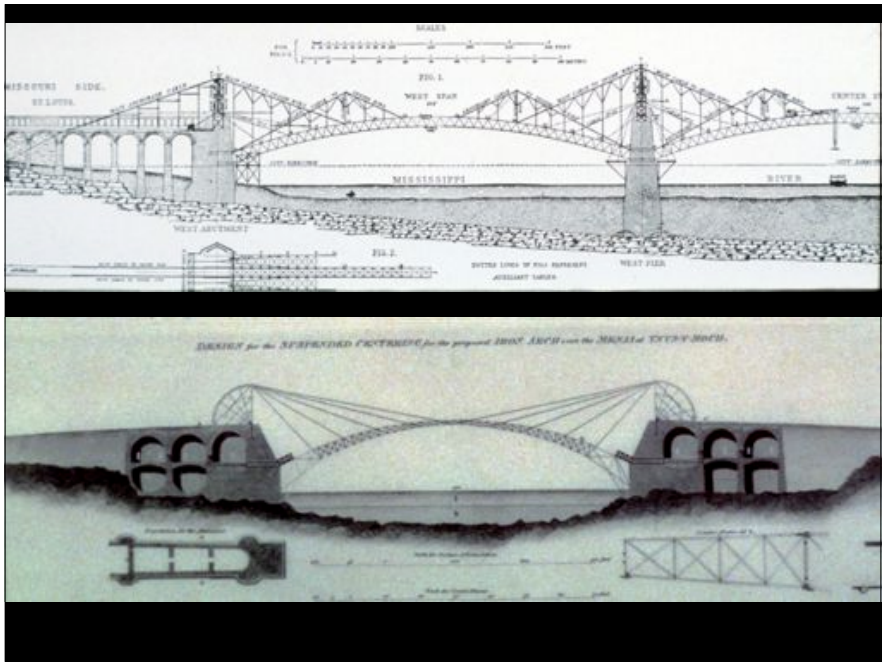






122 feet to bedrock

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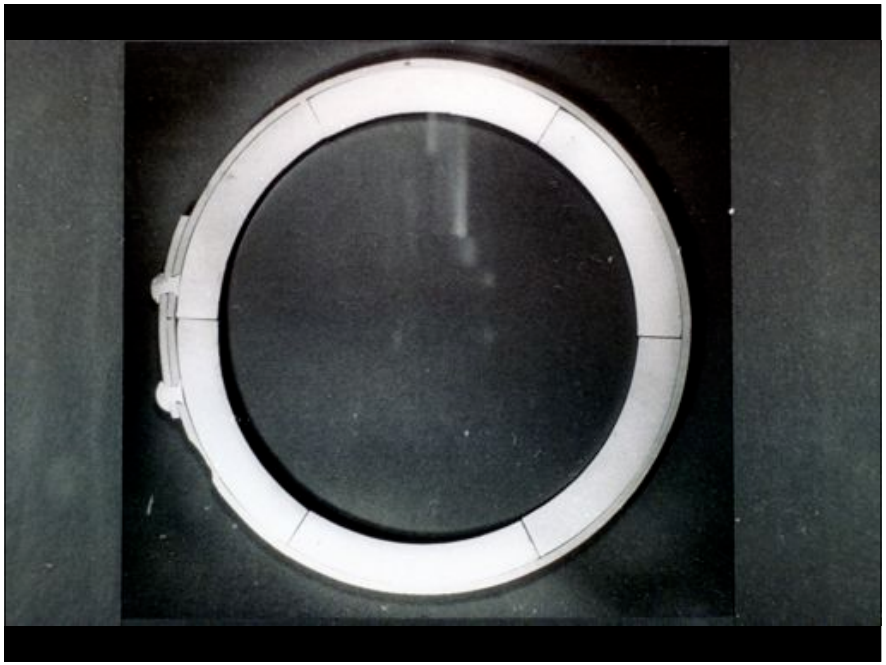
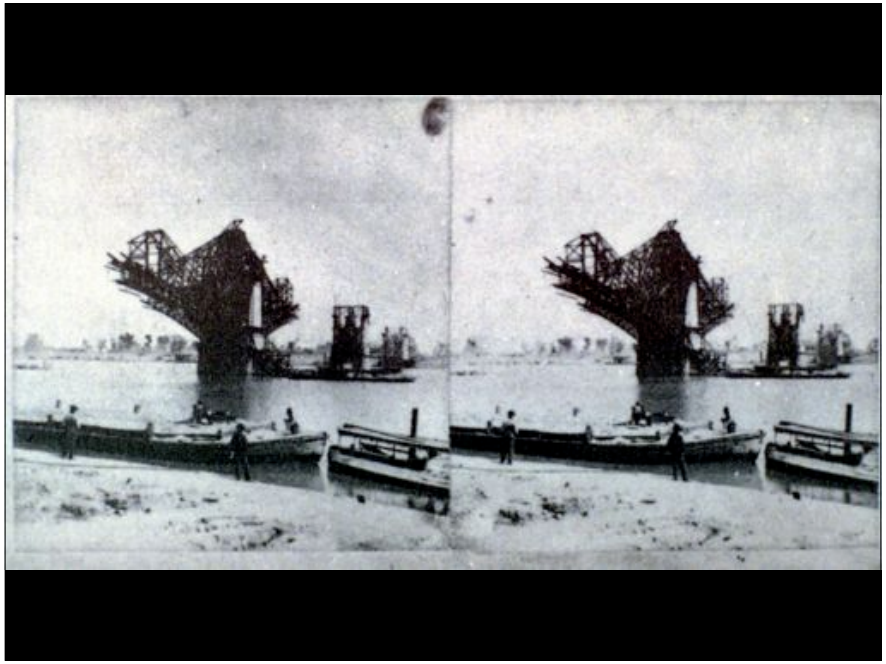
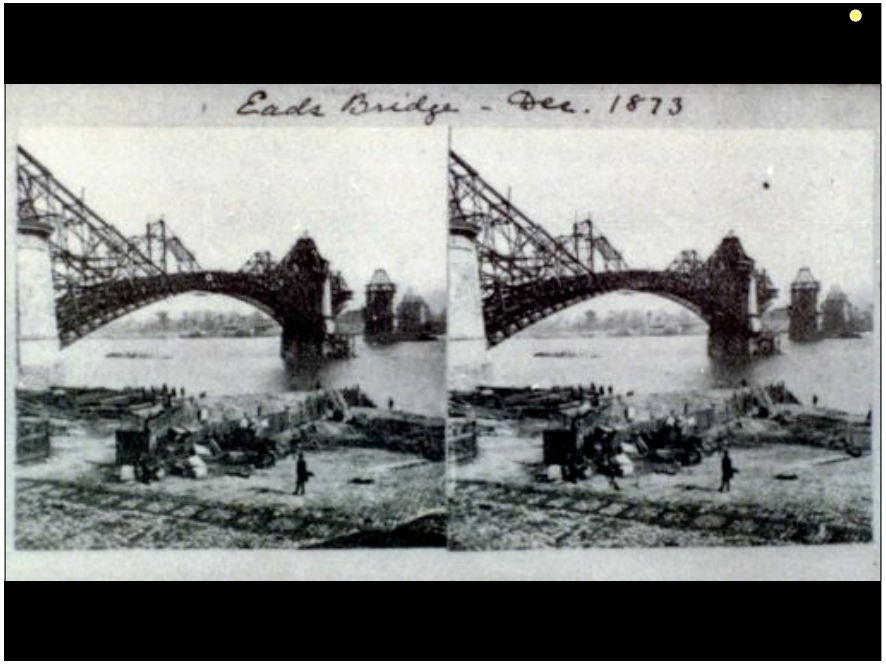
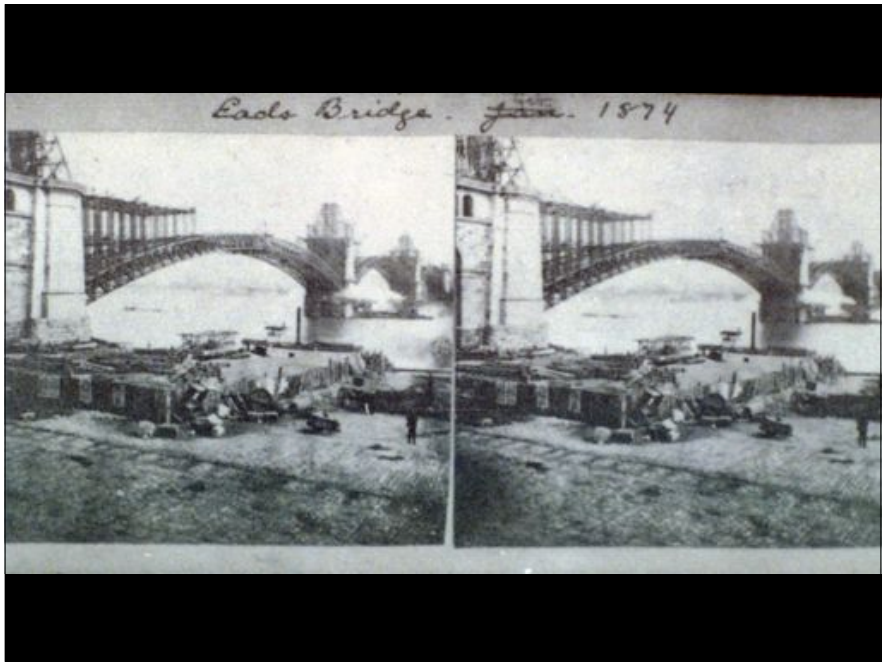
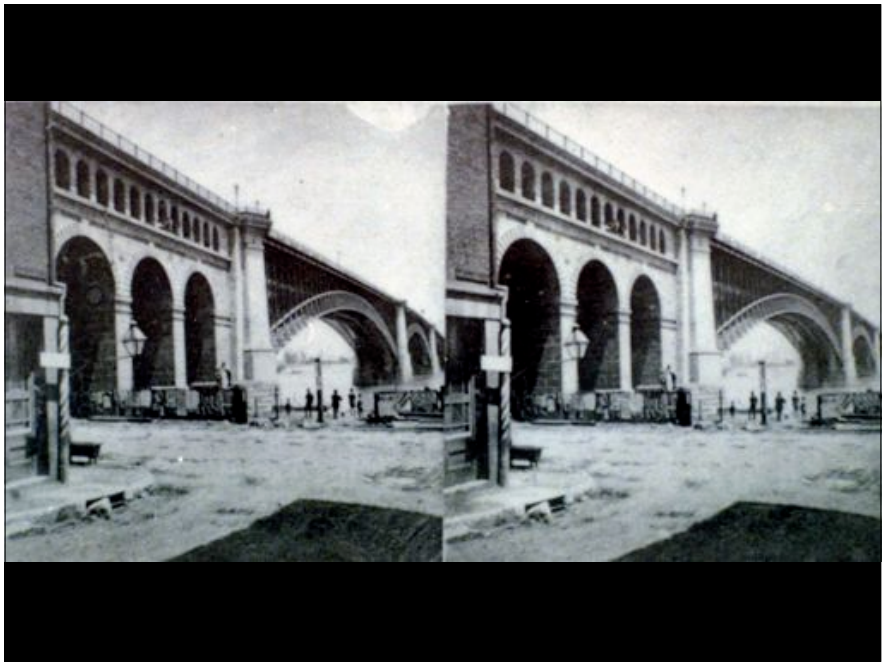
RIVER
WEST ABUTMENT
WEST PIER



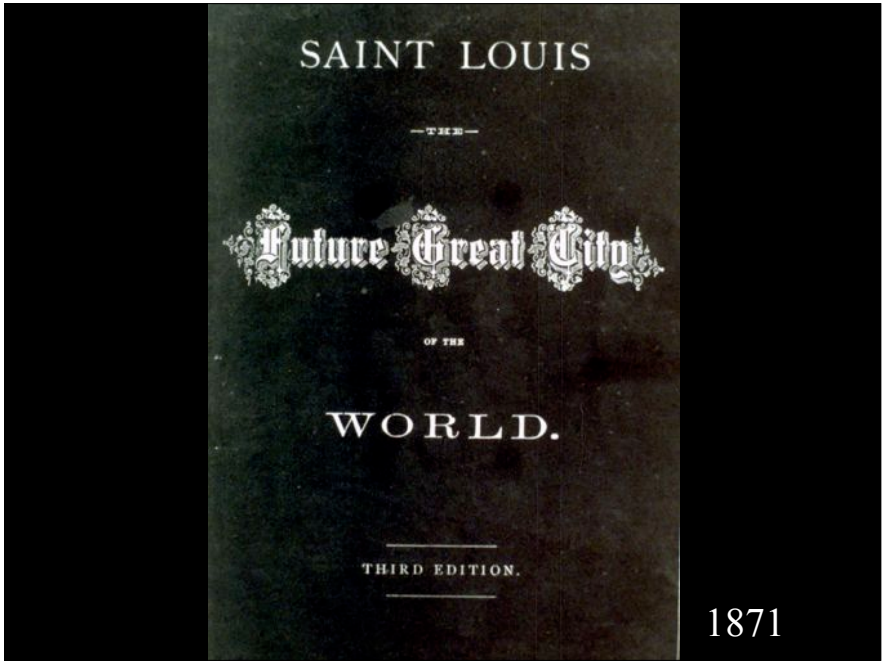



Eads Bridge - Dec. 1873


Eads Bridge. June. 1874



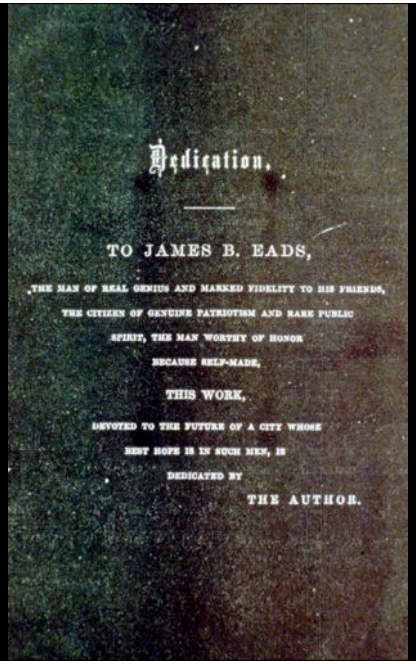

THE GREAT ST LOUIS BRIDGE.
ACROSS THE MISSISSIPPI RIVER.

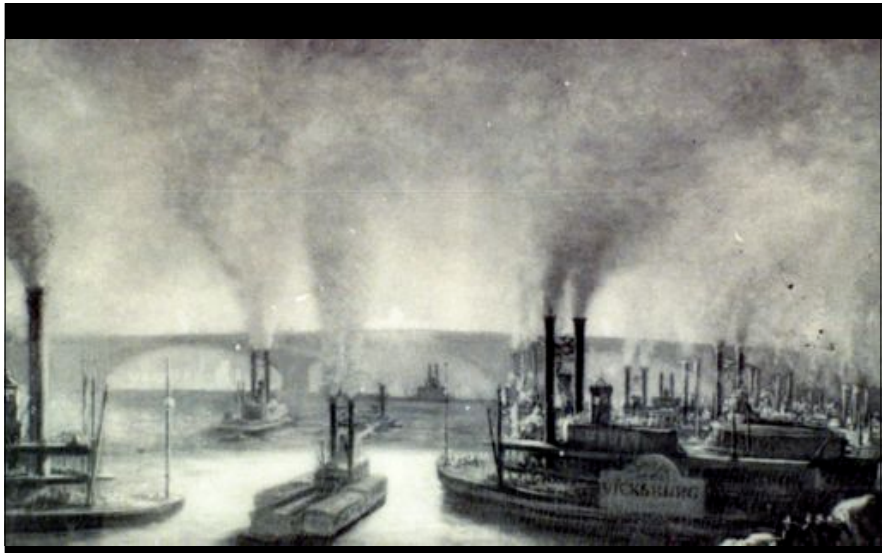

SAINT LOUIS
—THE—
Future Great City
OF THE
WORLD.
THIRD EDITION.

1871

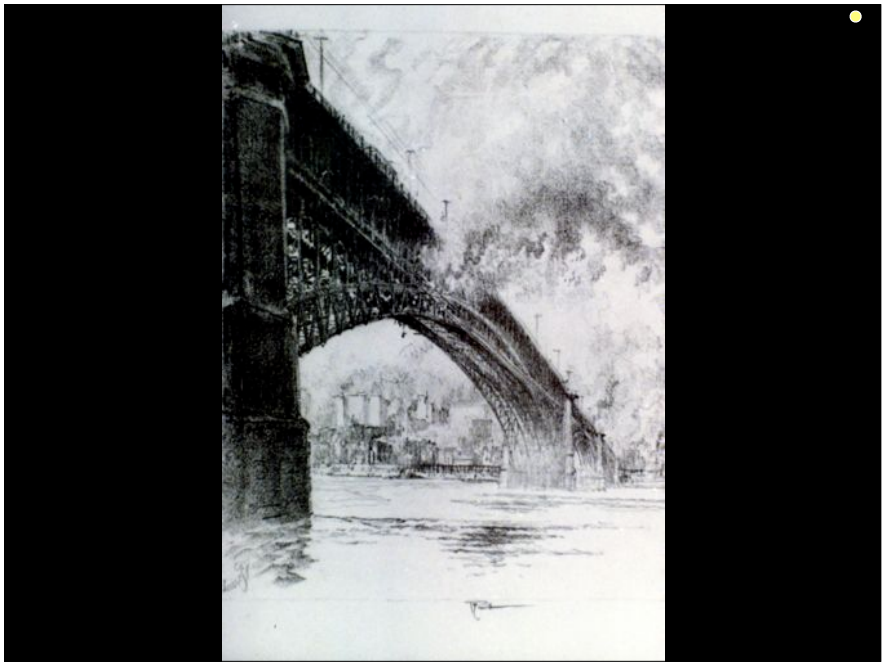
Population of St. Louis in 1870, per United States census						312,963
Population increased at the rate of 10 per cent per annum to 1880						811,742
"	"	"	9	"	"	1890 1,917,671
"	"	"	6	"	"	1900 3,464,079
"	"	"	4	"	"	1910 5,083,297
"	"	"	3	"	"	1920 6,831,502
"	"	"	3	"	"	1930 9,180,967
"	"	"	2	"	"	1940 11,192,633
"	"	"	2	"	"	1950 13,643,757
"	"	"	1	"	"	1960 15,071,194
"	"	"	1	"	"	1970 16,647,941

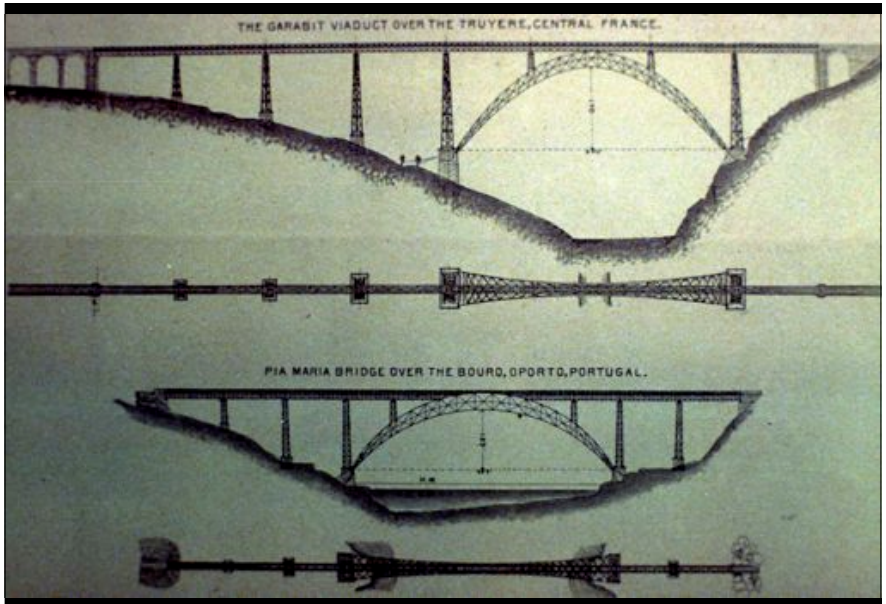
2002 population of the metropolitan area is 2,600,000



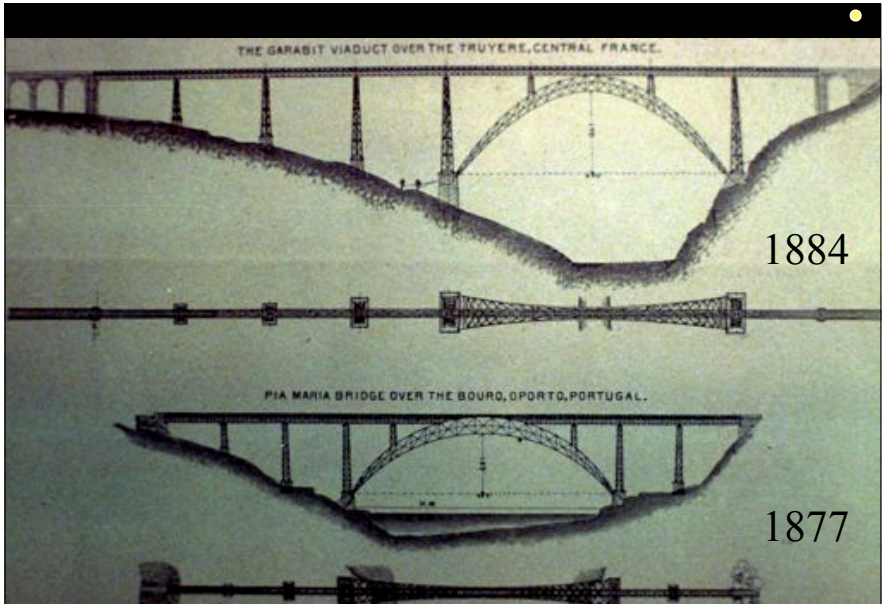


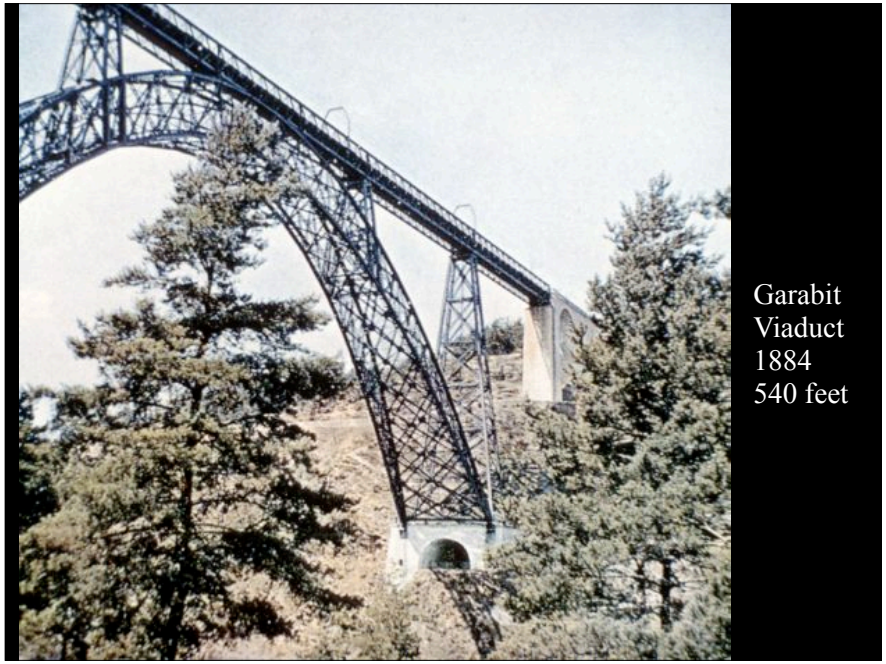
July 4, 1874



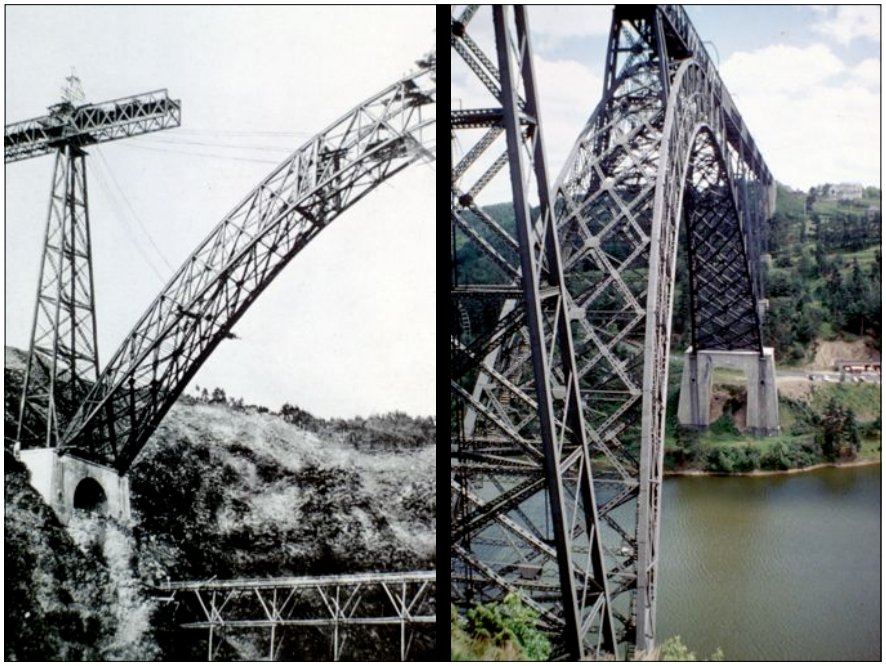


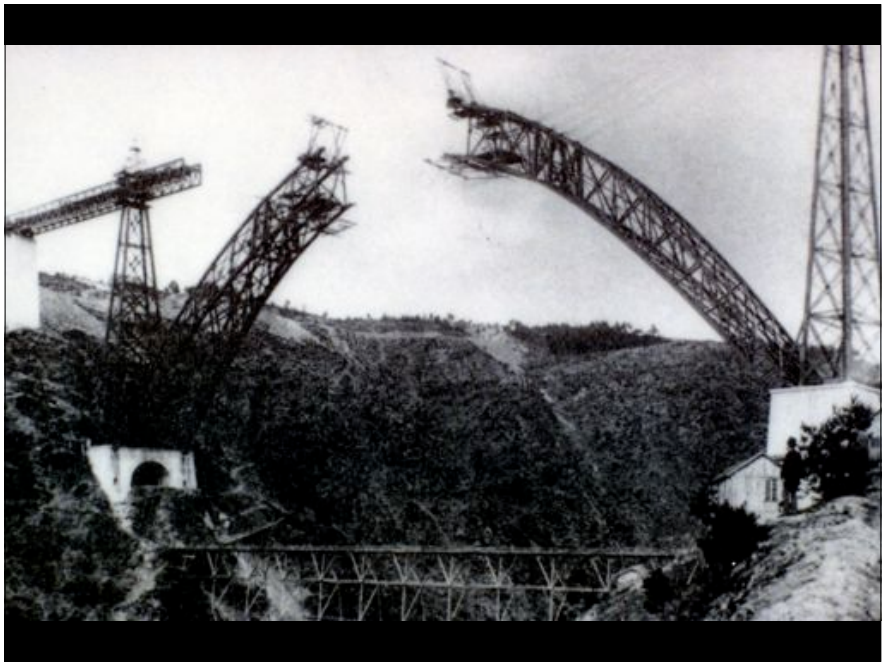
Can you identify differences?

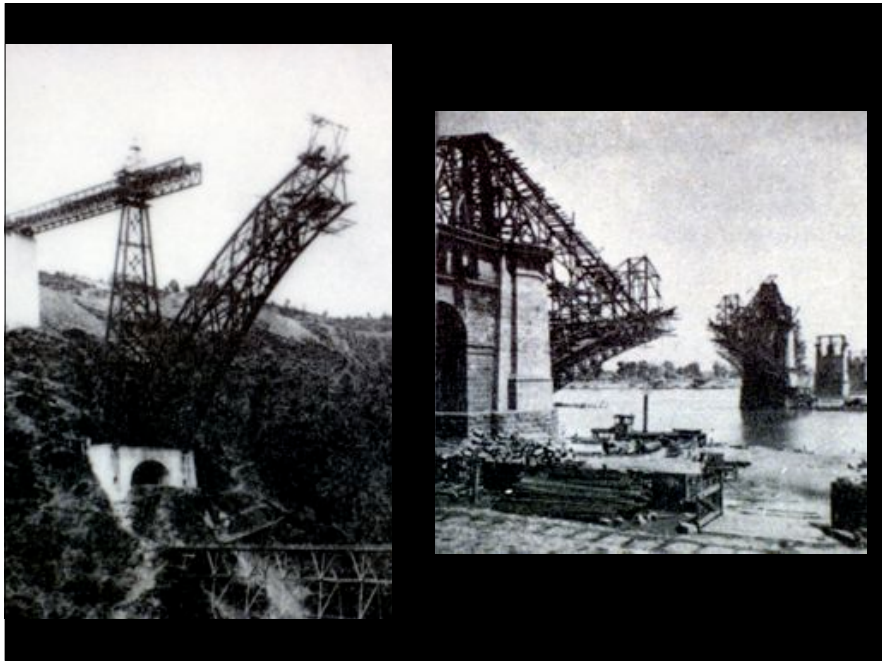




Garabit
Viaduct
1884
540 feet







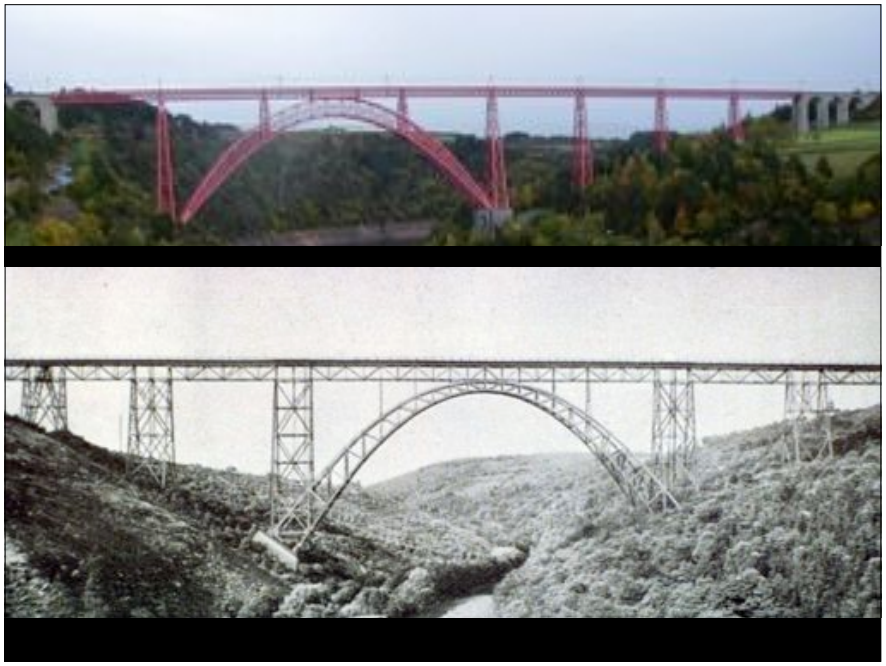
Koblenz

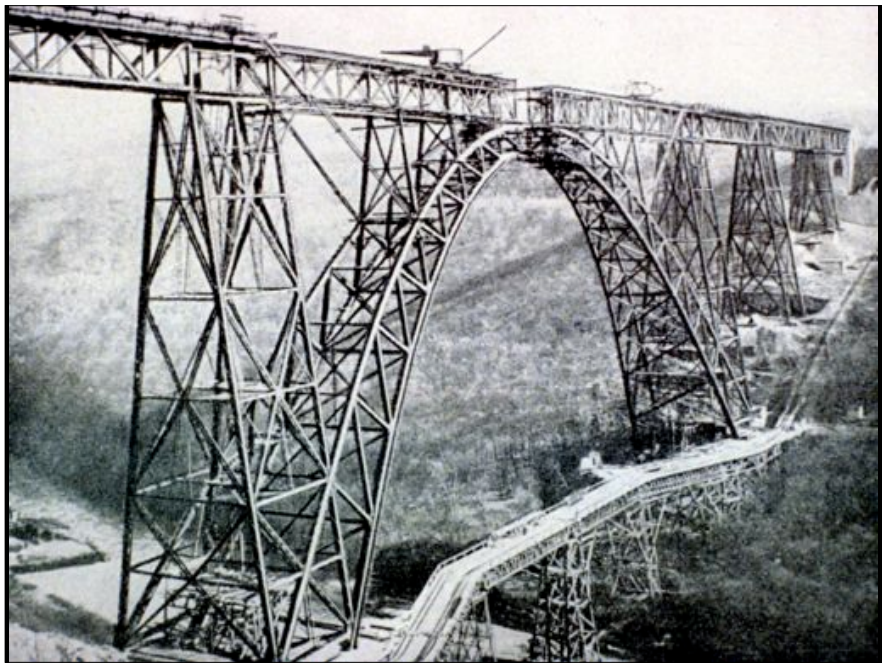
Eads

Pia Maria

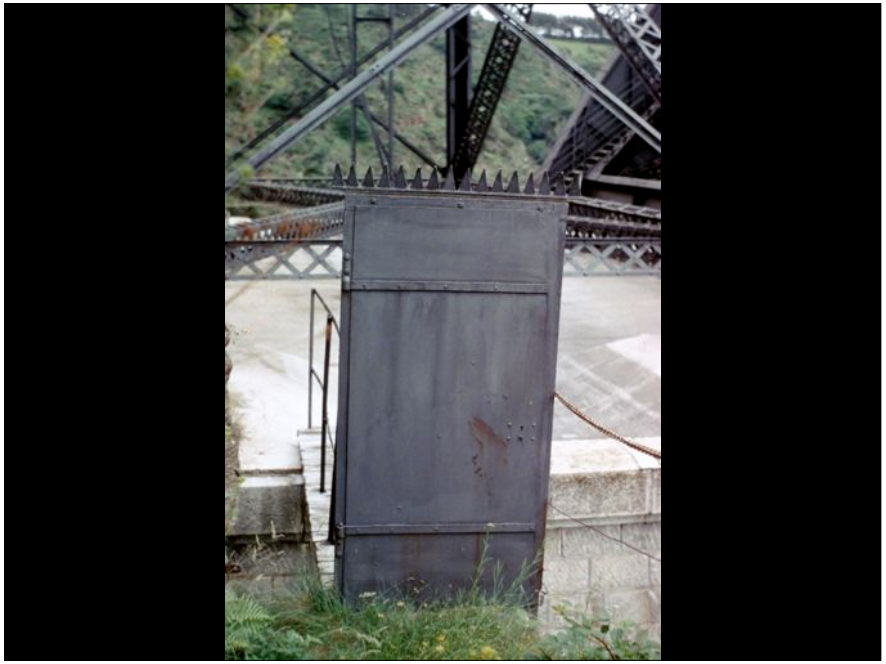
Garabit

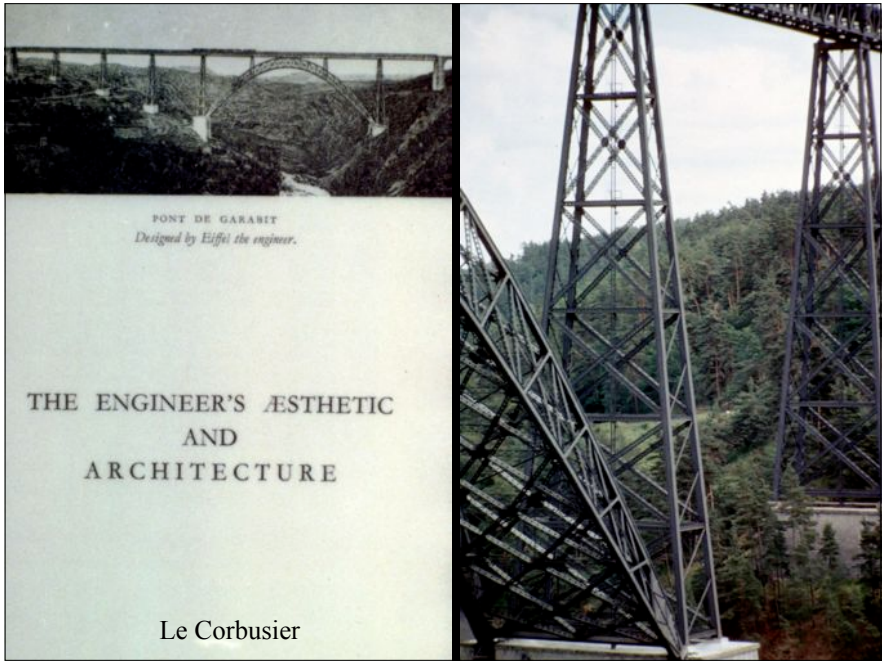
http://www.structurae.de/en/photos/img3815.php
Garabit Viaduct.
Photo by Jacques Mossot

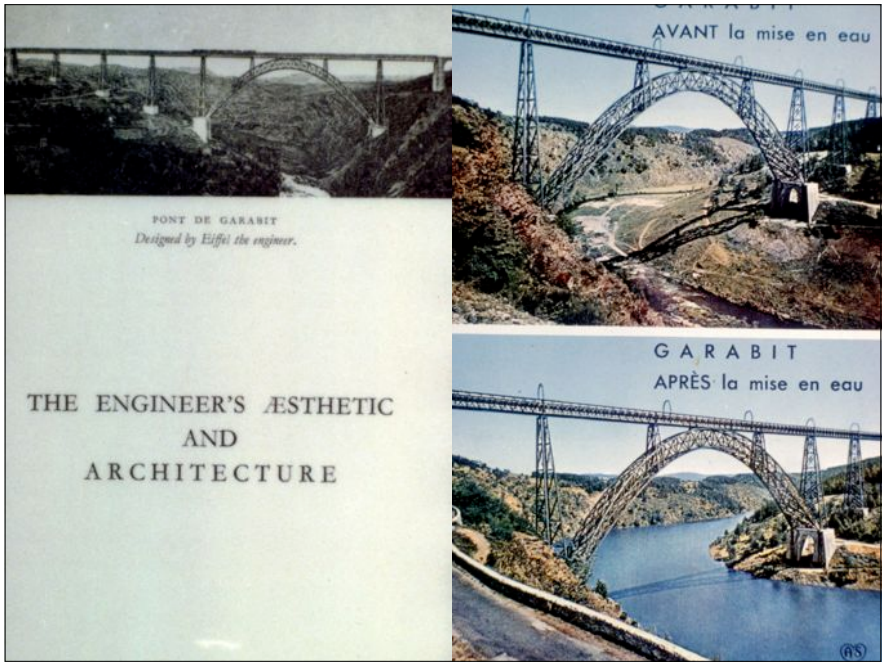





Garabit




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
AVANT la mise en eau
GARABIT
APRÈS la mise en eau


United
Kingdom
Ireland
Netherlands
Belgium


Firth of Tay
Firth of Forth

Court of inquiry proceedings, for Sir Thomas Bouch

re: collapse of the Firth of Tay Br.

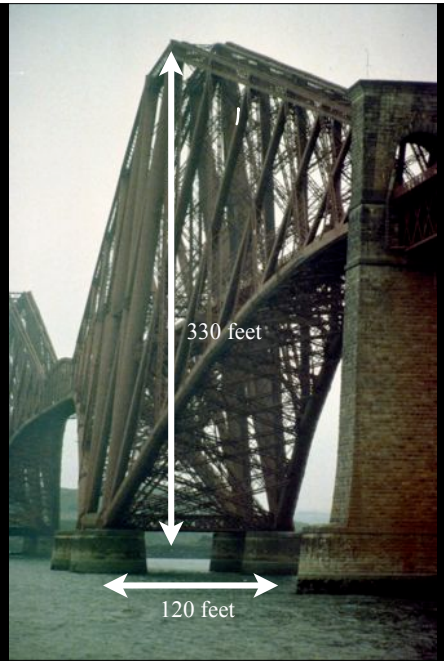
Q: Sir Thomas, did you in designing this bridge, make any allowance at all for wind pressure?

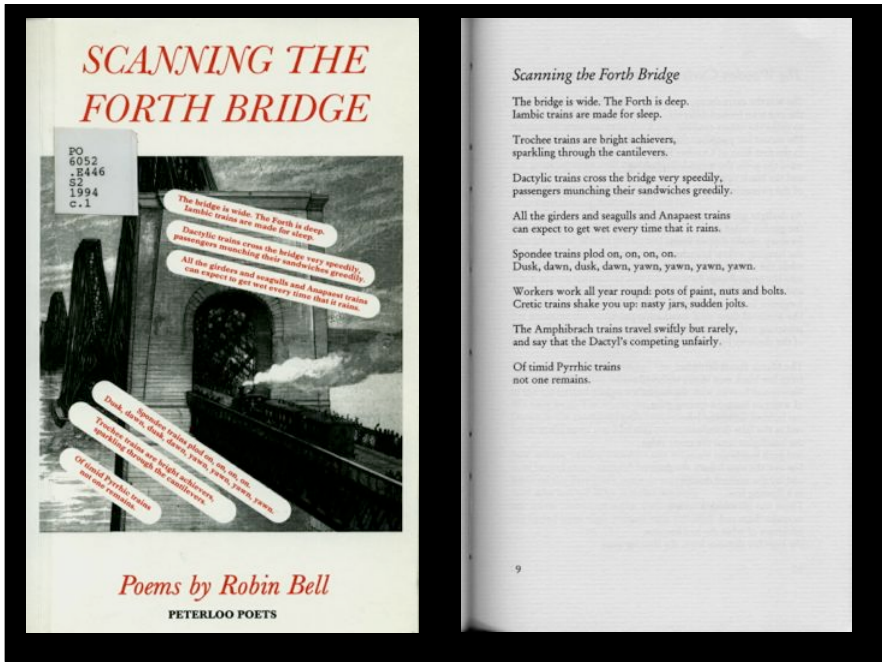
A: Not specially.

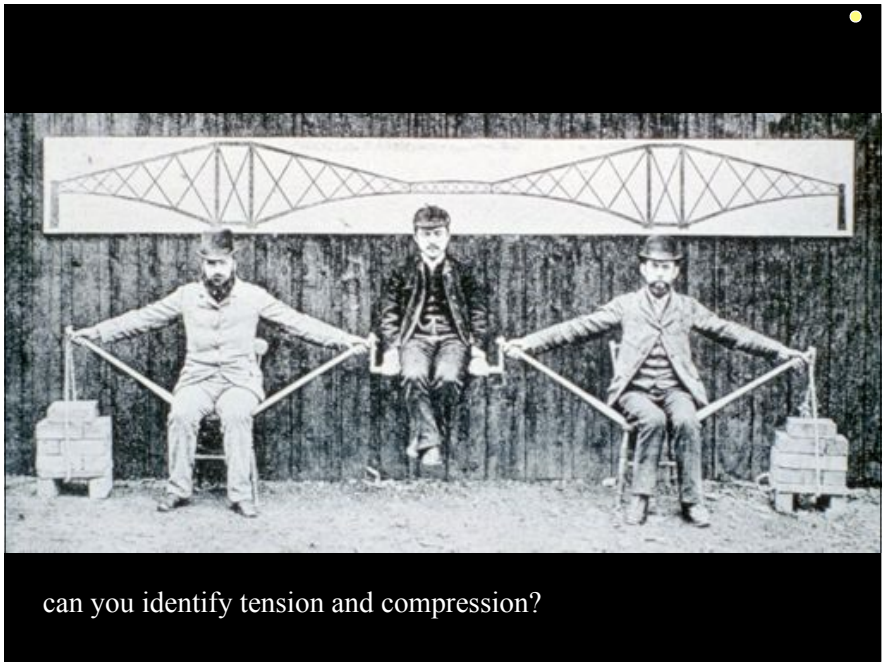
Q: You made no allowance?

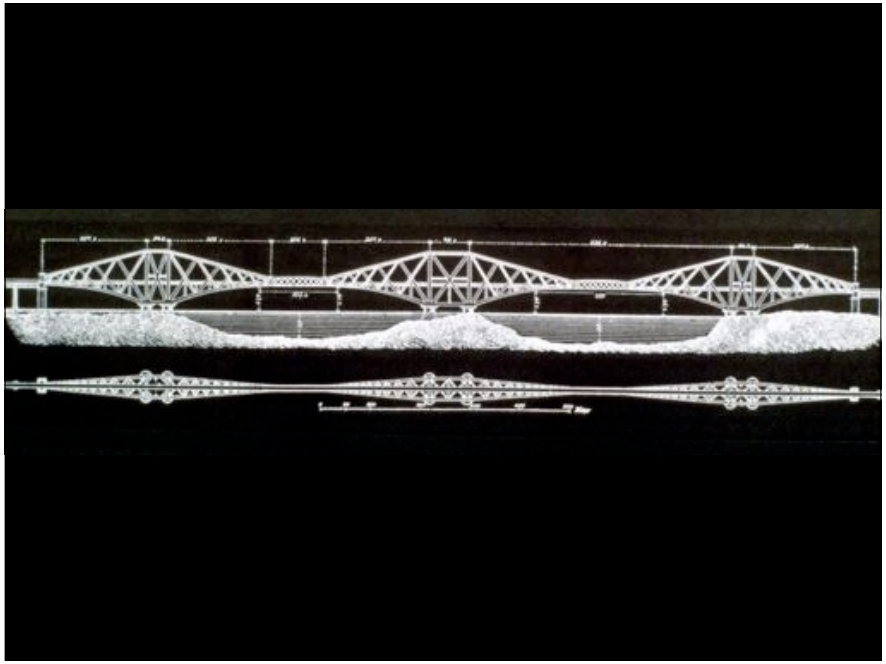
A: Not specially.

Firth of Forth Bridge - Benjamin Baker - 1890 - 1710 feet




SCANNING THE FORTH BRIDGE
PO 6052 .E446 S2 1994 c.1
The bridge is wide. The Forth is deep. Iambic trains are made for sleep.
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. Dusk, dawn, dusk, dawn, yawn, yawn, yawn, yawn.
Trochee trains are bright achievers, sparkling through the cantilevers.
Of timid Pyrrhic trains not one remains.
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.
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.
9


can you identify tension and compression?



Social-Scientific-Symbolic

Eads Br.
Garabit Br.
Forth Br.

Economy-Efficiency-Elegance

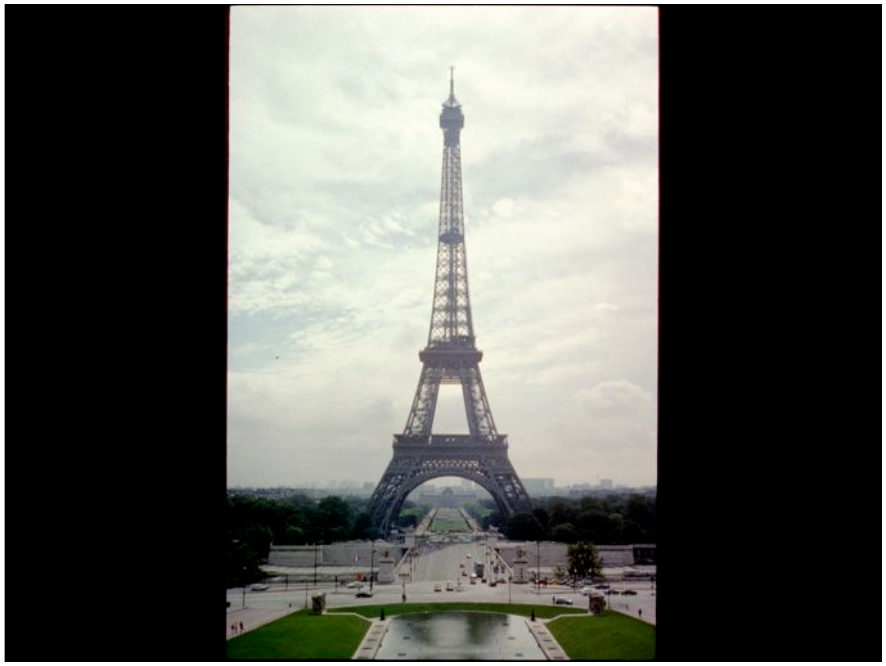
Eiffel Tower Structural Study

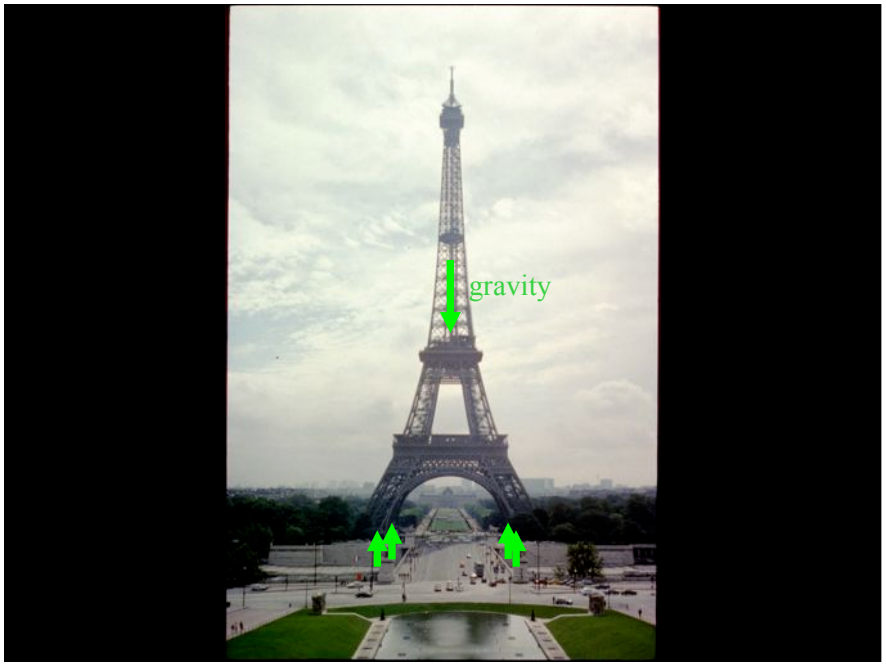
introduction to statics

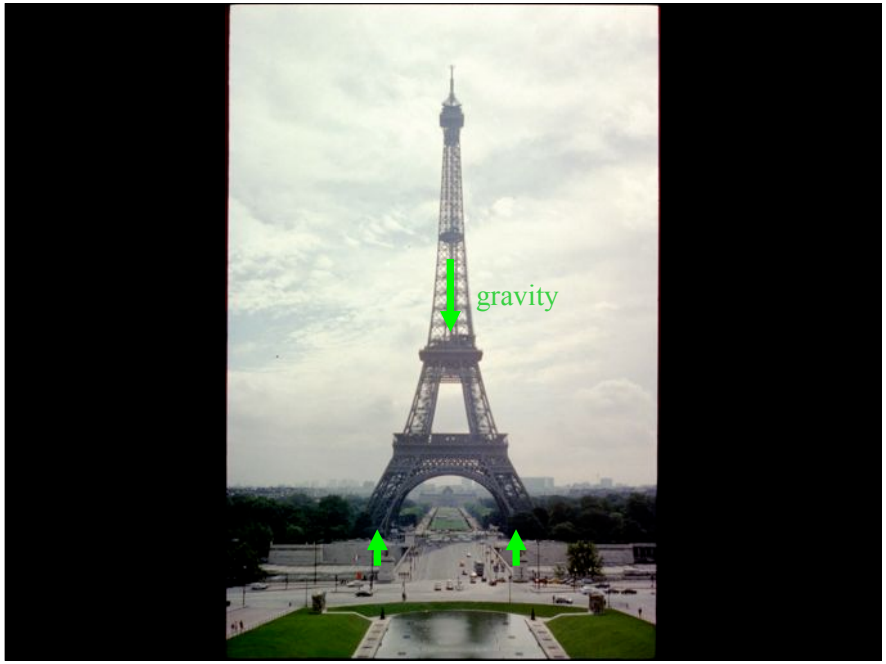
Tools and methods for structural analysis

Free body diagrams
Equilibrium
Load path

Free Body Diagrams




gravity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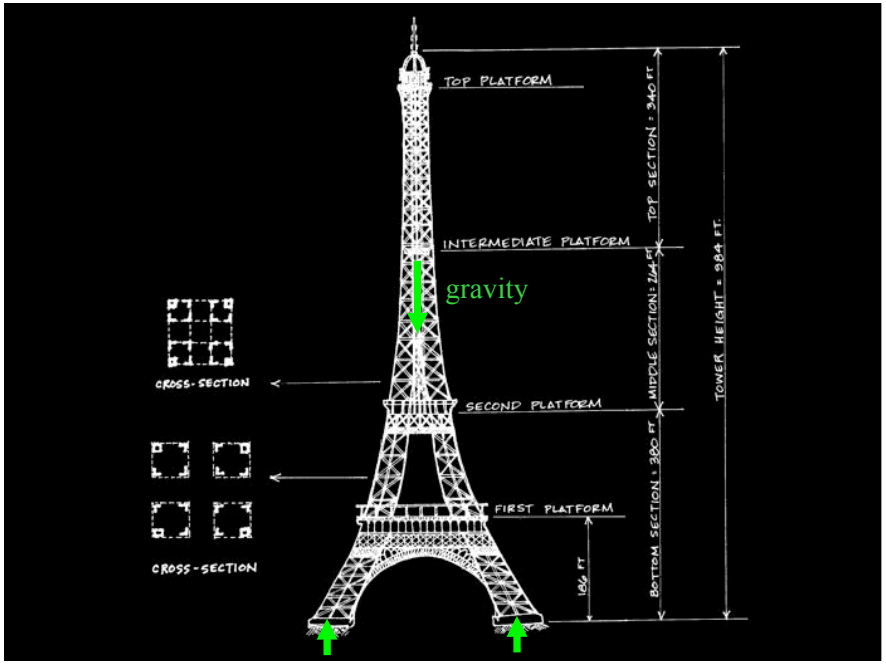
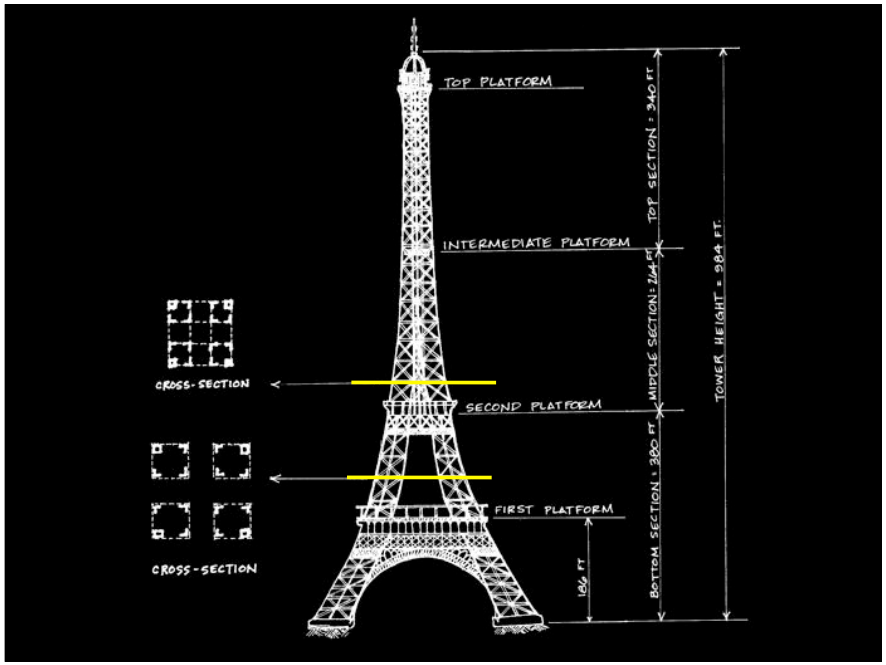
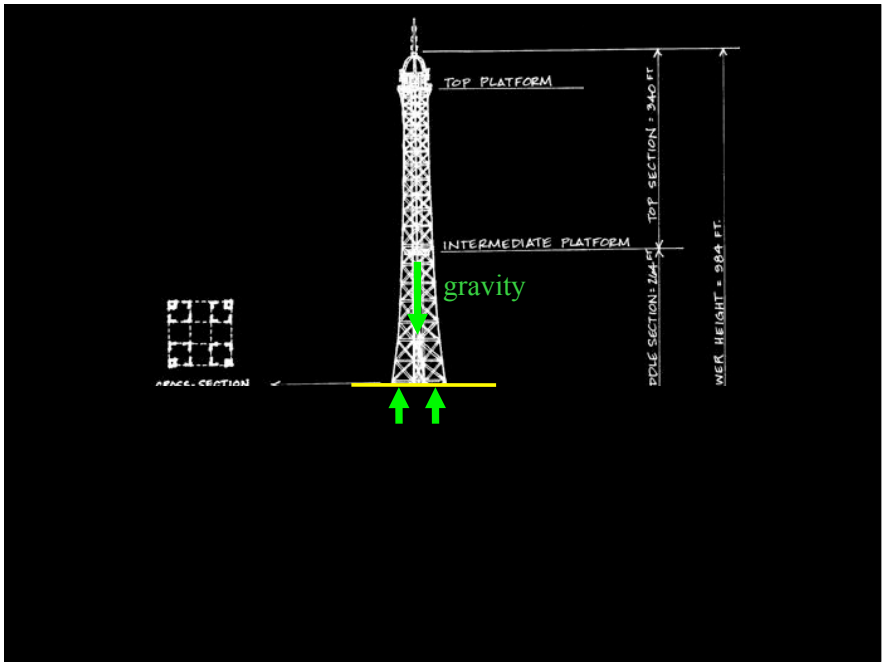

TOP PLATFORM
INTERMEDIATE PLATFORM
gravity
SECOND PLATFORM
FIRST PLATFORM
CROSS-SECTION
CROSS-SECTION
TOP SECTION = 340 FT.
MIDDLE SECTION = 344 FT.
BOTTOM SECTION = 380 FT.
186 FT
TOWER HEIGHT = 984 FT.


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


TOP PLATFORM
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gravity
TOP SECTION = 340 FT.
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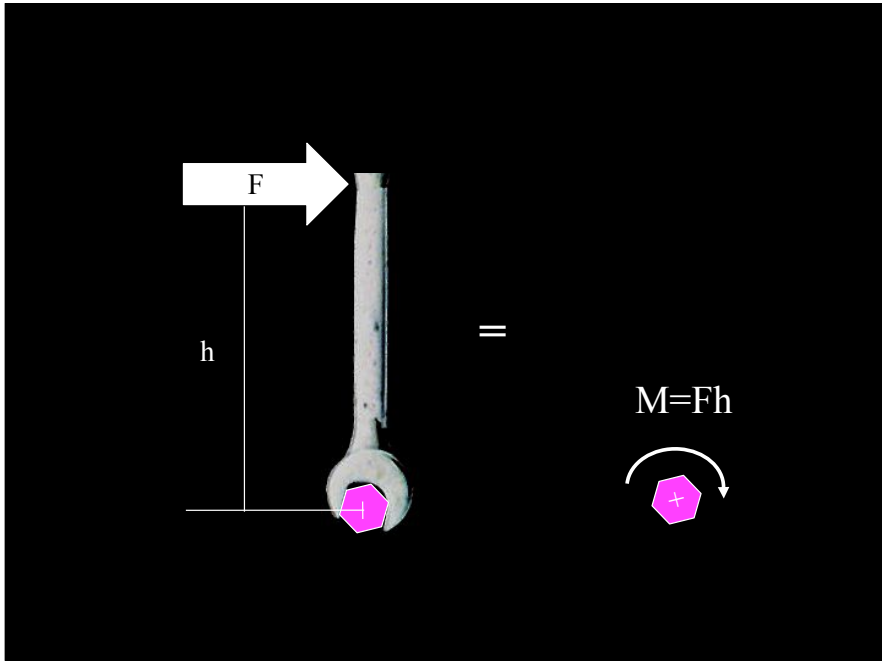
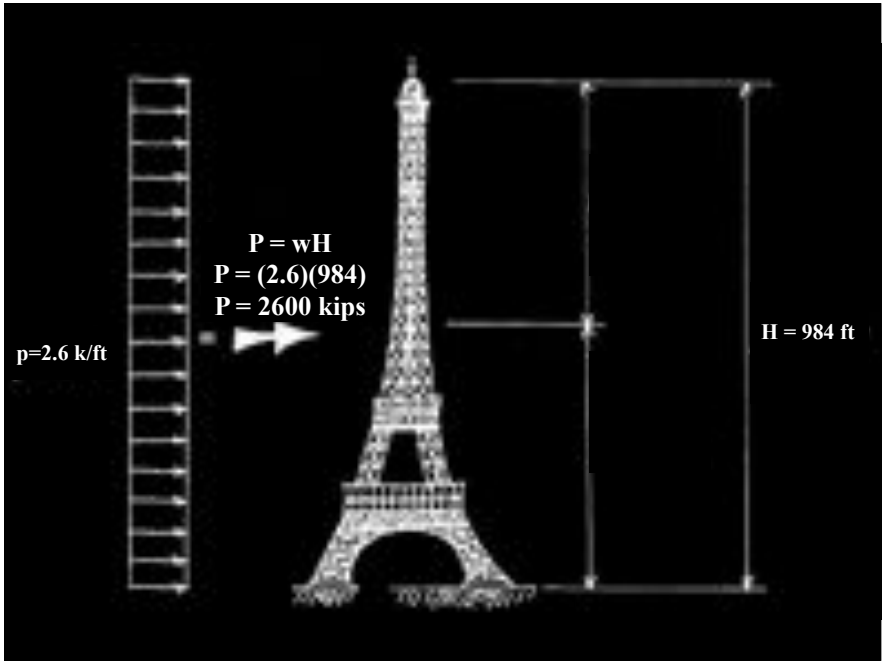
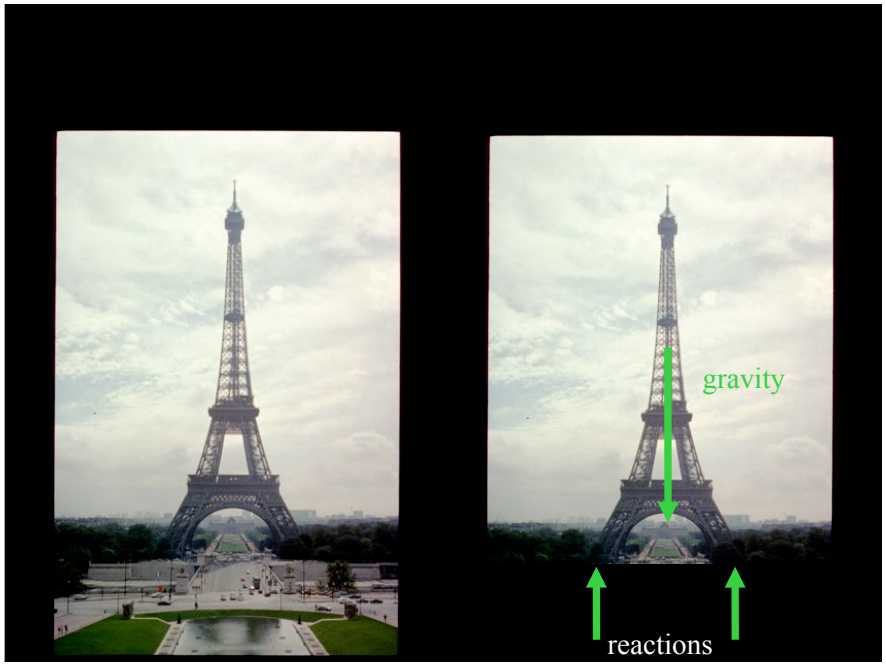
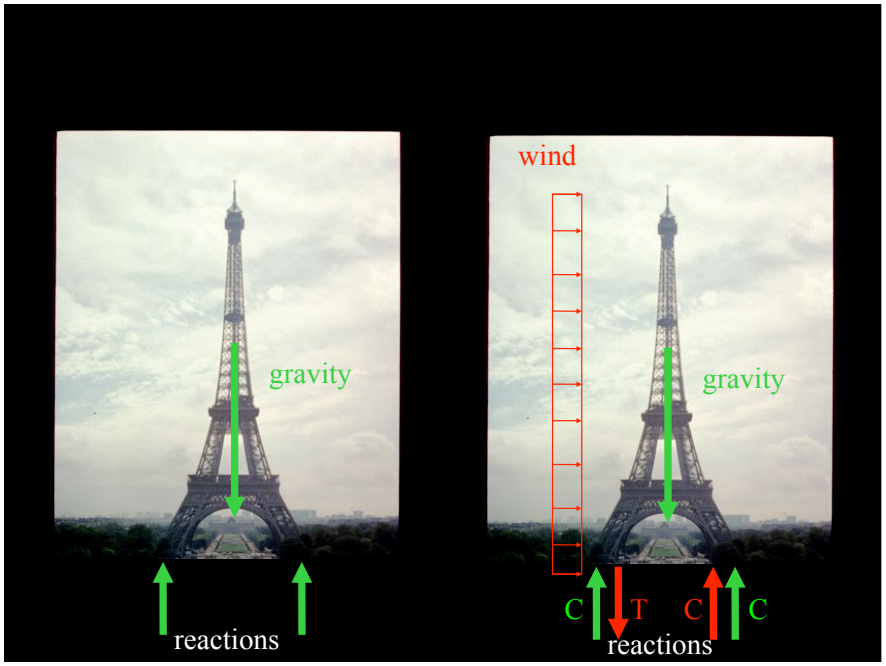
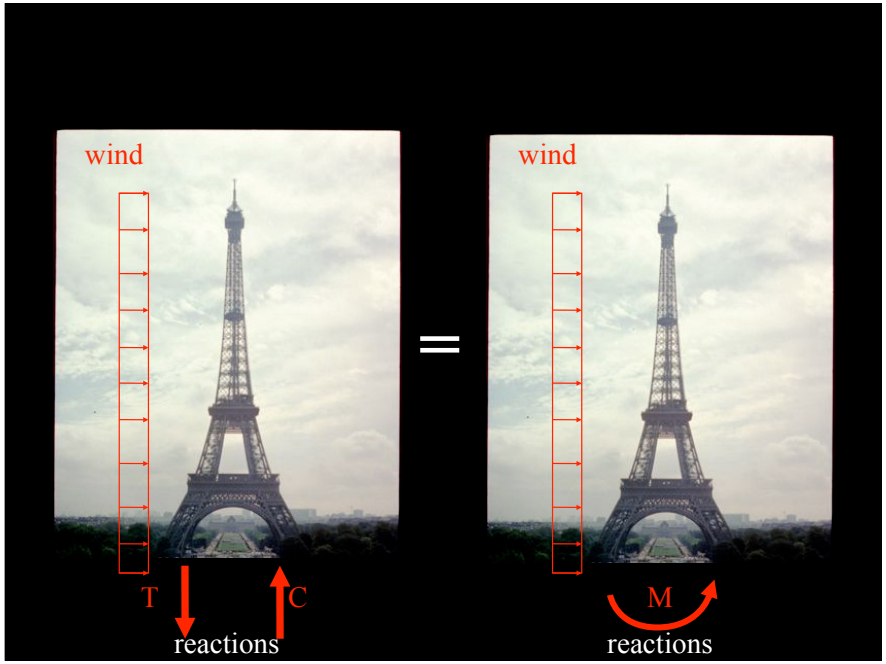
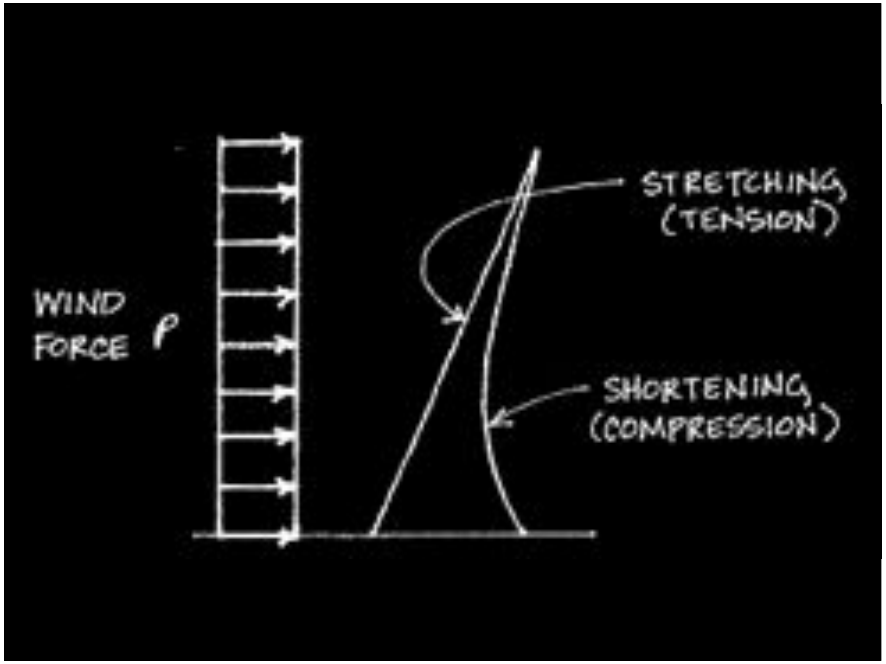

F
h
=
M=Fh

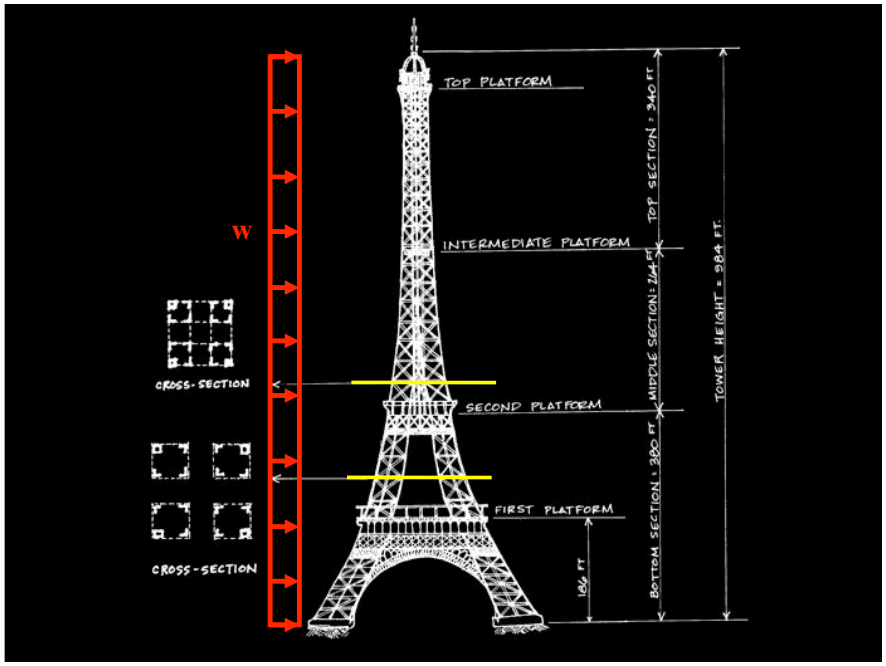

P = wH
P = (2.6)(984)
P = 2600 kips
p=2.6 k/ft
H = 984 ft

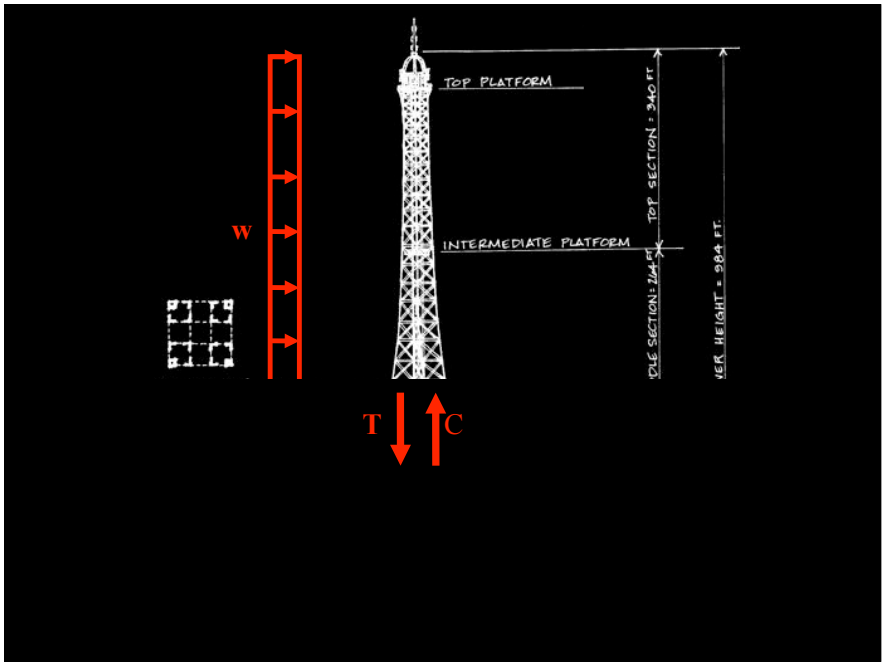

gravity
reactions

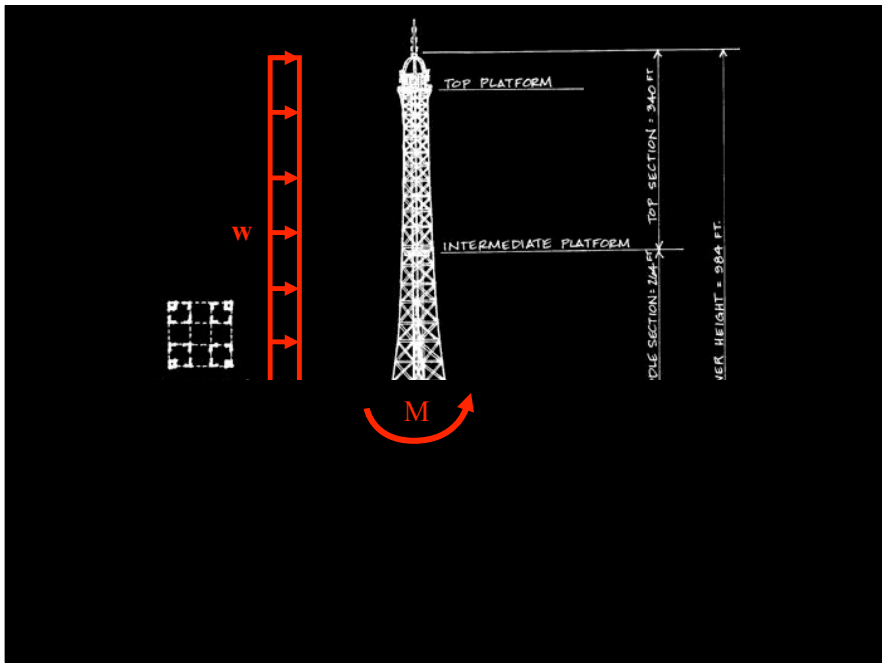

gravity
reactions
wind
gravity
C
T
C
C
reactions


wind
T
C
reactions
=
wind
M
reactions


WIND
FORCE
p
STRETCHING
(TENSION)
SHORTENING
(COMPRESSION)



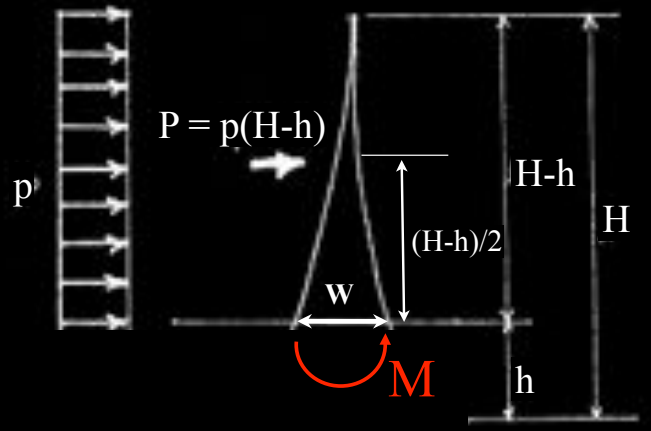




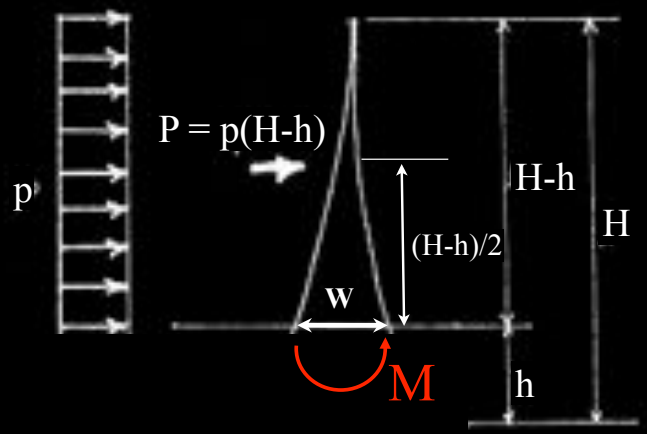
Civil Engineering Units

- 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

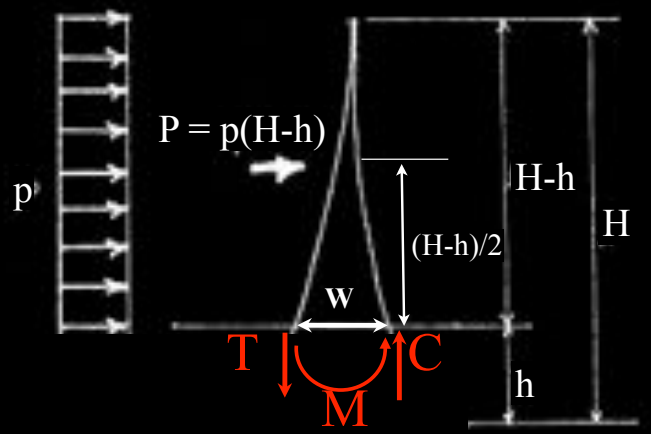


$\Sigma M_{section} = 0 \rightarrow M - p(H-h)(H-h)/2 = 0$



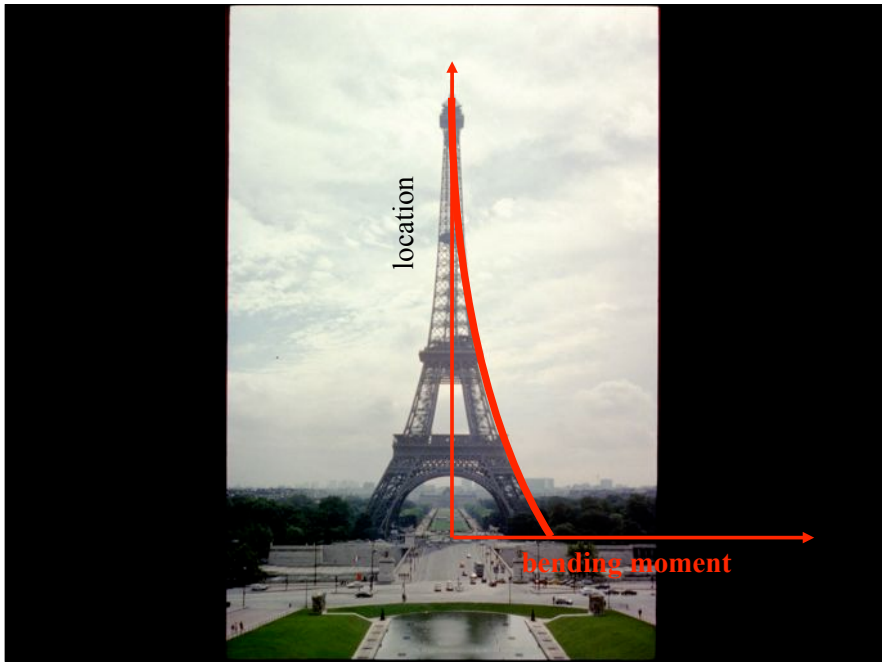
$\Sigma M_{section} = 0 \rightarrow M - p(H-h)(H-h)/2 = 0$

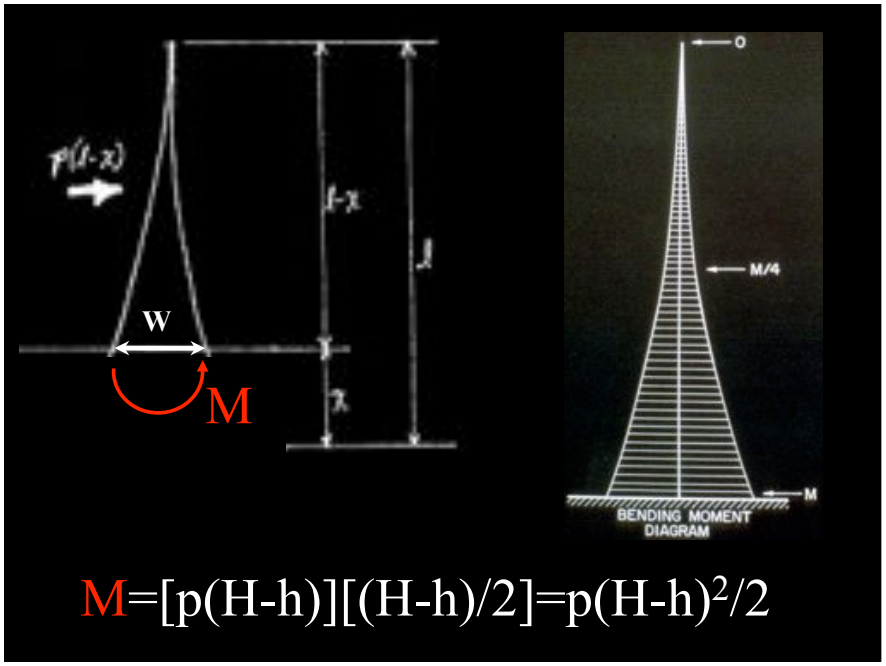
$M=[p(H-h)][(H-h)/2]=P(H-h)/2$



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

$C = -T = M/w$





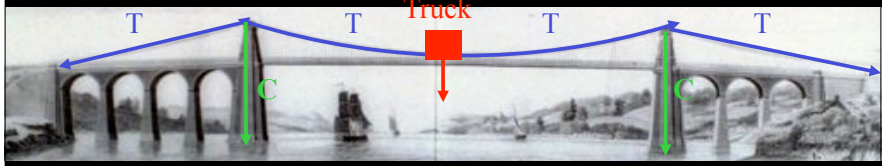
$M=[p(H-h)][(H-h)/2]=p(H-h)^2/2$

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?



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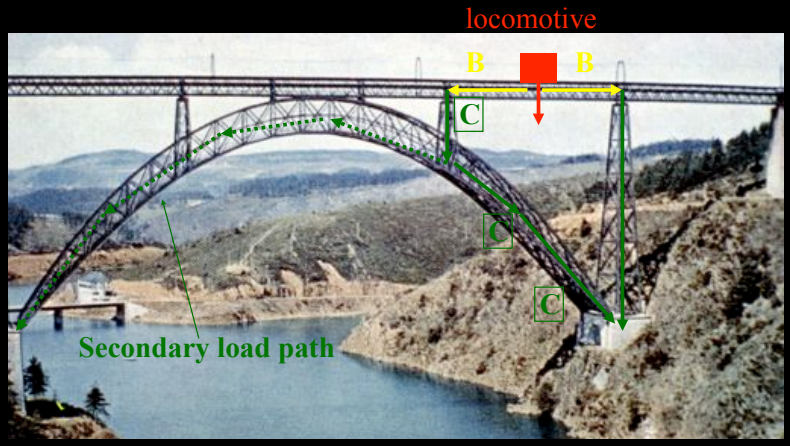

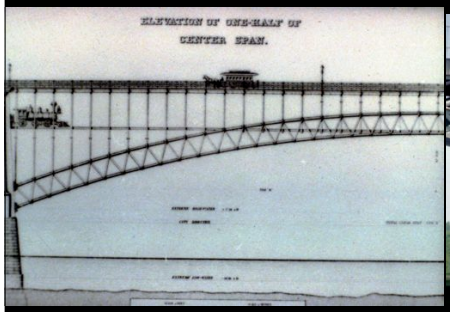

Pick the person on the railing, the carriage, or the locomotive -
describe the load path for the force you have selected...