Thomas Telford and the Modern Metal Bridge

Engineer as Artist – Efficiency, Economy, Elegance

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Computers for notetaking and course-related searches only

Independence, Iron and Industry
1776 - 1855

Telford
and the Metal Bridge

Watt, Fulton
and the Steamboat

Lowell, Francis
and American Textiles

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Canal and Aqueduct

First Navigable Aqueduct - 1761

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Restructuring of Nature

British Metal Forms

Science - new material
IRON

Social - new economy
INDUSTRIALIZATION

Symbolic - new vision
STRUCTURAL ART

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Science - new material
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Social - new economy
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‘Afternoon View at Coalbrookdale’
Where industrial revolution begins

INDUSTRIALIZATION*

Natural resources – coal and iron

Factory system – citizen wealth

Island isolation – strong Navy

*Arnold Toynbee's analysis

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The Iron Bridge of 1779

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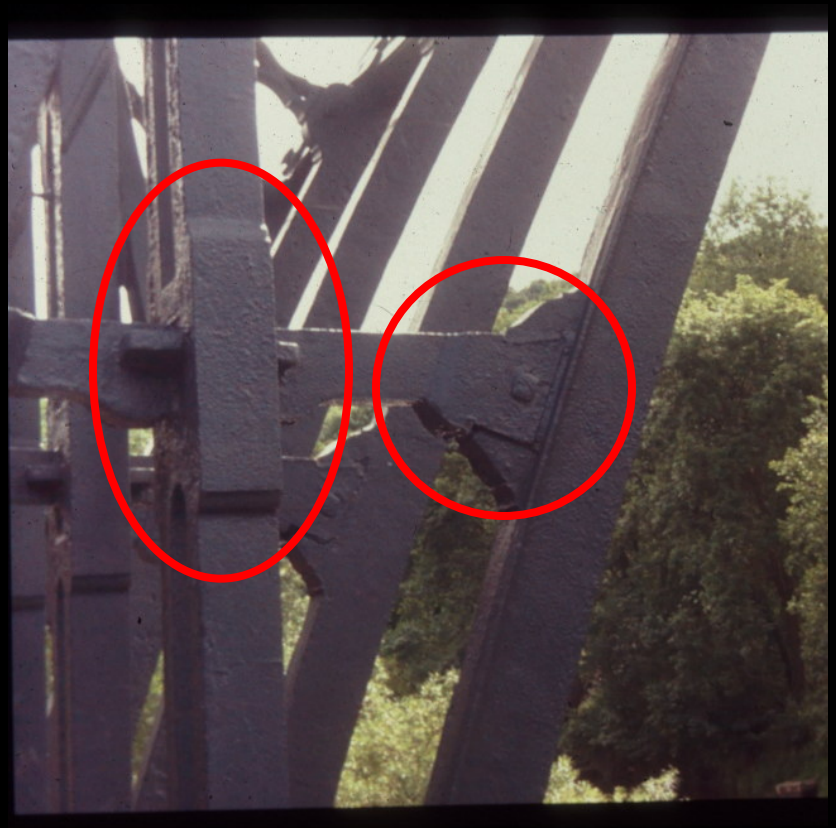
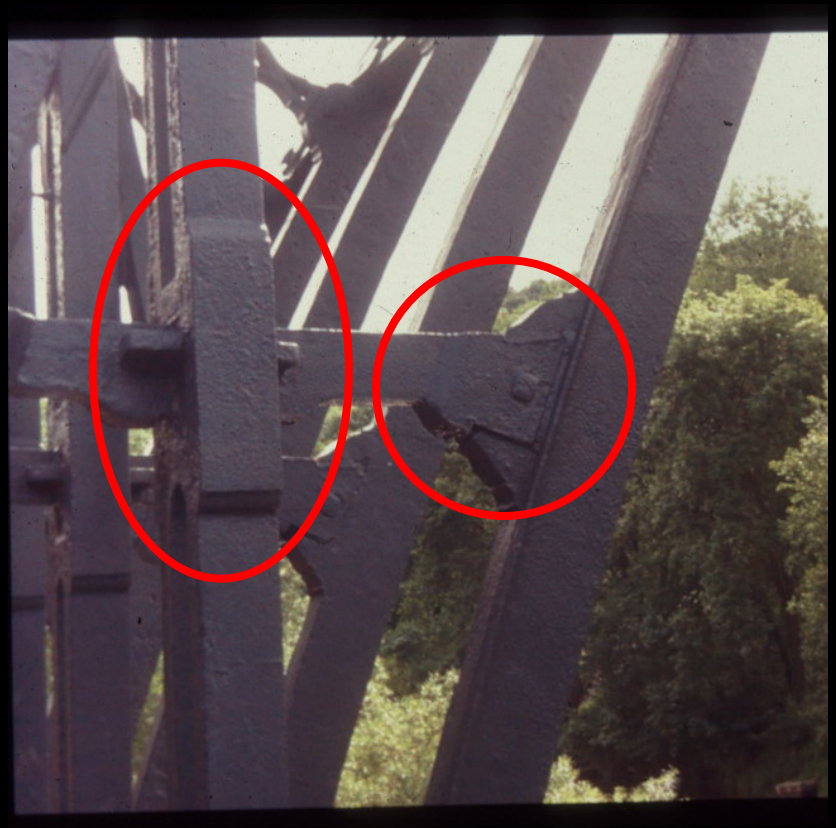


Joints typically used in wood:
Dovetail, Mortise and Tenon

The Iron Bridge of 1779



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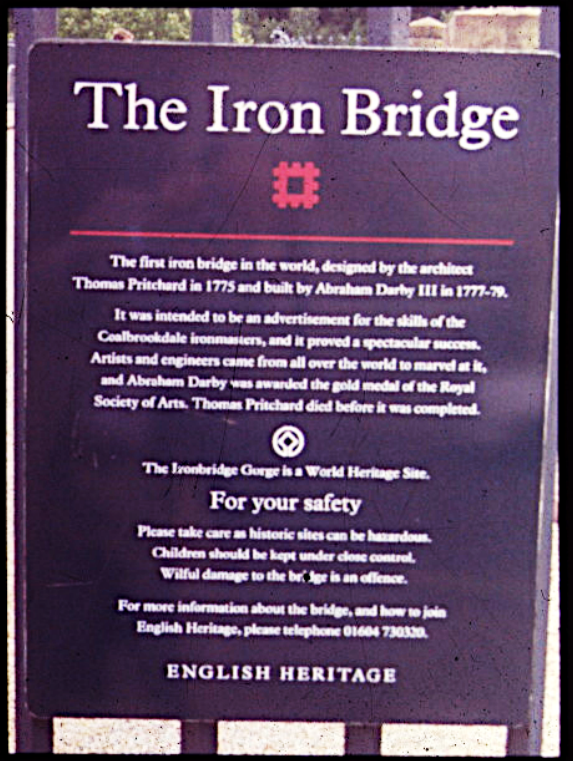
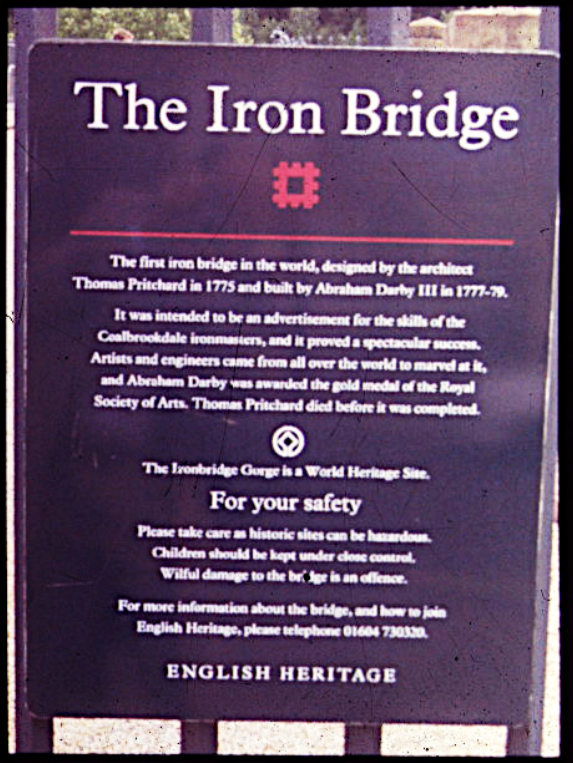


Processes

$$Fe_2O_3 + 3C + \frac{3}{2}O_2 \rightarrow 2Fe + 3CO_2$$

Transformation and Relationship

"It was intended to be an advertisement for the skill of Coalbrookdale ironmakers, …."



Processes

$$Fe_2O_3 + 3C + \frac{3}{2}O_2 \rightarrow 2Fe + 3CO_2$$

Transformation and Relationship

‘Coalbrookdale at Night’

Processes

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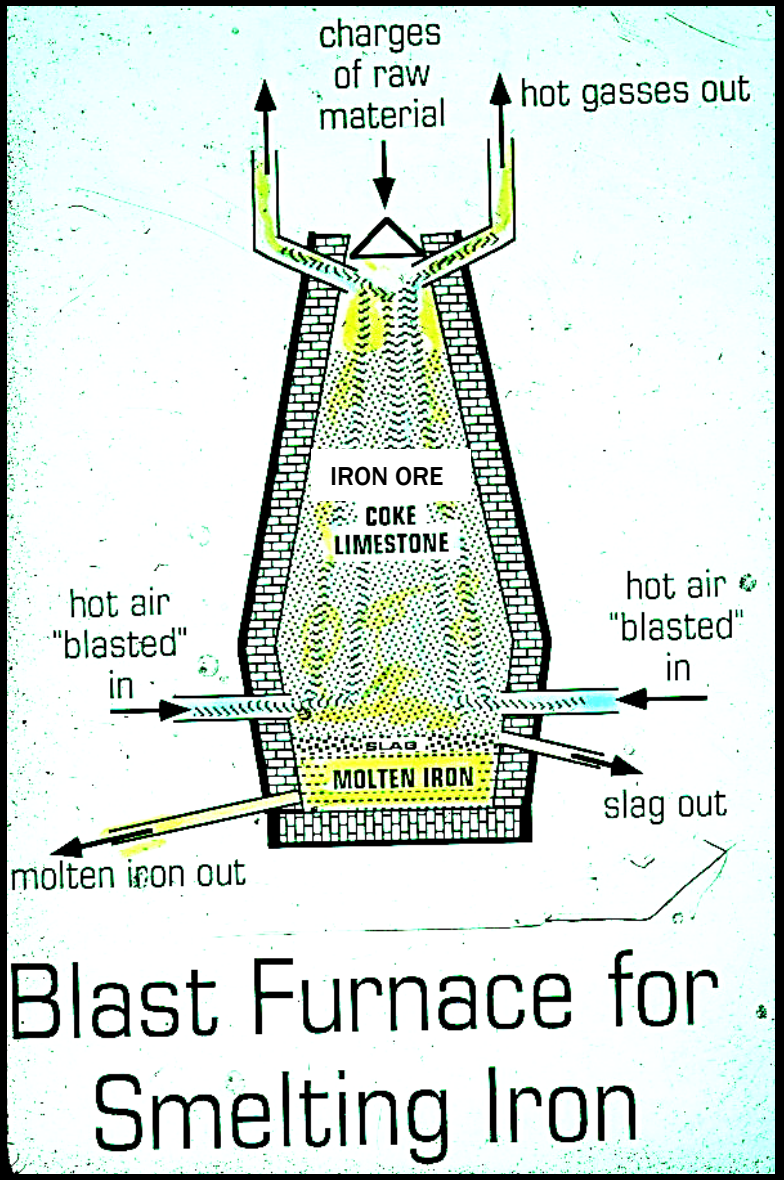
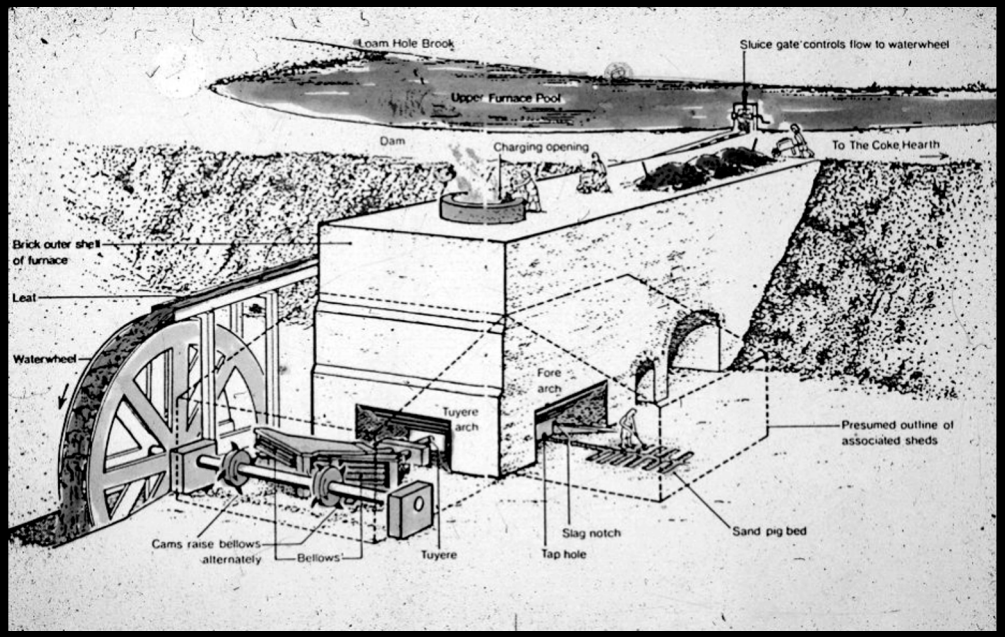
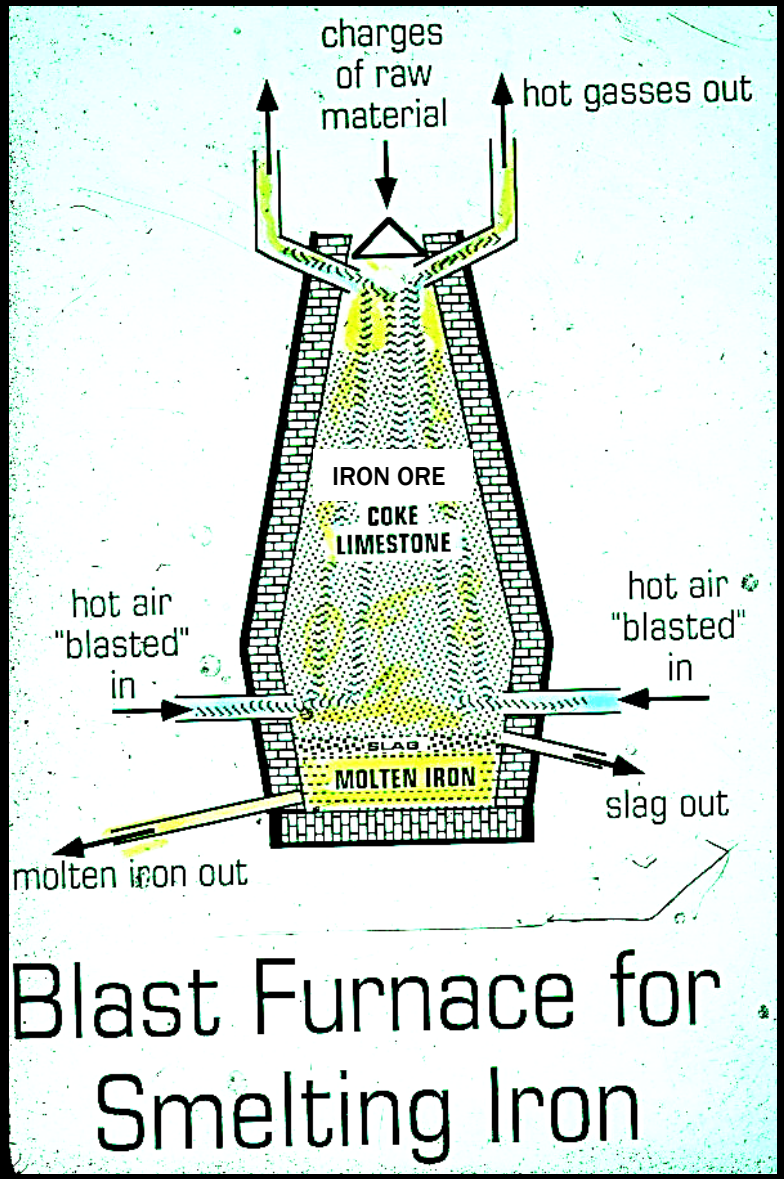
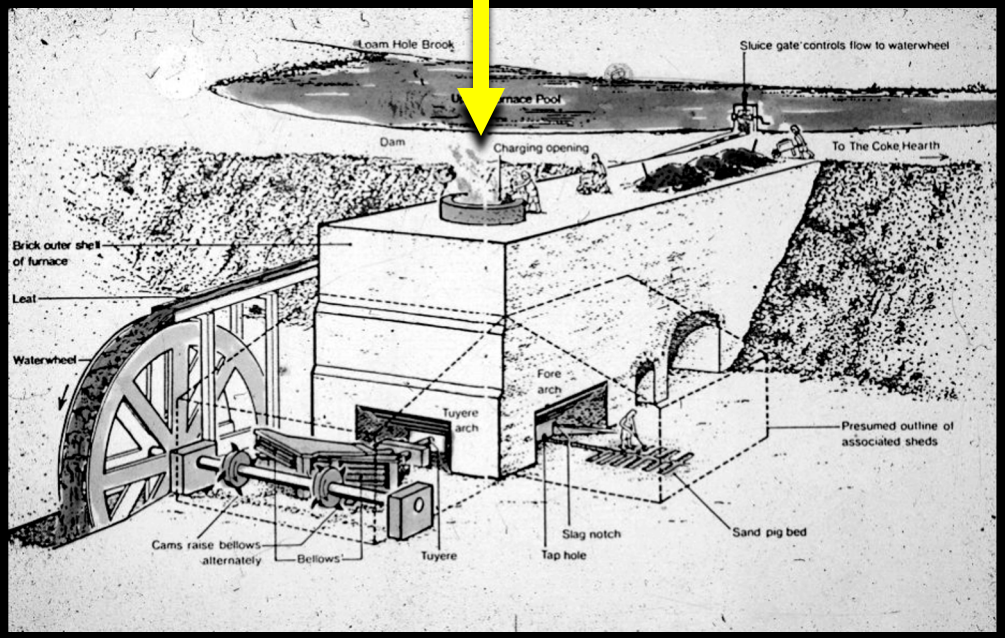
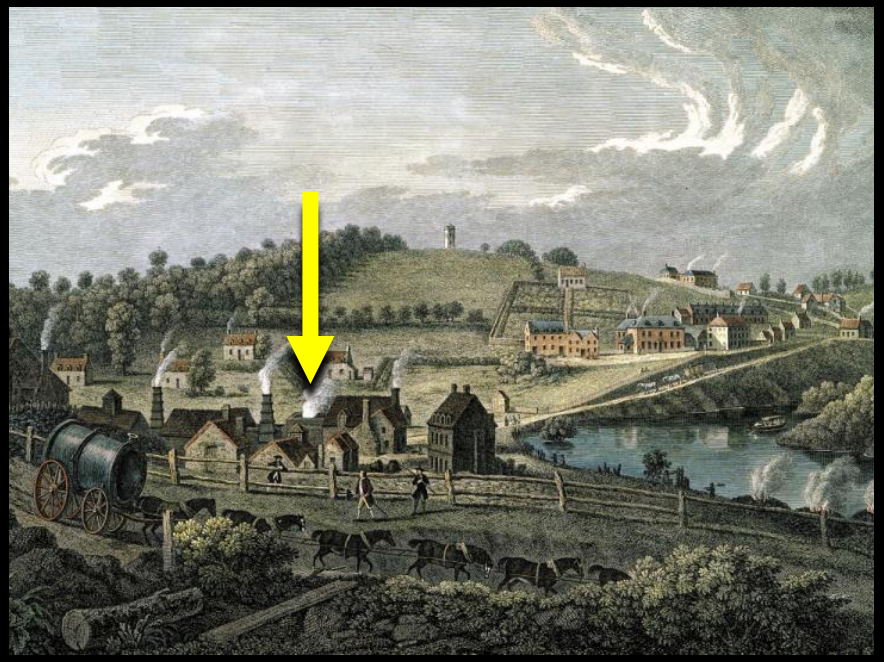
Transformation and Relationship



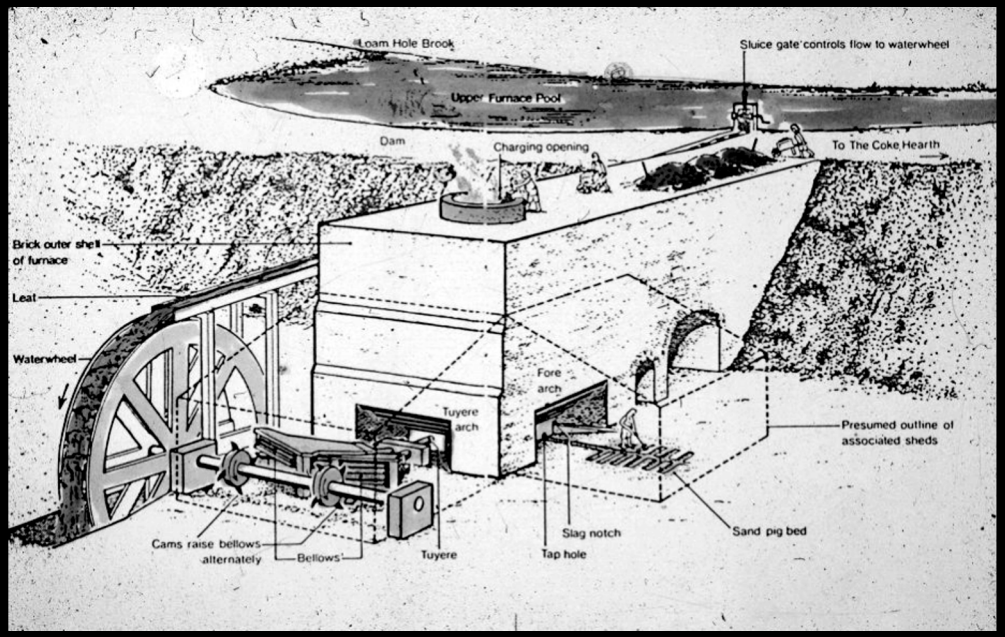

Loam Hole Brook
Sluice gate controls flow to waterwheel
Upper Furnace Pool
Dam
Charging opening
To The Coke Hearth
Brick outer shell of furnace
Leat
Waterwheel
Fore arch
Tuyere arch
Presumed outline of associated sheds
Cams raise bellows alternately
Bellows
Tuyere
Slag notch
Tap hole
Sand pig bed


charges of raw material
hot gasses out
IRON ORE
COKE
LIMESTONE
hot air "blasted" in
hot air "blasted" in
SLAG
MOLTEN IRON
slag out
molten iron out
Blast Furnace for Smelting Iron





‘Upper Works at Coalbrookdale’



Great Flood of 1795

Shropshire County Engineer
Thomas Telford

Great Flood of 1795

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Thomas Telford

Bildwas – Telford's First Iron Bridge
(30% longer using half as much iron)

MORE EFFICIENT BRIDGE
Minimum Materials

IRON

Stronger than wood and stone

More permanent than wood

Lighter structures than stone

Bildwas – Telford's First Iron Bridge
(30% longer using half as much iron)

MORE EFFICIENT BRIDGE
Minimum Materials

= important

Crushing Stress

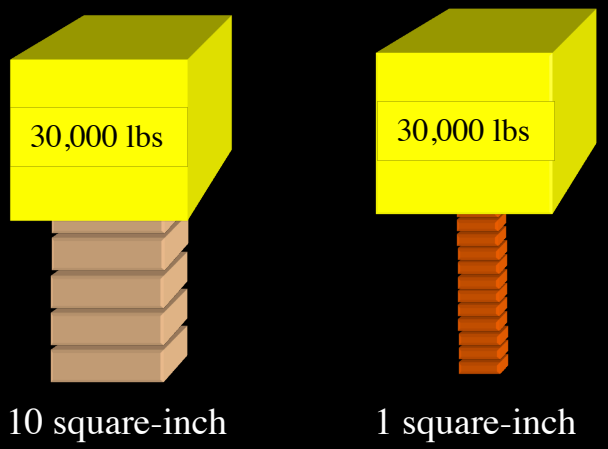
IRON

Stronger than wood and stone

More permanent than wood

Lighter structures than stone

= important



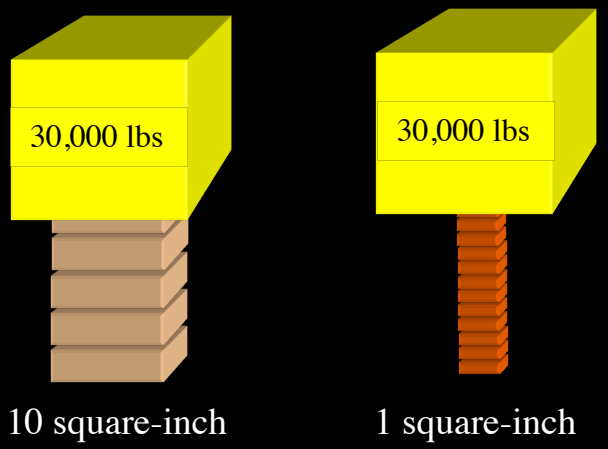
$$f_{stone} = 3000\,psi$$

$$f_{iron} = 30{,}000\,psi$$

Where is the load?

- Gravity load is 30,000 lbs;
- Stress is force / area (psi);
- Materials fail when stress exceeds limit

Crushing Stress



DEMONSTRATION

- Tension versus Compression
- Links in a Chain
- Blocks in a Stack
- Anchors – Towers – Load

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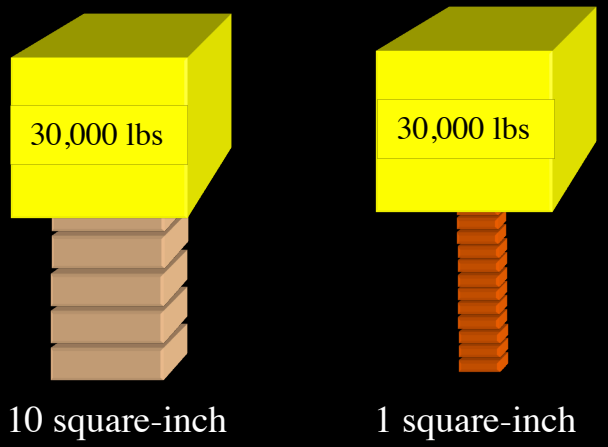
Where is the load?

Crushing Stress



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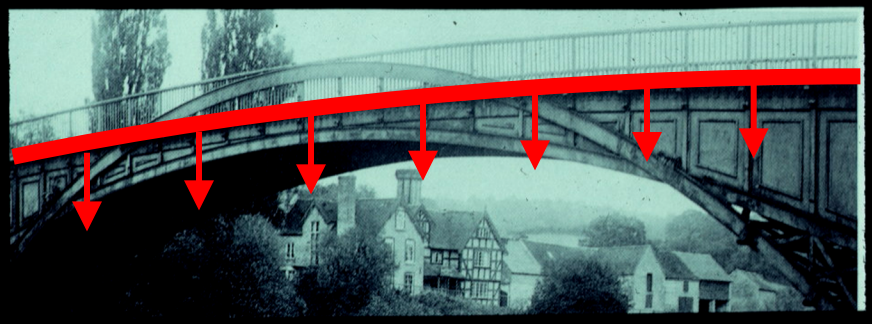

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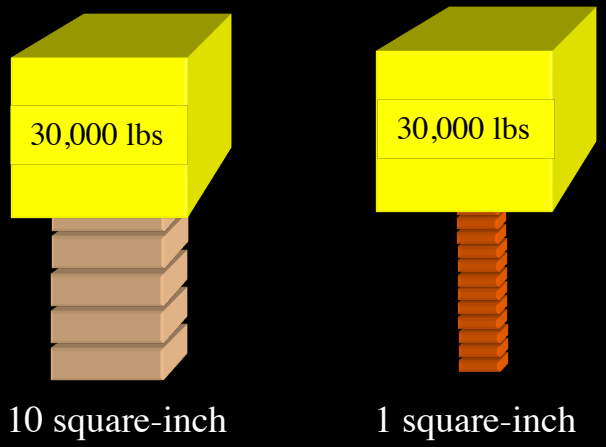

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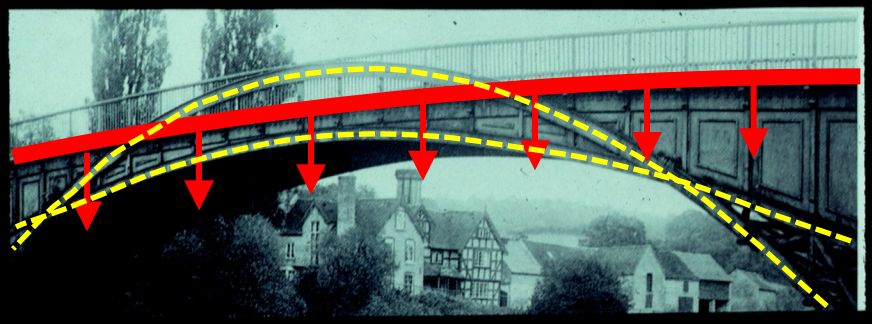


Where is the load?

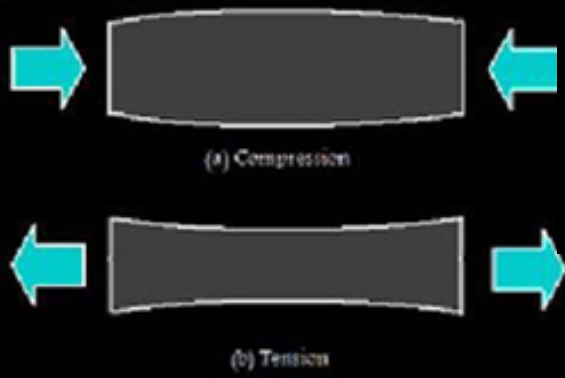
Two arches hold it up

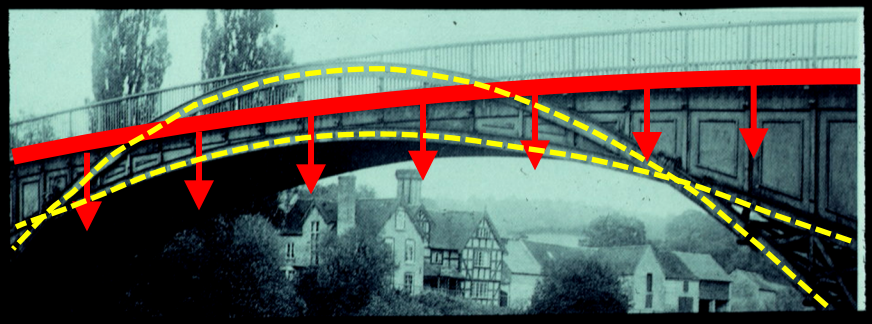
DEMONSTRATION

ARCH versus CABLE

Arch – compression

Cable – tension





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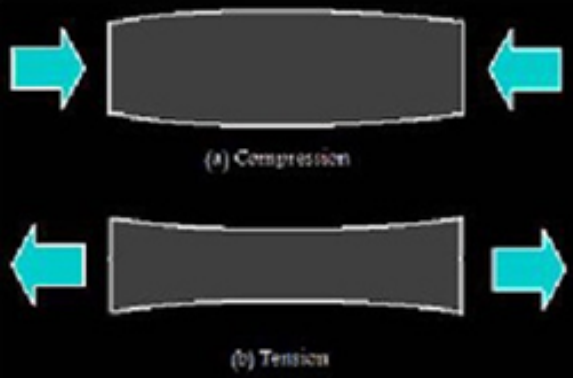

Thomas Telford (1757 – 1834)

Stonemason and Architect

Surveyor and Engineer

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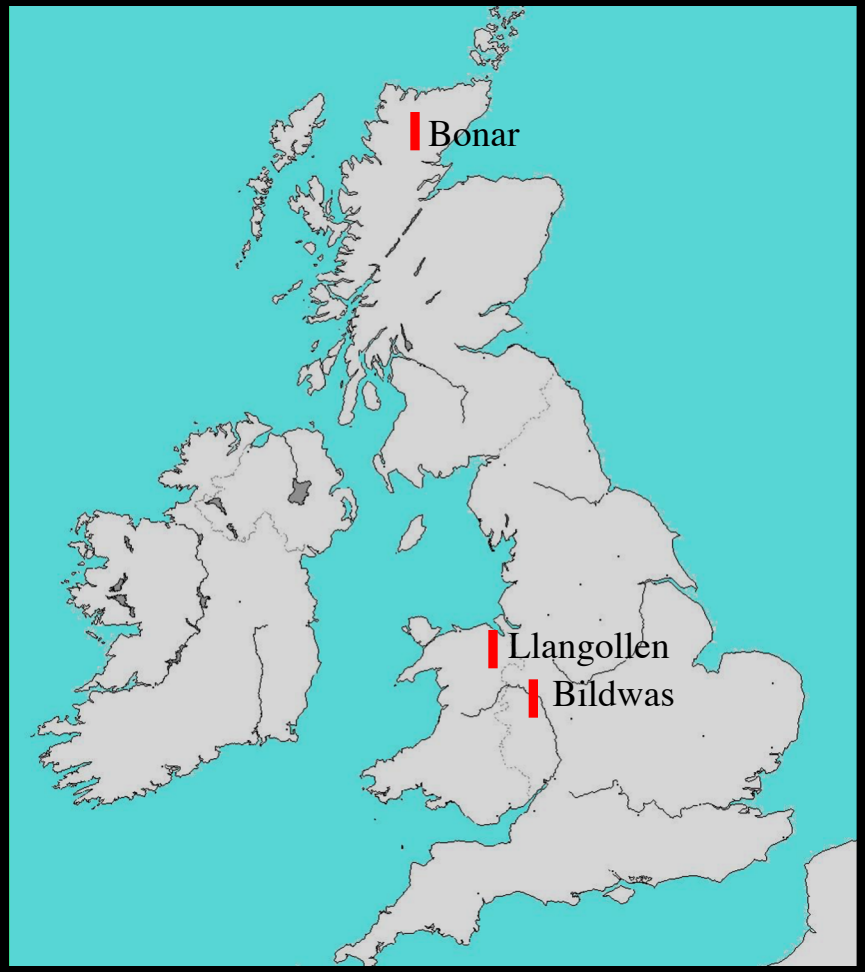

1796 – Bildwas – 130 foot arch

1805 – Llangollen – short arches

1810 – Bonar – 150 foot arch

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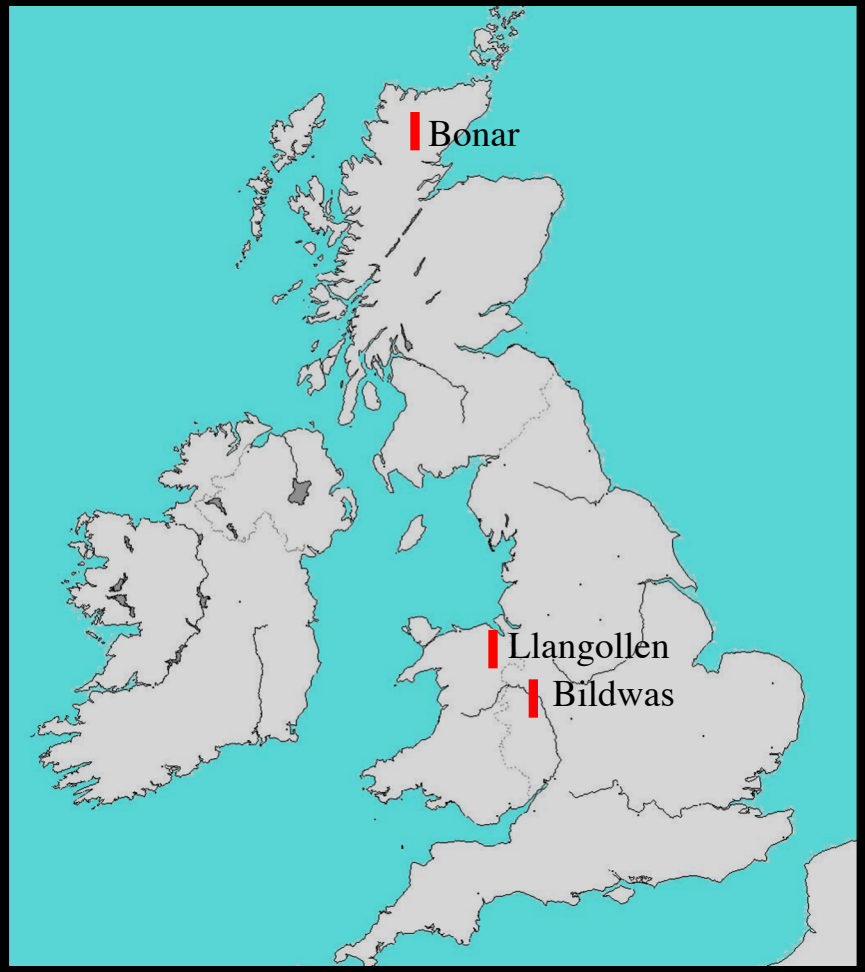

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Llangollen Aqueduct

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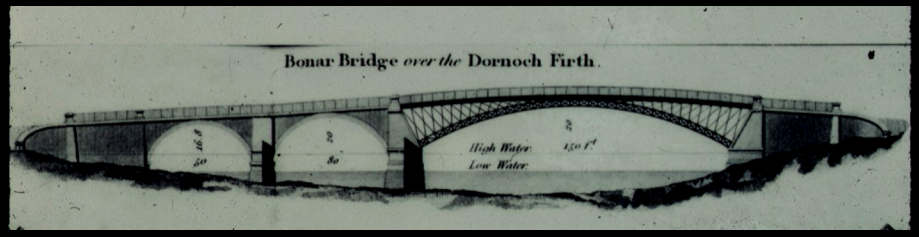
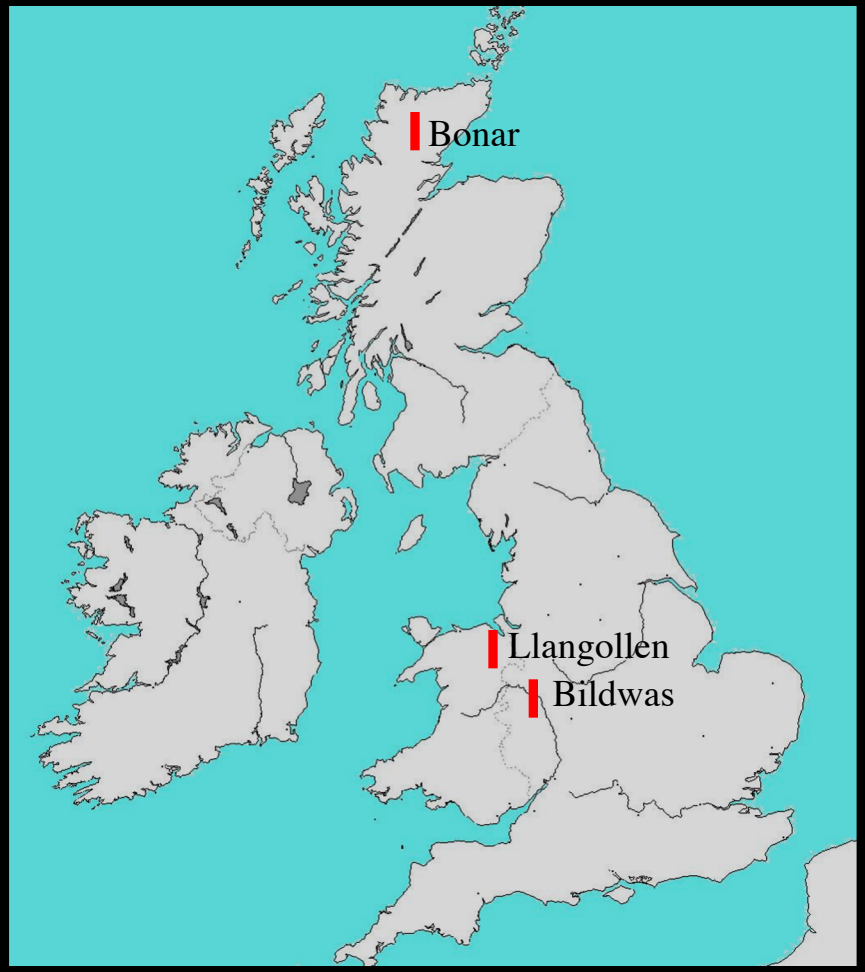
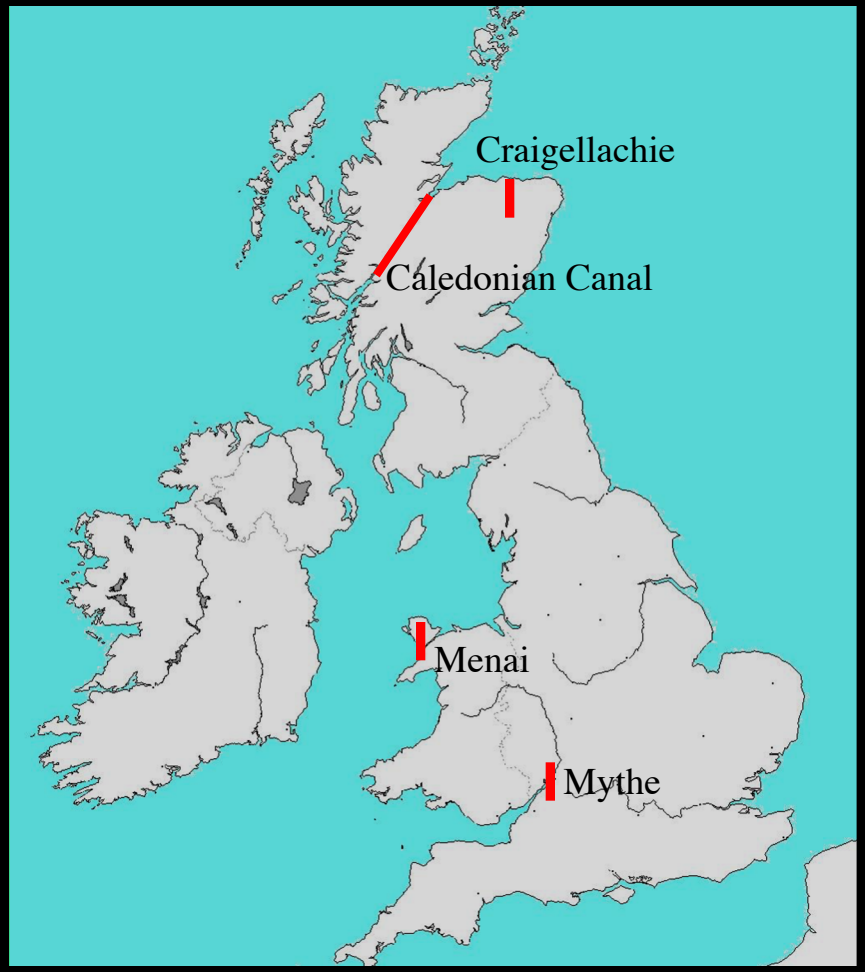

Bonar Bridge over the Dornoch Firth.
High Water
Low Water


Bonar
Llangollen
Bildwas



Thomas Telford – later works

1814 – Craigellachie – 150 foot arch

1822 – Caledonian Canal

1824 – Mythe – 170 foot arch

1826 – Menai – 580 foot suspension

Caledonian Canal

1803 start – 1822 finish

29 locks and 10 bridges

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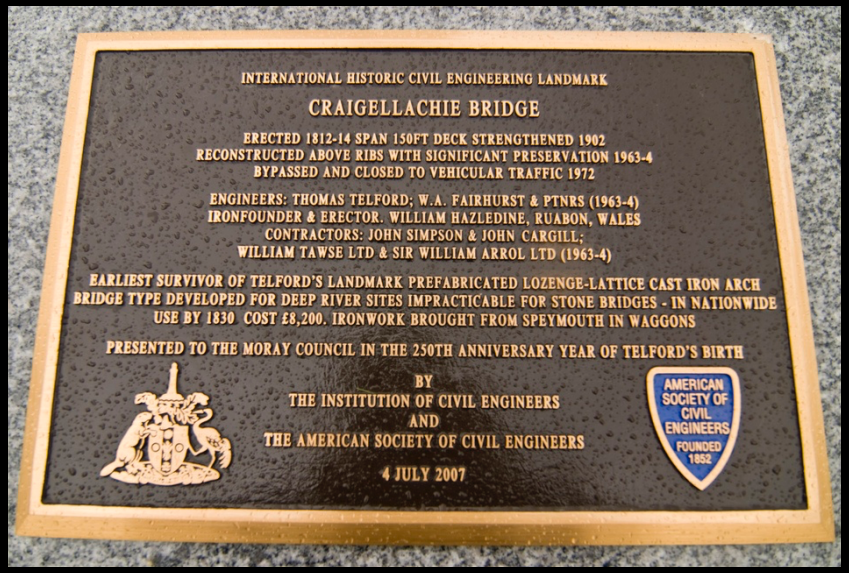

"Earliest survivor of Telford's Cast Iron Arch Bridge"

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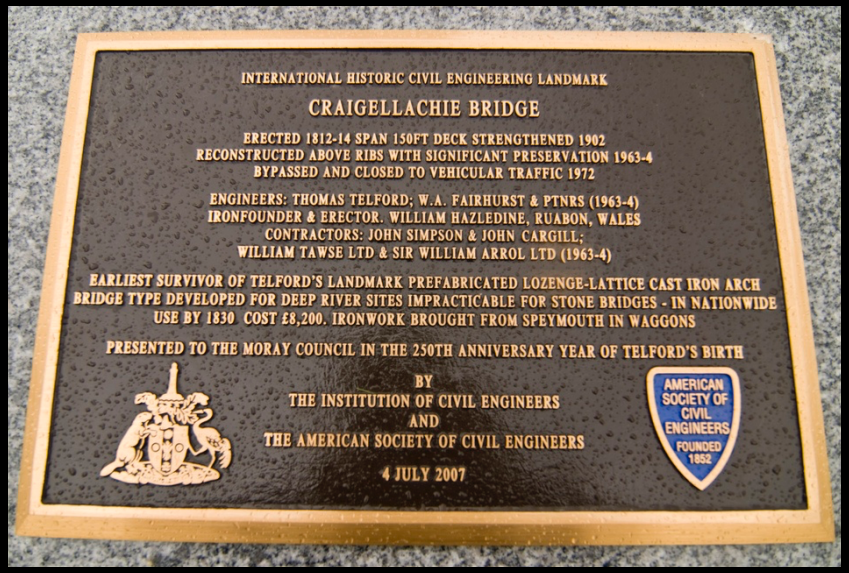

"Earliest survivor of Telford's Cast Iron Arch Bridge"

"The bridge is of iron, beautifully light, in a situation where the utility of lightness is instantly perceived. … The only defect, and a sad one it is, is that the railing for the sake of paltry economy is of the meanest possible form, and therefore out of character with the rest of the iron work." -- Robert Southey

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Iron Bridge versus Craigellachie*		
curve:	**semi-circular** arch	**"parabolic"** arch
method:	**mutilated** arch	**unbroken** arch
spandrel:	**circles** decor	**triangles** for support

* Telford's Analysis in Encyclopedia Britannica

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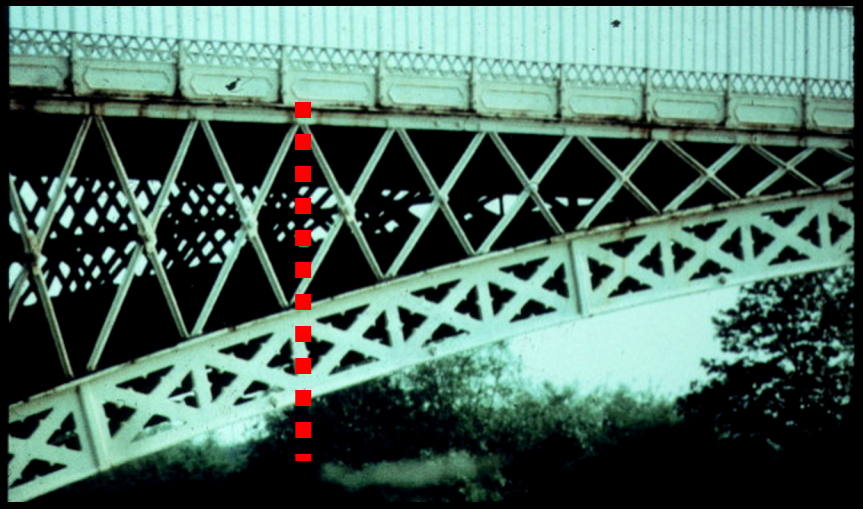
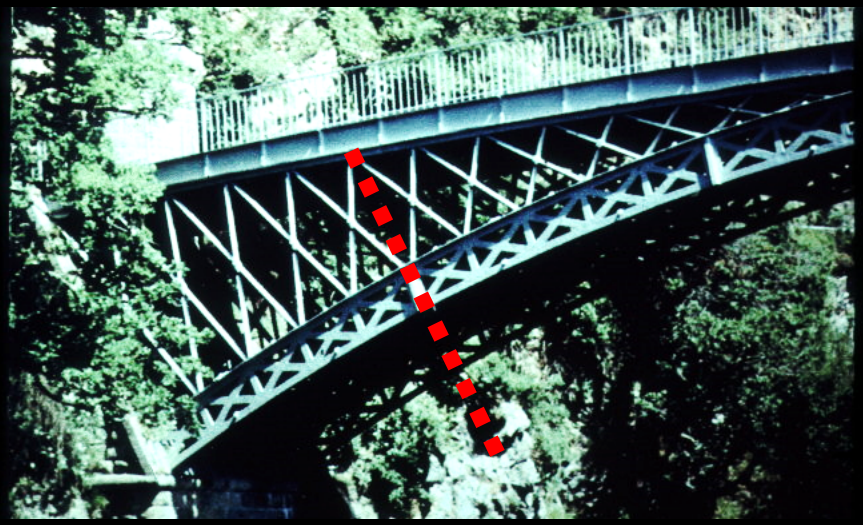
Mythe

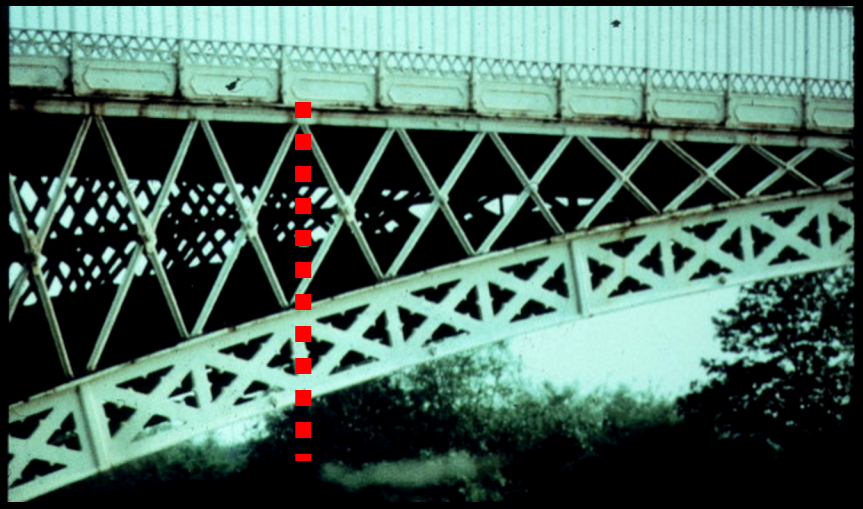
Craigellachie

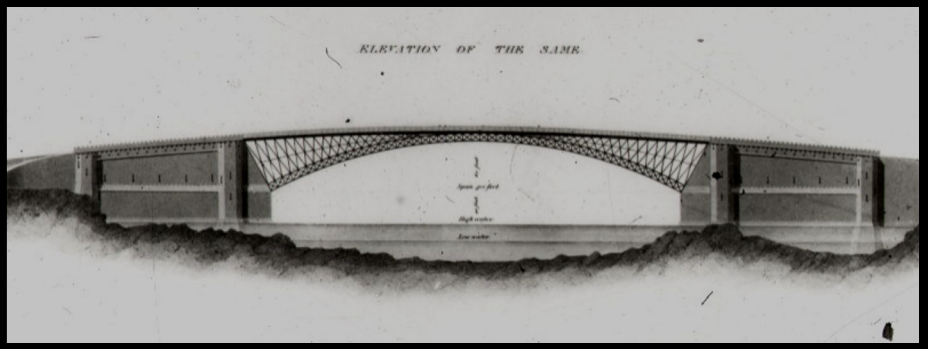


Mythe

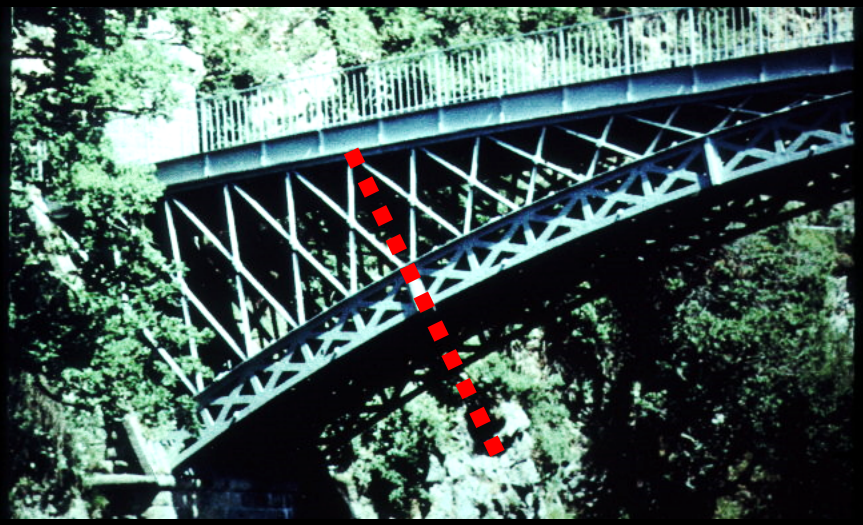


Craigellachie



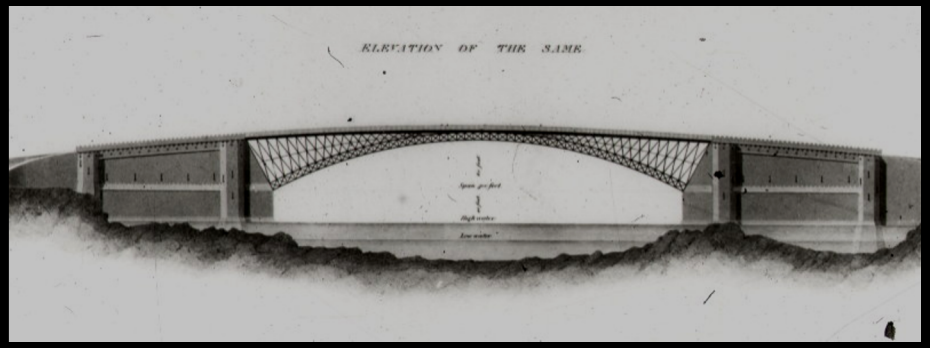


The bridge Telford wanted to build



Cable versus Arch

The bridge that Telford built



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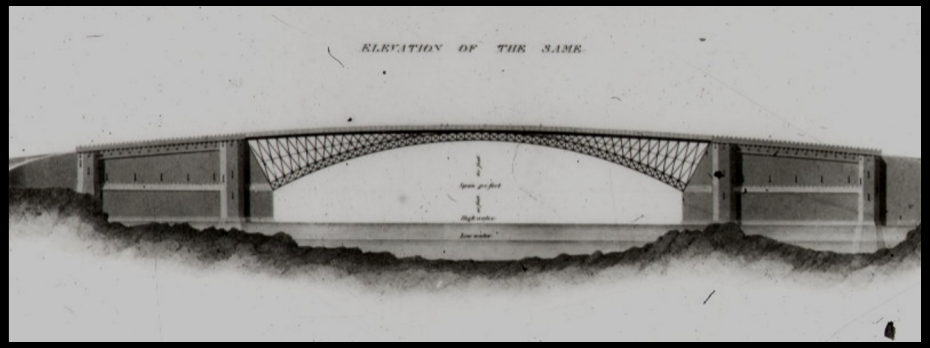

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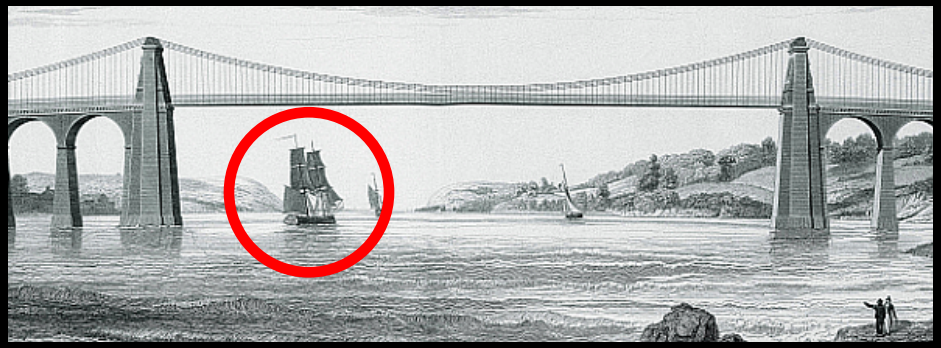

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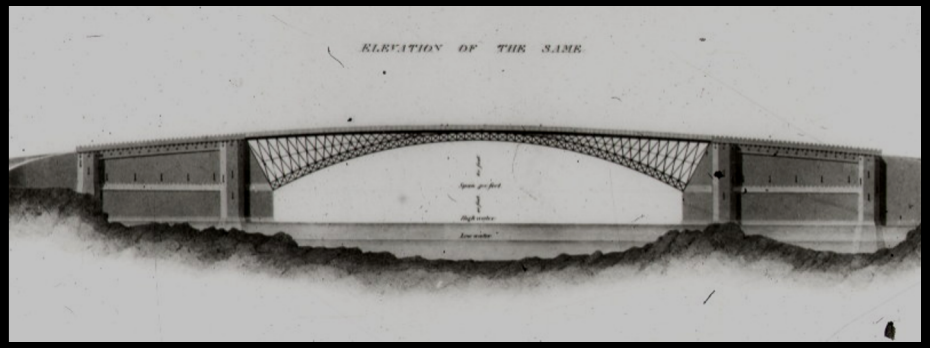
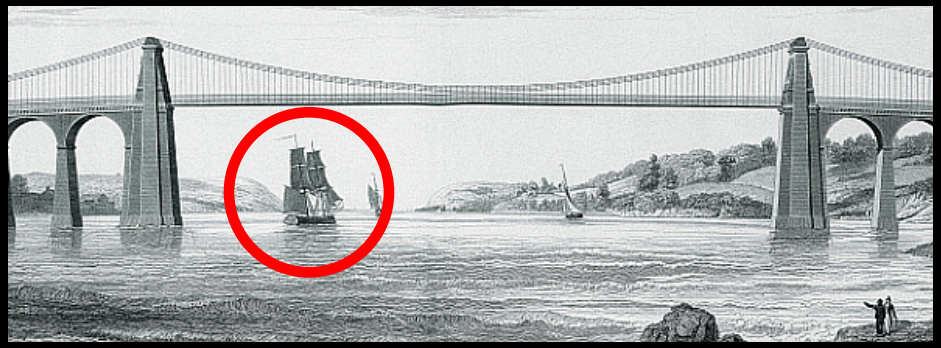


The bridge Telford wanted to build

Lord Nelson's Ship – HMS Victory

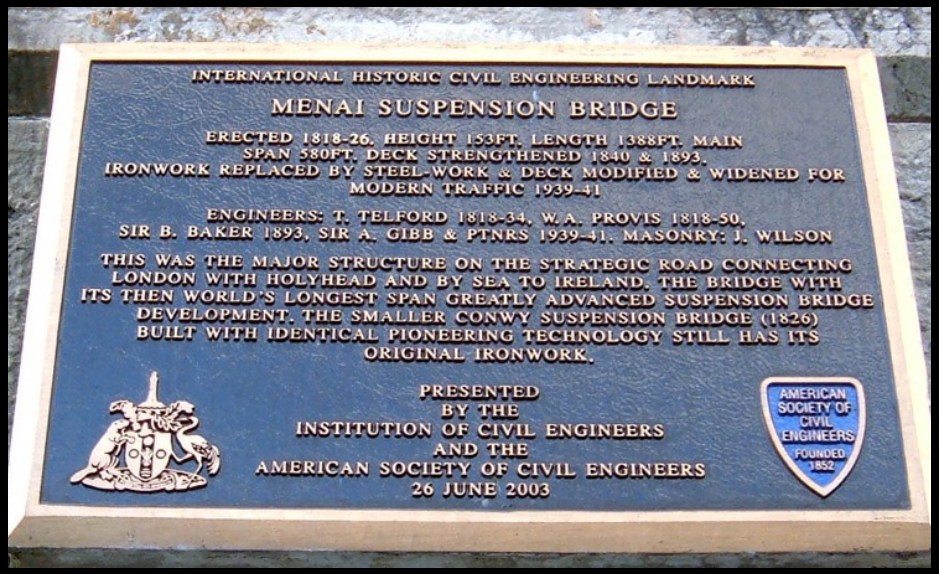
Politics and Economics



The bridge that Telford built

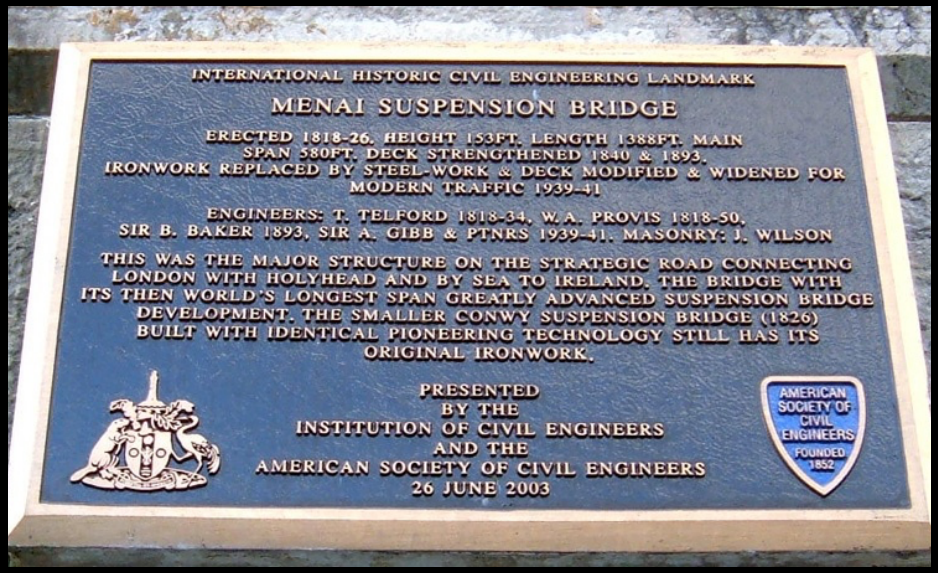
Eye-bars and Linked Chain

Lord Nelson's Ship – HMS Victory



Eye-bars and Linked Chain

"This was the major structure on the Strategic Road connecting London with Holyhead, and by sea with Ireland."



"This was the major structure on the Strategic Road connecting London with Holyhead, and by sea with Ireland."

Roads are Lines of Communication
Connects London to Dublin

DEMONSTRATION

How does it work?
What is the function?

Stone towers support a chain which support suspension cables which hold up a flexible deck.

Bridge replaces a ferry across the Menai Straits. The first vehicle to cross is a horse-drawn mail carriage.

Roads are <u>Lines of Communication</u>
Connects London to Dublin

Severn Bridge (1966)
for cars and trucks

Roads are <u>Lines of Communication</u>
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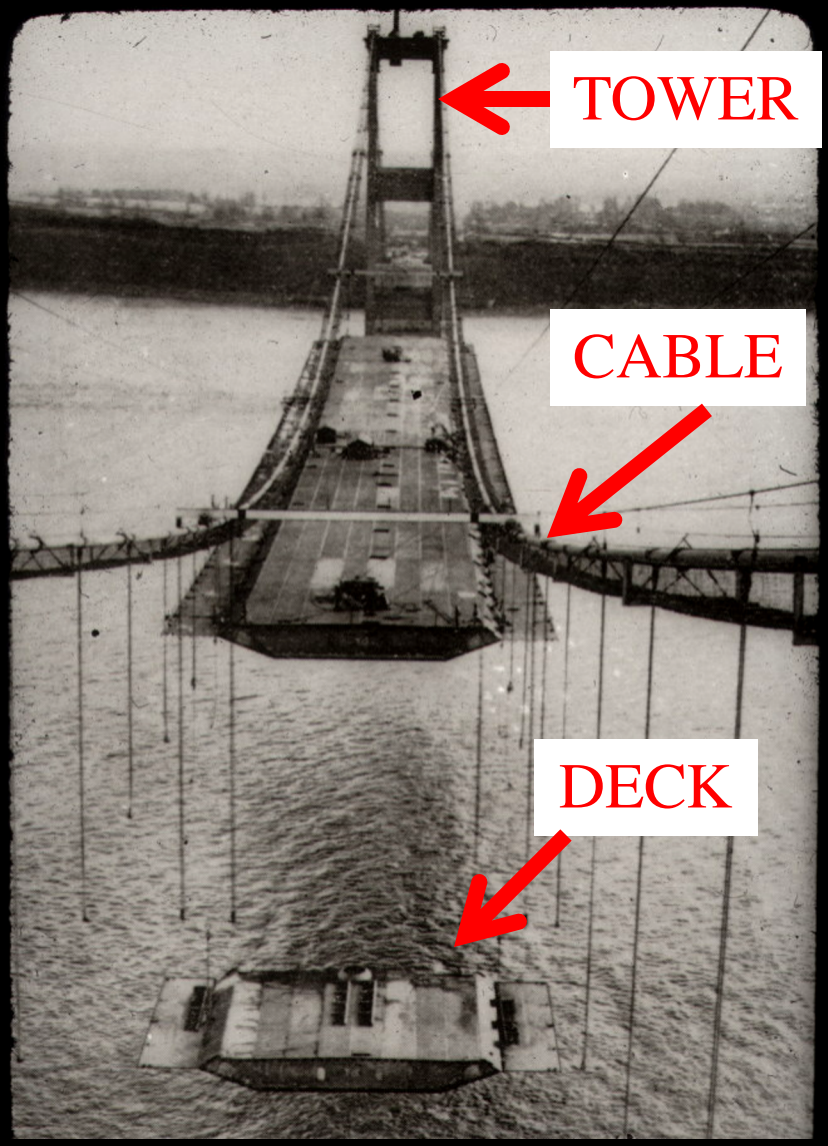

Severn Bridge (1966)
for cars and trucks

Cable Suspension Bridge

How does it work?

Cable supported
TOWER in COMPRESSION

Deck supported
CABLE in TENSION

Structures

$$H = \frac{1}{8} \; qL \; \frac{L}{d}$$

Transformation and Relationship

Science – Economics – Art

Cable Suspension Bridge

How does it work?

Cable supported
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Deck supported
CABLE in TENSION

Structures

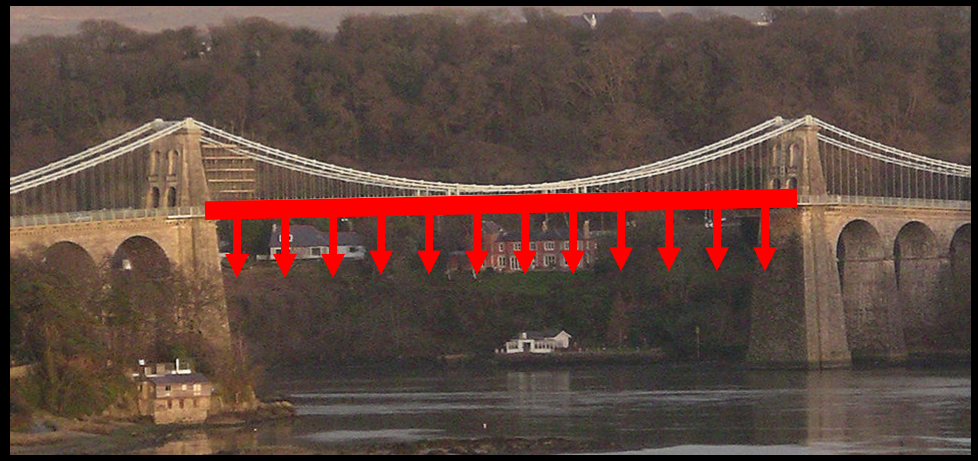
$$H = \frac{1}{8} qL \frac{L}{d}$$

Transformation and Relationship

Science – Economics – Art

Where is the load?

Total deck weight = qL



STRUCTURAL ART
minimum materials EFFICIENCY
minimum cost ECONOMY
maximum expression ELEGANCE

Structures

$$H = \frac{1}{8} qL\frac{L}{d}$$

Transformation and Relationship

Science – Economics – Art

What is the form?

Flat; "Beautifully Light"

STRUCTURAL ART
minimum materials EFFICIENCY
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maximum expression ELEGANCE

STRUCTURAL ART

minimum materials
EFFICIENCY

minimum cost
ECONOMY

maximum expression
ELEGANCE

"Telford's is a happy life: everywhere making roads, building bridges, forming canals and creating harbours – works of sure, solid, permanent utility; everywhere employing a great number of persons."
-- Robert Southey (1819)

STRUCTURAL ART

minimum materials
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OTHMAR
H. AMMANN
1879-1965
HELVETIA
20
HANS THÖNI
COURVOISIER


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Key Ideas

What is the innovation?

Flat and Efficient Iron Bridge

How does it happen?

Telford – an Engineer-Artist and Public Works Entrepreneur

What is the legacy?

Iconic Structural Art