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
Independence, Iron and Industry
1776 - 1855

Telford
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Canal and Aqueduct
First Navigable Aqueduct - 1761
Canal and Aqueduct
First Navigable Aqueduct - 1761
Restructuring of Nature

Eskdale

Barton Aqueduct

1760

1820

Restructuring of Nature
British Metal Forms

Science - new material
IRON

Social - new economy
INDUSTRIALIZATION

Symbolic - new vision
STRUCTURAL ART

Restructuring of Nature
British Metal Forms

Science - new material
IRON

Social - new economy
INDUSTRIALIZATION

Symbolic - new vision
STRUCTURAL ART

‘Afternoon View at Coalbrookdale’
Where industrial revolution begins
INDUSTRIALIZATION*  

Natural resources – coal and iron  
Factory system – citizen wealth  
Island isolation – strong Navy  

*A. Toynbee’s analysis

‘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

The Iron Bridge of 1779
Joints typically used in wood: Dovetail, Mortise and Tenon

The Iron Bridge of 1779
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“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

“It was intended to be an advertisement for the skill of Coalbrookdale ironmakers, ...”
Processes

\[ \text{Fe}_2\text{O}_3 + 3\text{C} + \frac{3}{2}\text{O}_2 \rightarrow 2\text{Fe} + 3\text{CO}_2 \]

Transformation and Relationship

‘Coalbrookdale at Night’
Processes

\[ \text{Fe}_2\text{O}_3 + 3\text{C} + \frac{3}{2}\text{O}_2 \rightarrow 2\text{Fe} + 3\text{CO}_2 \]

Transformation and Relationship

Blast Furnace for Smelting Iron
Blast Furnace for Smelting Iron

- Charges of raw material
- Hot gasses out
- Hot air "blasted" in
- Hot air "blasted" in
- Molten iron out
- Slag out
‘Upper Works at Coalbrookdale’
Iron Bridge

Great Flood of 1795
Shropshire County Engineer
Thomas Telford

Great Flood of 1795
Iron Bridge

Ironbridge, Shropshire
Shropshire County Engineer
Thomas Telford

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

MORE EFFICIENT BRIDGE
Minimum Materials
<table>
<thead>
<tr>
<th>IRON</th>
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<tbody>
<tr>
<td>Stronger than wood and stone</td>
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Bildwas – Telford’s First Iron Bridge (30% longer using half as much iron)

MORE EFFICIENT BRIDGE
Minimum Materials

= important
IRON

Stronger than wood and stone
More permanent than wood
Lighter structures than stone

\[ f_{\text{iron}} = 30,000 \text{ psi} \]
\[ f_{\text{stone}} = 3000 \text{ psi} \]
Where is the load?

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

DEMONSTRATION

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

Crushing Stress

\[ f_{\text{stone}} = 3000 \text{ psi} \]
\[ f_{\text{iron}} = 30,000 \text{ psi} \]
Where is the load?

Crushing Stress

\[ f_{\text{stone}} = 3000 \, \text{psi} \]

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Crushing Stress

Where is the load?

\[
f_{stone} = 3000 \text{ psi} \]

\[
f_{iron} = 30,000 \text{ psi}
\]
Where is the load?
Two arches hold it up

DEMONSTRATION
ARCH versus CABLE
Arch – compression
Cable – tension
Where is the load?

Two arches hold it up

DEMONSTRATION

ARCH versus CABLE

Arch – compression

Cable – tension
Thomas Telford (1757 – 1834)

Stonemason and Architect
Surveyor and Engineer
Thomas Telford (1757 – 1834)

- Stonemason and Architect
- Surveyor and Engineer

- 1796 – Bildwas – 130 foot arch
- 1805 – Llangollen – short arches
- 1810 – Bonar – 150 foot arch
Thomas Telford (1757 – 1834)

Stonemason and Architect
Surveyor and Engineer

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Stonemason and Architect
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Llangollen Aqueduct
Llangollen Aqueduct
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

Thomas Telford – later works

1814 – Craigellachie – 150 foot arch
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Thomas Telford – later works

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“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

“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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The bridge Telford wanted to build
Cable versus Arch

The bridge that Telford built

The bridge Telford wanted to build
Cable versus Arch

The bridge that Telford built

The bridge Telford wanted to build

Wrought Iron

Cast Iron
Cable versus Arch

The bridge that Telford built

The bridge Telford wanted to build

Politics and Economics

Lord Nelson’s Ship – HMS Victory
The bridge that Telford built

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.

Rocks are Lines of Communication
Connects London to Dublin
Severn Bridge (1966) for cars and trucks

Roads are **Lines of Communication**
Connects London to Dublin
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

TOWER in COMPRESSION

Deck supported

CABLE in TENSION
Structures

The equation for the height $H$ of a structure is given by:

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

Transformation and Relationship

Science – Economics – Art

Where is the load?

Total deck weight $= qL$

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Structures

$$H = \frac{1}{8} qL \left( \frac{L}{d} \right)$$

Transformation and Relationship

Science – Economics – Art

What is the form?
Flat; “Beautifully Light”

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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)
“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)
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