A high-angle, perspective view looking down the length of a red-painted steel truss bridge. The bridge's complex lattice of beams and girders creates a strong sense of depth and structure. Below the bridge, a river flows through a town with houses and green hills in the background. The sky is blue with some clouds.

History of the Built Environment

TRANSPORT INFRASTRUCTURE LANDMARKS IN BRITAIN

by Professor Roland A Paxton FICE FRSE

School of the Built Environment Heriot-Watt University

Vice-chairman Institution of Civil Engineers Panel for Historical Engineering Works

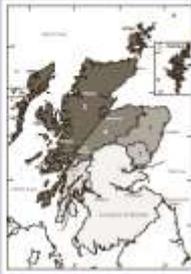
"The publisher's own guidebook to inform anyone with an interest in civilisation."

"Civilisation: From the Stone Age to the Present Day"

The first volume in the series, *Civilisation: From the Stone Age to the Present Day*, is a comprehensive and accessible guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.

The series is a unique and comprehensive guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.

The series is a unique and comprehensive guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.



This is a companion book to the series, which covers the history of civilisation from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.



Civil Engineering Heritage
Scotland Highland and Islands

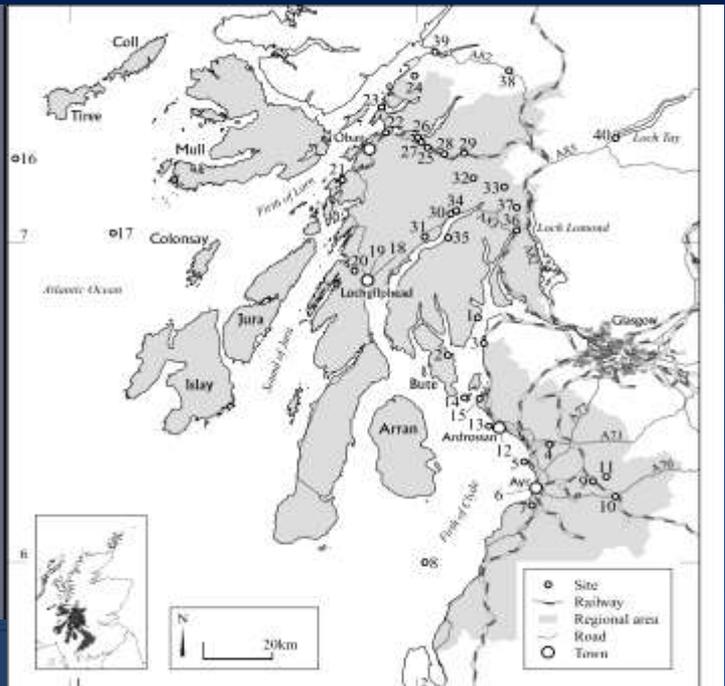
Thomas Telford
www.thomastelford.co.uk

CIVIL ENGINEERING HERITAGE



SCOTLAND HIGHLAND AND ISLANDS

Roland Paxton and Jim Shipway



"A guidebook and guidebook to inform anyone with an interest in civilisation."

"Civilisation: From the Stone Age to the Present Day"

The first volume in the series, *Civilisation: From the Stone Age to the Present Day*, is a comprehensive and accessible guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.

The series is a unique and comprehensive guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.

The series is a unique and comprehensive guide to the history of civilisation, from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.



This is a companion book to the series, which covers the history of civilisation from the Stone Age to the present day. It is written by a leading expert in the field, and is a must-read for anyone interested in the history of civilisation.



Civil Engineering Heritage
Scotland Lowlands and Borders

Thomas Telford
www.thomastelford.co.uk

CIVIL ENGINEERING HERITAGE



SCOTLAND LOWLANDS AND BORDERS

Roland Paxton and Jim Shipway



UK coverage by ICE **Civil Engineering Heritage** Books

Civil Engineering is about *harnessing the great forces in nature for the use and convenience of man.*

Tonight in the best tradition of this mission we are going to briefly identify and review the achievement of a selection of civil engineering landmarks which have contributed immeasurably to the development of the art and society's well-being

TRANSPORT LANDMARKS 1760-1900

Improvements sustaining the *Industrial Revolution*:

ROADS Significantly improved by Abercrombie, Telford and McAdam from 1800-30 [then an inter-city decline until c.1905]

CANALS Ship and narrow boat – Bridgewater 1760, Forth & Clyde 1790, Caledonian 1822 and Manchester Ship 1894

RAILWAYS Iron plateways c.1800 – Liverpool & Manchester from 1830 [first inter-city] - developed nationally to the era of the Tay 1878 (longest) and Forth Bridges 1890 (largest)

BRIDGES WERE AN ESSENTIAL COMPONENT OF ALL

Power sources for locomotion in Britain 1760-1890

[men, wind, tides, gravity, horses, steam (from c.1804)]

In the pre-steam-power era it was an accepted generalisation that for inland transport the load a horse could draw by cart or wagon (at about 2-3 mph) was:

on a road – 1-1½ tons;

on a plateway [railway] – up to 10 tons;

on a canal or river – up to 100 tons.

From these figures it is easy to see, that before the application of steam-power to roads, railways and transport by water, why the *Industrial Revolution* was serviced by canals and railways in preference to roads

R E M A R K S

ON THE PRESENT

SYSTEM OF ROAD MAKING;

WITH OBSERVATIONS,

DEDUCED FROM PRACTICE AND EXPERIENCE,

WITH A VIEW TO A REVISION OF THE EXISTING LAWS, AND
THE INTRODUCTION OF IMPROVEMENT IN

THE METHOD OF MAKING, REPAIRING, AND
PRESERVING ROADS,

AND

DEFENDING THE ROAD FUNDS FROM MISAPPLICATION.

SEVENTH EDITION,

CAREFULLY REVISED, WITH AN

APPENDIX,

AND

REPORT FROM THE SELECT COMMITTEE OF THE HOUSE
OF COMMONS, JUNE 1822,

WITH EXTRACTS FROM THE EVIDENCE.

BY JOHN LOUDON M^CADAM, ESQ.

GENERAL SURVEYOR OF THE ROADS IN THE
BRISTOL DISTRICT.

LONDON :

PRINTED FOR LONGMAN, HURST, REES, ORME, AND
BROWN, PATERNOSTER ROW.

1823.

John Loudon McAdam achieved an improvement in road making nationally from 1816-30 by applying a simple and easy to implement system and improved management, but his roads needed continual maintenance. Unlike Telford, whose method of construction was more substantial, he did not engineer his roads to line and gradient requiring cuttings, bridges and embankments.

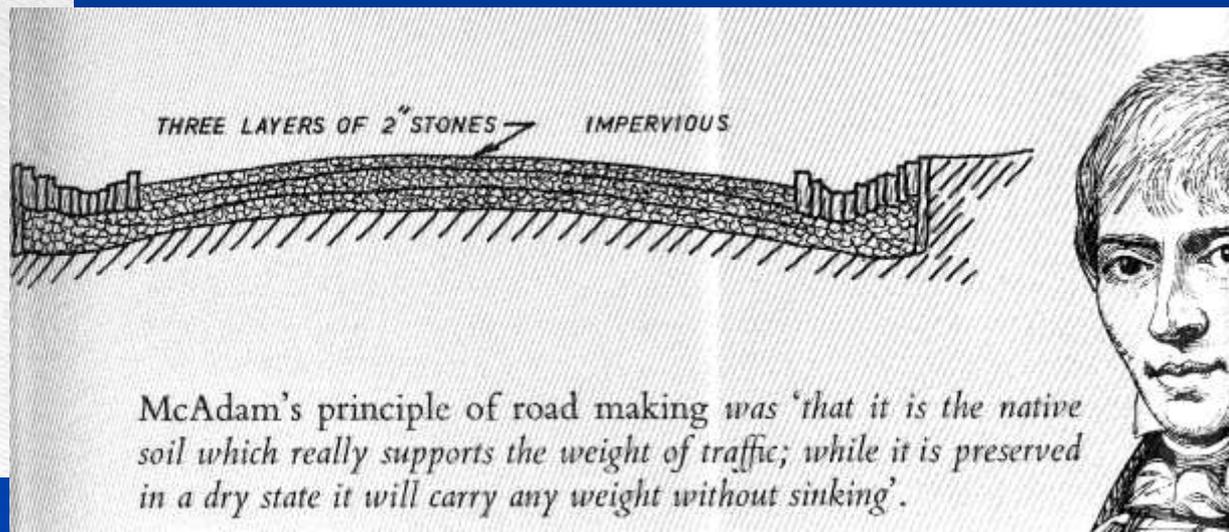


Fig. 4
Breast Wall on the Holyhead Road,
North Wales.

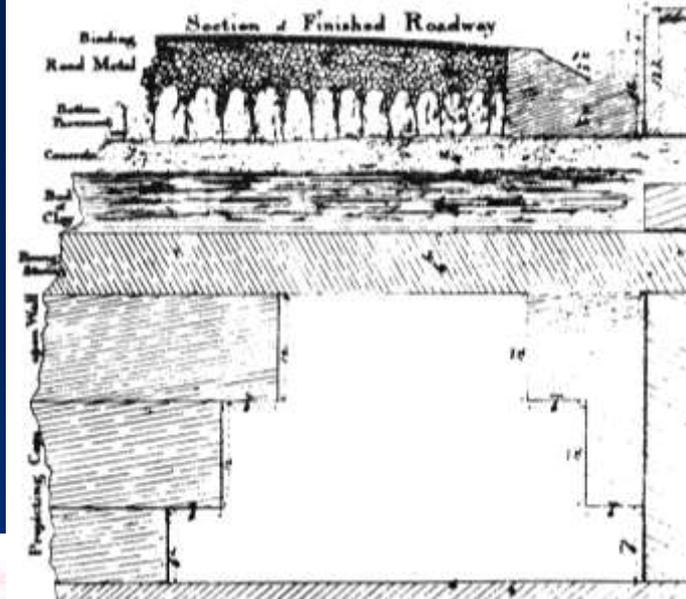
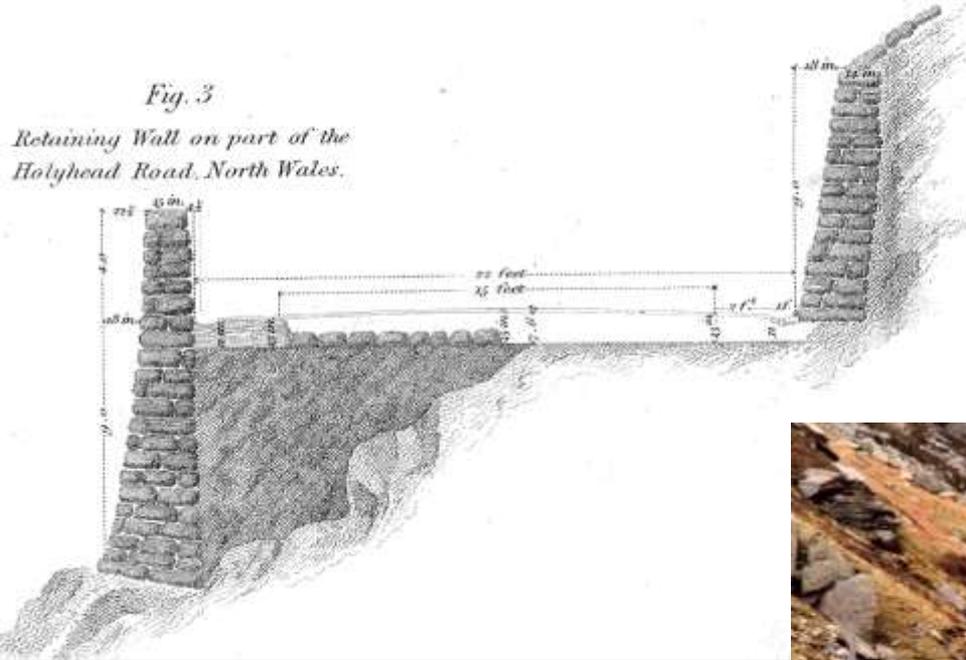


Fig. 3

Retaining Wall on part of the
Holyhead Road, North Wales.



Telford's road-making
in North Wales in
1820s.
Dean Bridge top right.
Note stone foundation
under the road metal



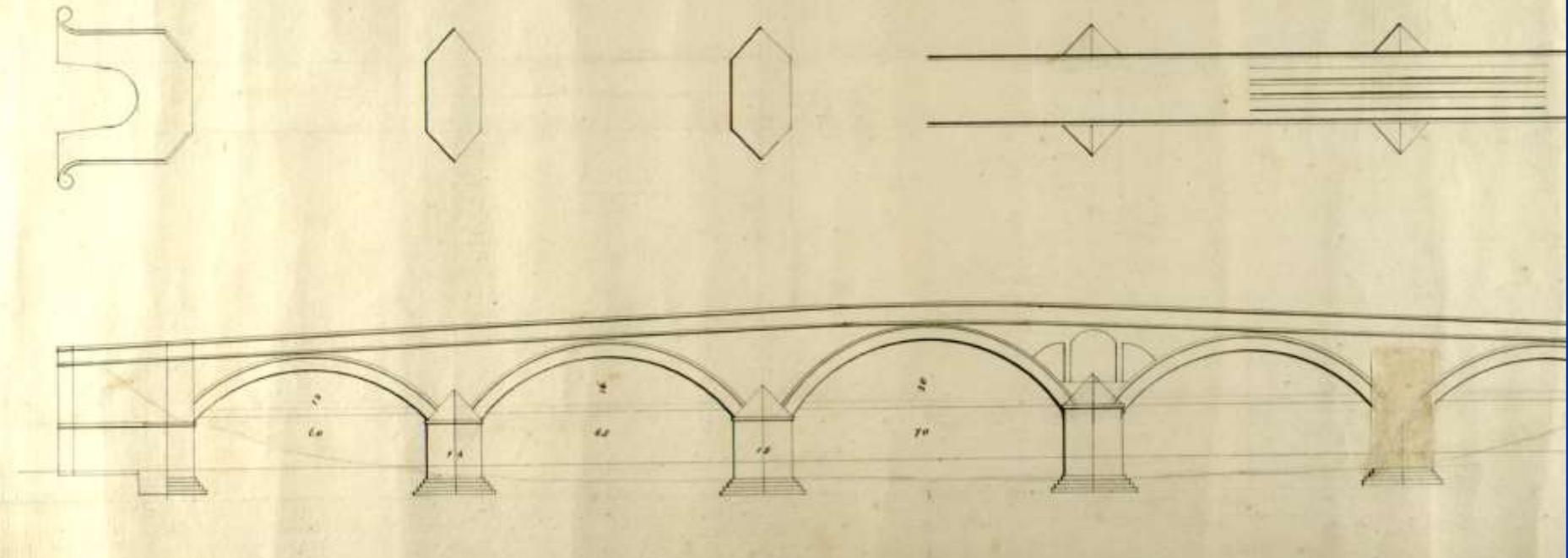


Great North Road (A9) 1926 – North of Blair Atholl, basically Telford's method which was still being used in the 1950s.



East Linton Bridges c 1550 and c 1870. Medieval bridges were narrow, of small stone (ribbed or plain) or timber spans.

Rutherglen Bridge



Rutherglen Bridge, Glasgow – James Watt 1774. Not a landmark but a good example of Watt's civil engineering. Note weight reduction features over right-hand piers.



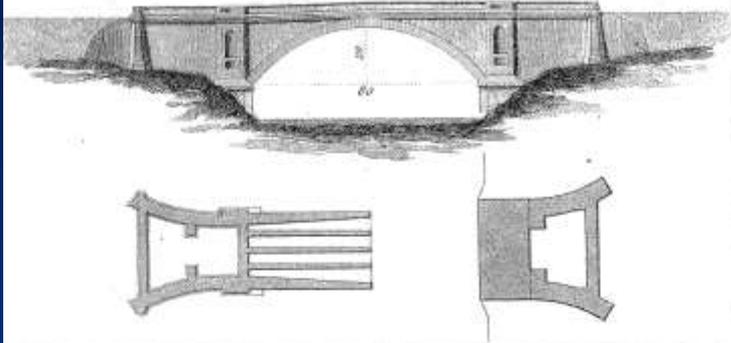
Coalbrookdale Bridge 1781 – span 100 ft 6 in, 6 in greater than central arch of Blackfriars Bridge (London). Made practicable by improved iron making. A landmark bridge improvement. The world's first large iron bridge. On semi-circular arch principle.



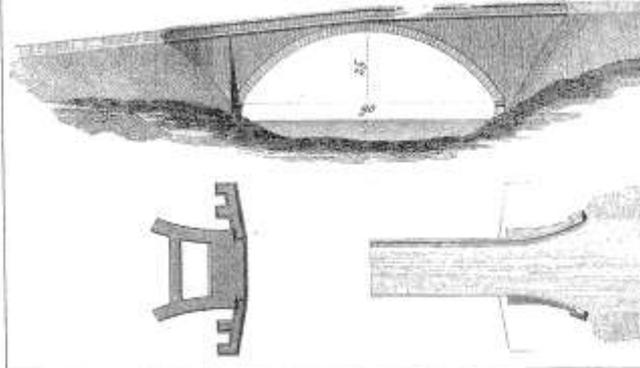
Bonar Bridge 1812 – Telford – First of a innovative iron genre achieving spans greater than could then be achieved in stone.

GLASGOW and CARLISLE ROAD.

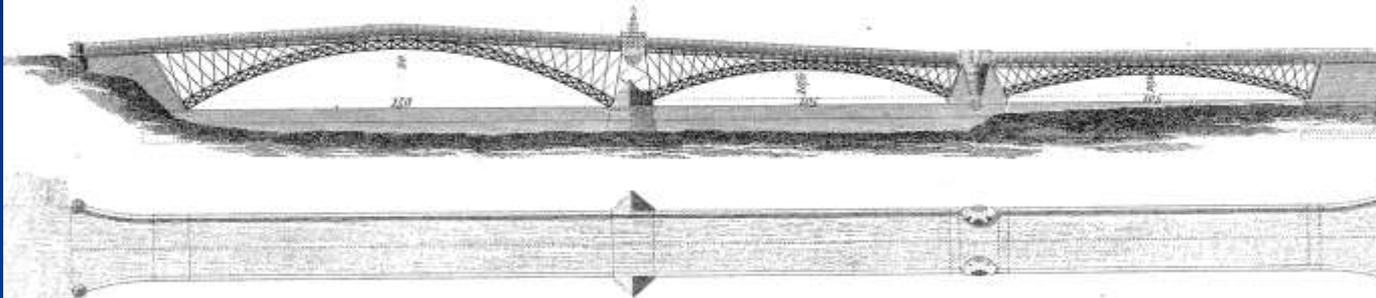
Bridge over the River Avon near Hamilton.



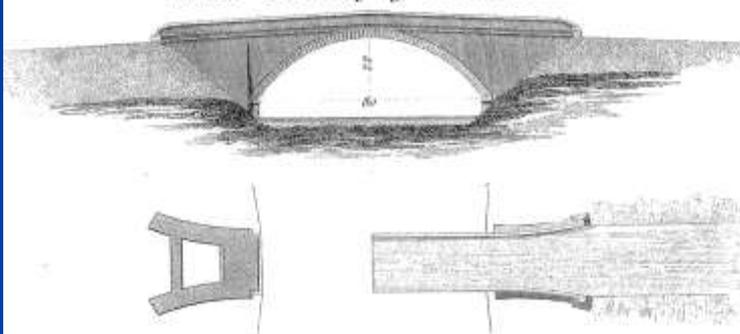
Bridge over the River Clyde at Elvanfoot in the County of Lanark.



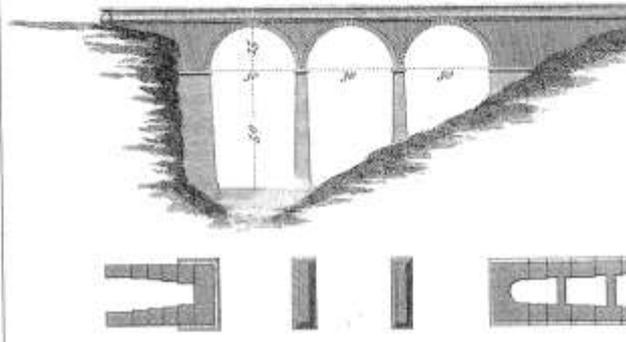
Bridge over the River Eske in the County of Cumberland.



Bridge over the River Annan at Johnstone Mill, in the County of Dumfries.



Bridge over Birkwood Burn near Lismah.

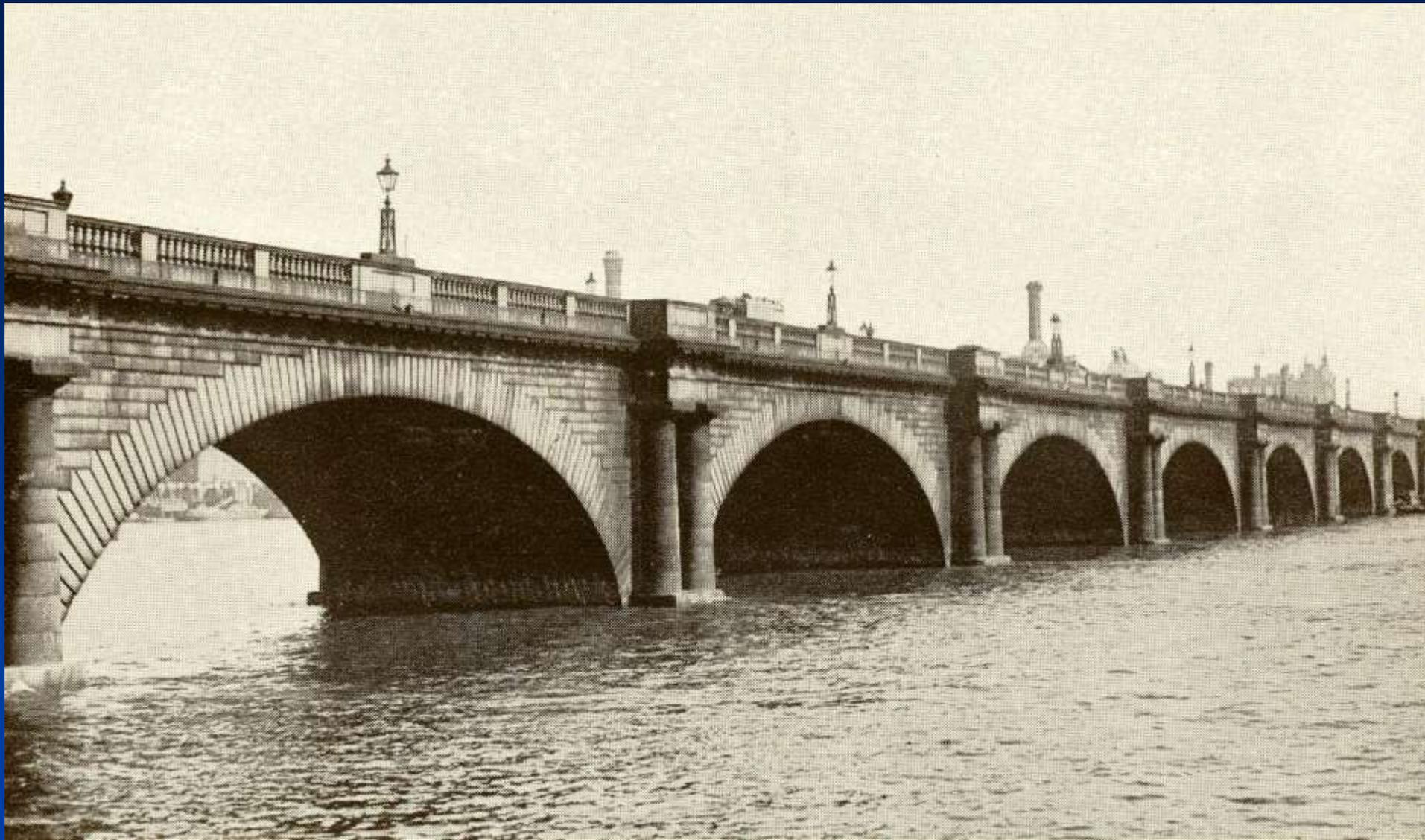


Glasgow and
Carlisle Road
Bridges
[Telford] 1822

Note the
multi-span
cast iron
arches of the
Bonar genre
[formerly at
the aptly
named Metal
bridge Inn on
the A 74] The
finest is still in
service at
Tewkesbury



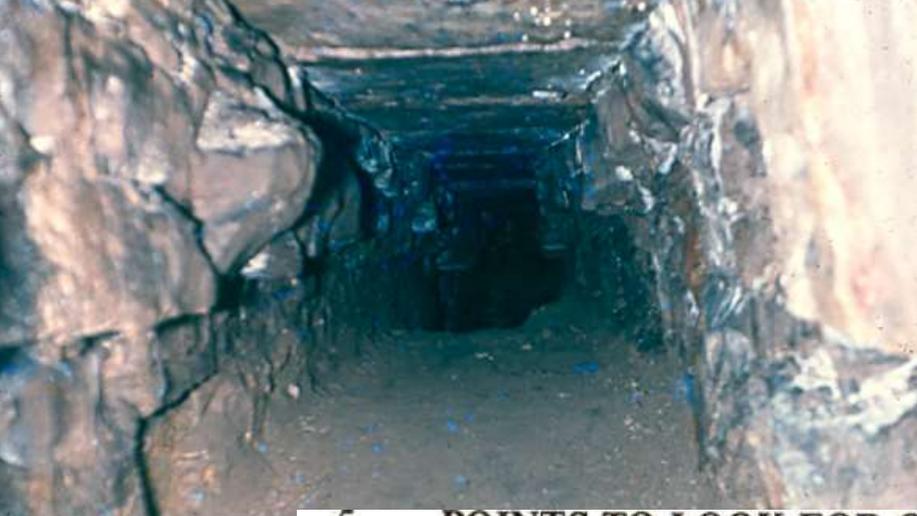
Tewkesbury
Bridge
1823-26



Waterloo Bridge, London, 1817-1934 a John Rennie landmark with 9 elliptical arches – dubbed ‘the finest bridge in Europe’.



Dean Bridge, Edinburgh 1832 – a landmark bridge in terms of its sophisticated elegance in masonry A Telford masterpiece



Dean Bridge, Edinburgh 1832

5. POINTS TO LOOK FOR ON SITE and POSTSCRIPT

1. The direct line and high level of the bridge which is typically Telford.
2. The impression of lightness that the external arches and pilasters give to the bridge elevation. Try to envisage the delicate operation of arch formation from the narrow pilasters before the main arch spandrels were built (Fig. 8A).

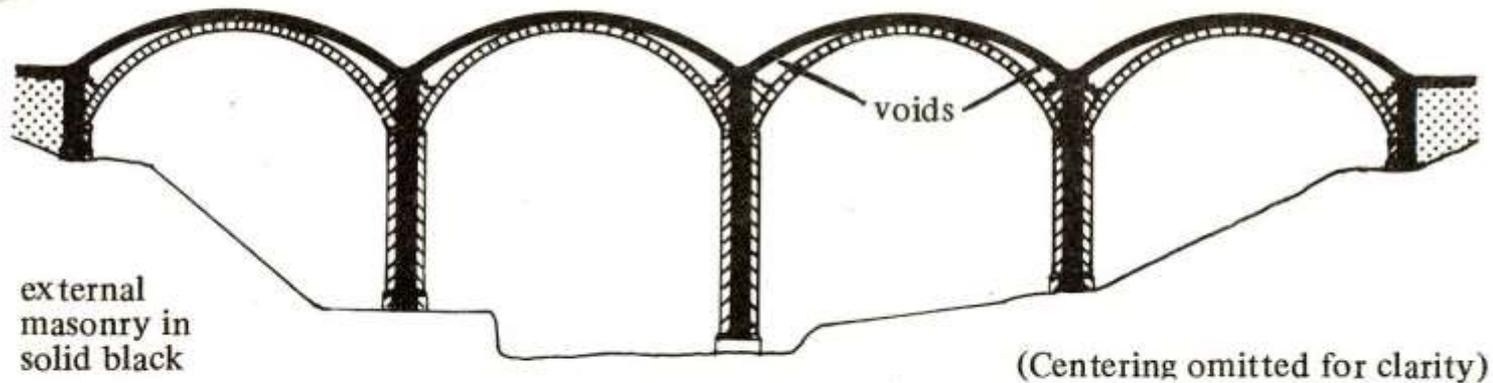
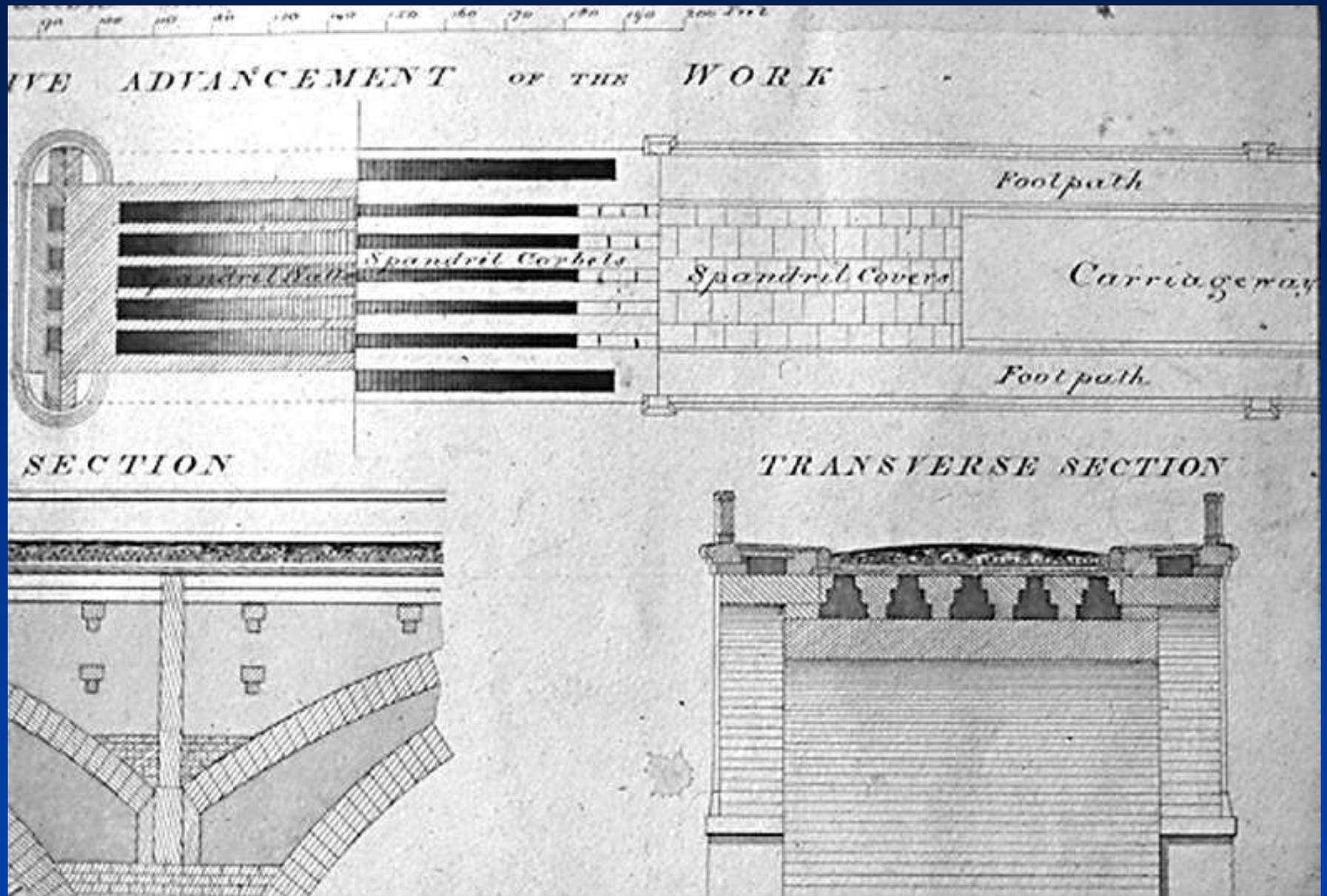


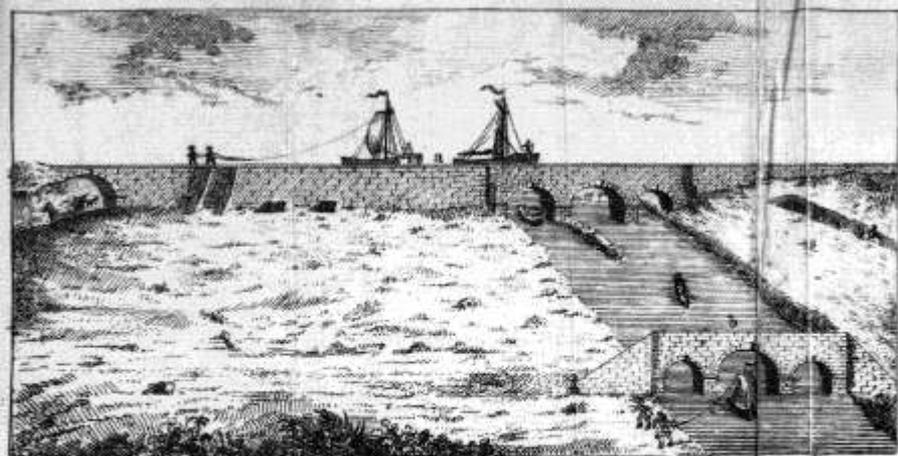
Fig 8A—Dean Bridge—Progress of masonry work on striking upper arch centering.

3. The high quality of the Craigeith stone masonry. The piers are particularly fine. Look for the close joints and nipper indentations on the ashlar blocks.

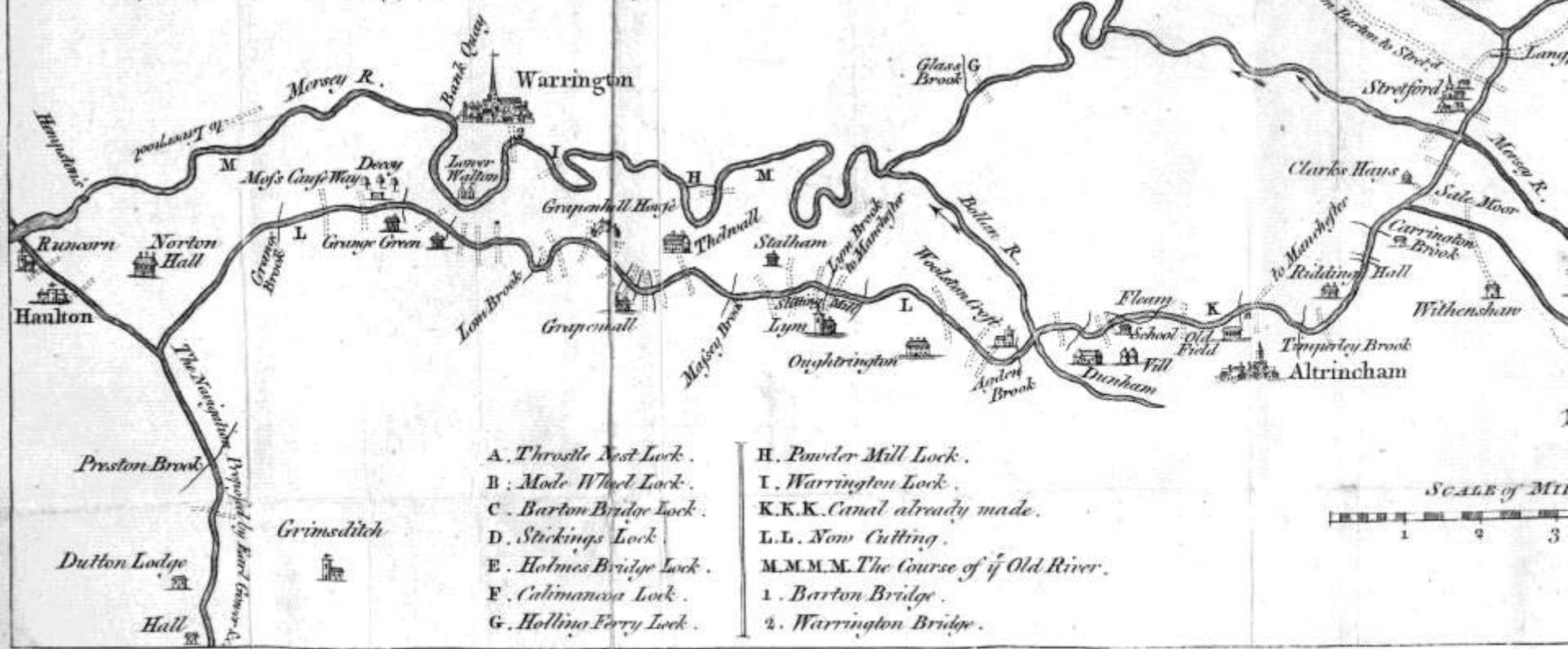


Dean Bridge Drawing 1832

A PLAN
of the
Duke of Bridgewater's
Navigable Canal
already made
With the Extension proposed from
ALTRINCHAM
to
LIVERPOOL.



a. The Duke of Bridgewater's Navigation a cross of Irwell. b. Barton Bridge over D.



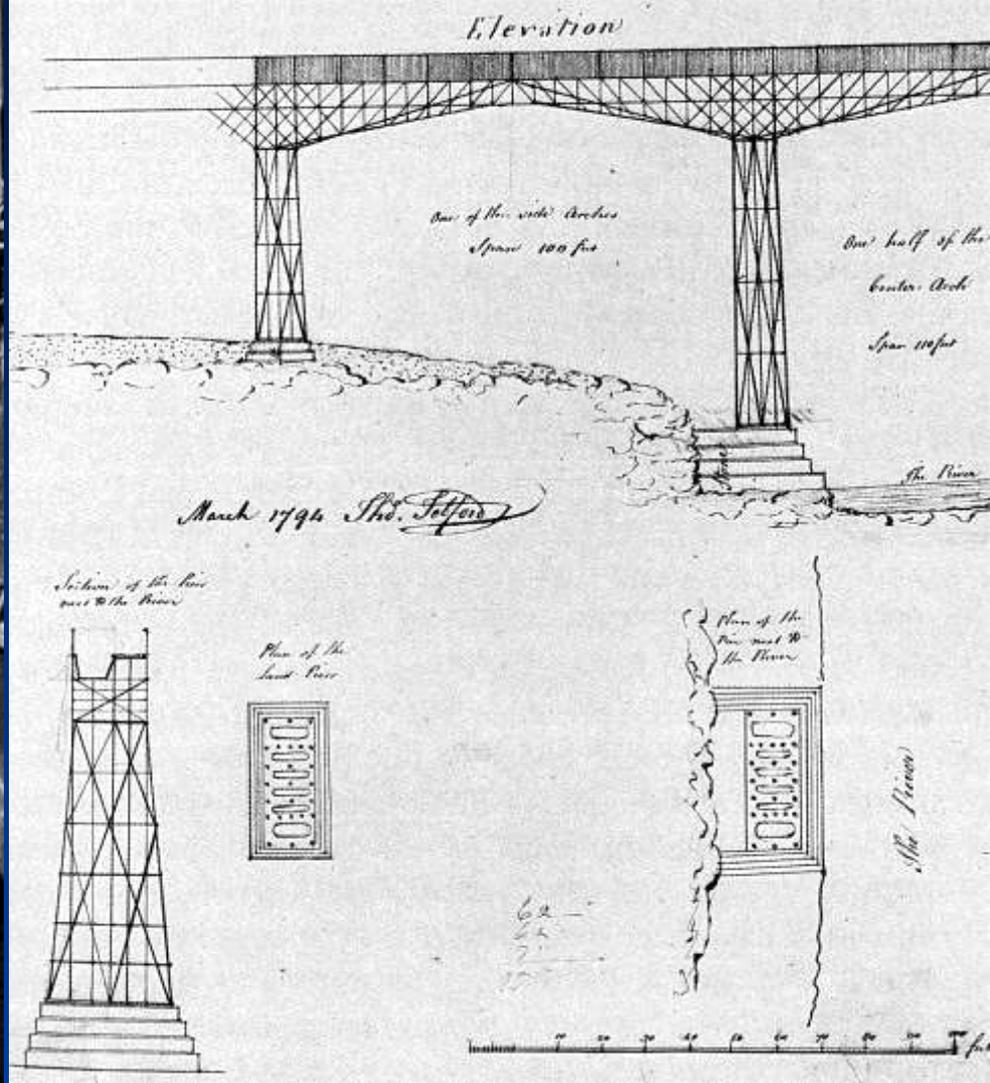
- | | |
|------------------------|---|
| A. Throstle Nest Lock. | H. Powder Mill Lock. |
| B. Mole Wheel Lock. | I. Warrington Lock. |
| C. Barton Bridge Lock. | K.K.K. Canal already made. |
| D. Stickings Lock. | L.L. New Cutting. |
| E. Holmes Bridge Lock. | M.M.M.M. The Course of <i>ij</i> Old River. |
| F. Calimancoa Lock. | 1. Barton Bridge. |
| G. Hollins Ferry Lock. | 2. Warrington Bridge. |



Bridgewater Canal 1761 – cheap coal from Worsley to Manchester



Thomas Telford:
250 YEARS OF INSPIRATION



Pontcysyllte Aqueduct on the Ellesmere Canal [Telford] 1805 – supreme structural engineering landmark of the canal age.

INTERNATIONAL HISTORIC CIVIL ENGINEERING LANDMARK

FORTH & CLYDE SHIP CANAL

CONSTRUCTED: GRANGEMOUTH TO GLASGOW 1768-77
GLASGOW TO BOWLING 1785-90

CLOSED: 1963

RE-OPENED: 2001

ENGINEERS: J. SMEATON, R. MACKELL, R. WHITWORTH

THIS CANAL, WHICH IN ADDITION TO INLAND TRAFFIC, ACCOMMODATED FULL-MASTED COASTAL SHIPS BETWEEN THE NORTH AND IRISH SEAS, REPRESENTS A WORLD LANDMARK IN CANAL ENGINEERING DEVELOPMENT. THE PROJECT SIGNIFICANTLY ADVANCED THE INDUSTRIAL REVOLUTION IN SCOTLAND, AND ITS ORGANIZATION PROVED THE MODEL FOR CIVIL ENGINEERING WORK DOWN TO THE PRESENT.

IN RECOGNITION OF THE
CANAL'S "MILLENNIUM LINK" REGENERATION

PRESENTED 30 JUNE 2000

BY THE

INSTITUTION OF CIVIL ENGINEERS

AND

AMERICAN SOCIETY OF CIVIL ENGINEERS

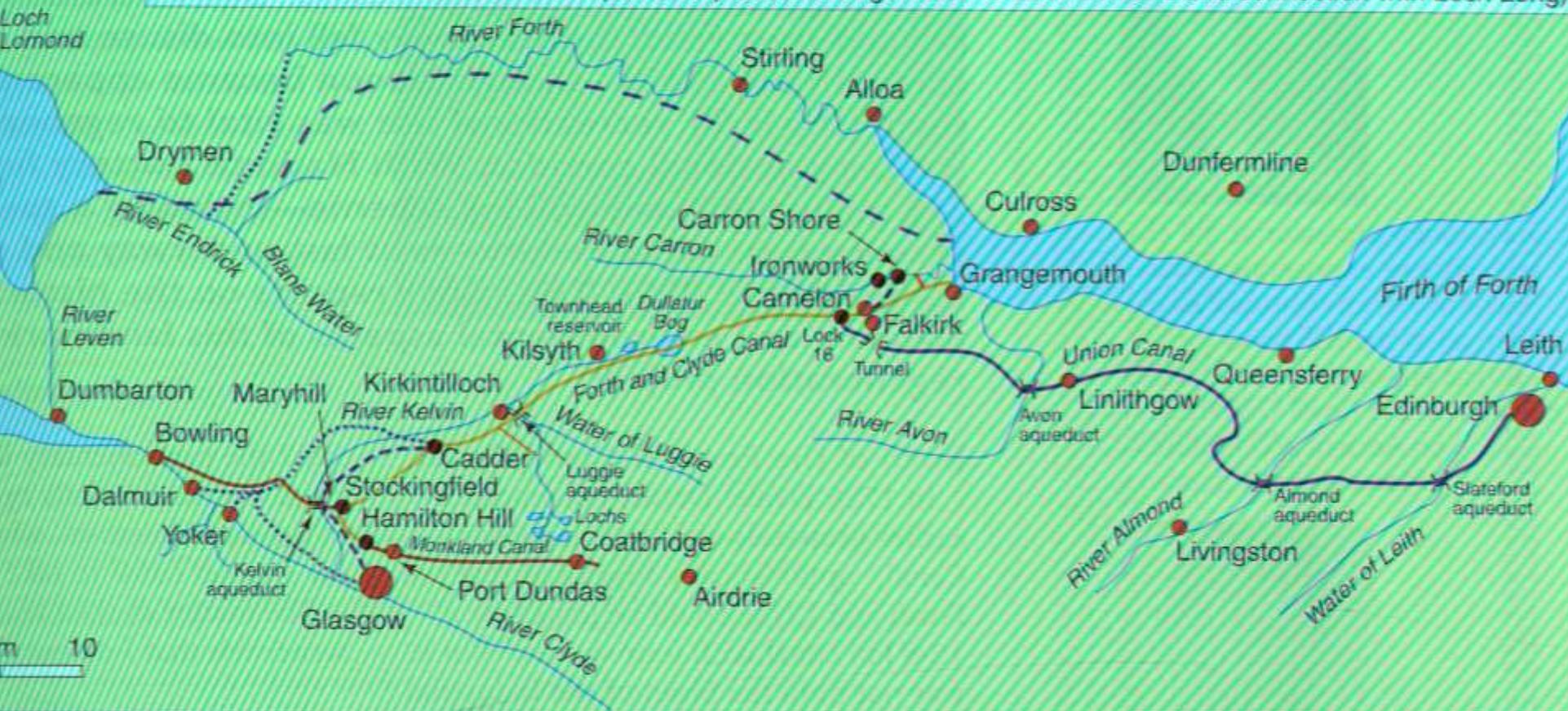


THE INSTITUTION OF
CIVIL ENGINEERS



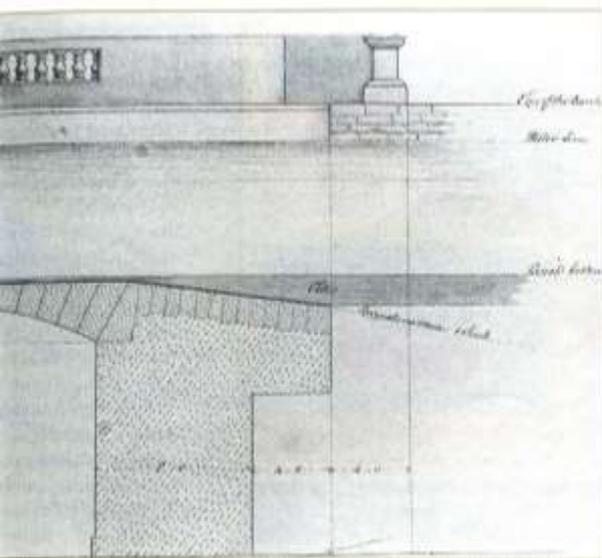
Forth & Clyde Canal Millennium Regeneration Plaque

- Smeaton 1764-7 (and as built line Cadder to Grangemouth)
 - - - Mackell & Watt 1766-7 (and as built line Cadder to Camelon)
 - Smeaton as built 1768-77 (Grangemouth to Hamilton Hill)
 - Whitworth, as built 1786-91 (Stockingfield to Bowling and Monkland Canal connection)
 - - - D&C Stevenson 1889-1914 (Level ship canal Grangemouth to Loch Lomond and connection with Loch Long)
- Note: The broken lines indicate unexecuted proposals

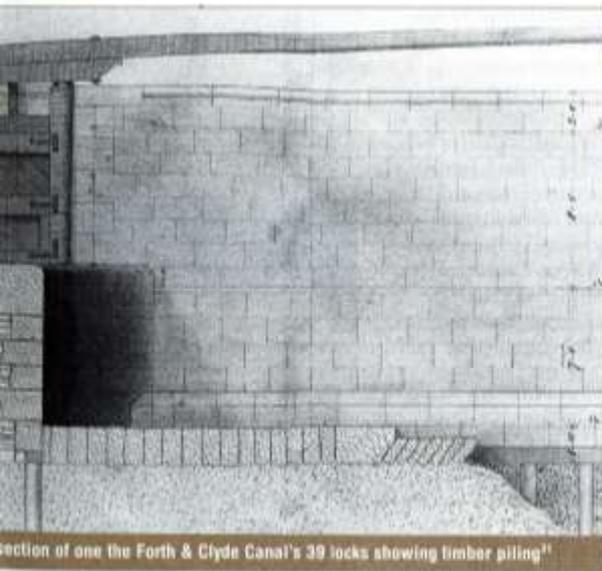


Forth & Clyde and Union canals as planned and constructed

Forth & Clyde Ship Canal plan



Section of the Camelion aqueduct²⁷—the road underpass with its decorative facade in the 19th century with a swing bridge



Section of one the Forth & Clyde Canal's 39 locks showing timber piling²⁸

tioned Bothland Burn feeder aqueduct at Kirkintilloch fed from the Bishop, Woodend, Gartsherrie and Johnston Lochs.

Camelion aqueduct

At Camelion, the underpass of the Edinburgh to Stirling Great Road in 1772 (Fig. 5),²⁹ with a more decorative masonry facade³⁰ than the other aqueducts, was replaced by a swing-bridge in the 19th century.

Locks

The 39 locks are 6.1 m wide by 22.5 m long between the gates with a 2.4 m fall (Fig. 6).³¹ In soft ground a timber floor and piling were used. From Grangemouth the canal rises 38 m by means of 16 locks over 6.4 km (Fig. 7),³² and a further four locks in the next 9.6 km to the 29 km long summit-level section from Dullatur Bog to Maryhill.

At Camelion, Smeaton designed the locks 'singly' so as to 'treasure up' a lock-full of water in 0.5 m depth of the channel between each lock. The channel was made wide enough for two vessels, to offer maximum flexibility in use.³³

Draw bridges

The original timber drawbridges, which had either one or two leaves (Fig. 8),³⁴ were replaced early last century by cast iron and timber bascule bridges (Fig. 9).³⁵

Embankments

Particular difficulties with embankment construction were encountered by taking the canal through, rather than around, Dullatur Bog

'it frequently happened, that when the banks were made apparently perfectly, they have sunk down several feet in the course of a day and had to be again renewed, so that it is believed about 55 ft. perpendicular

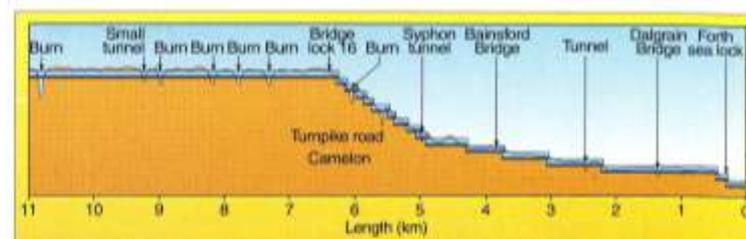


Fig. 7. Longitudinal profile of the east end of the Forth & Clyde Canal showing locks 1–16 required to rise about 38 m.³² All bridges were drawbridges to provide unlimited head room

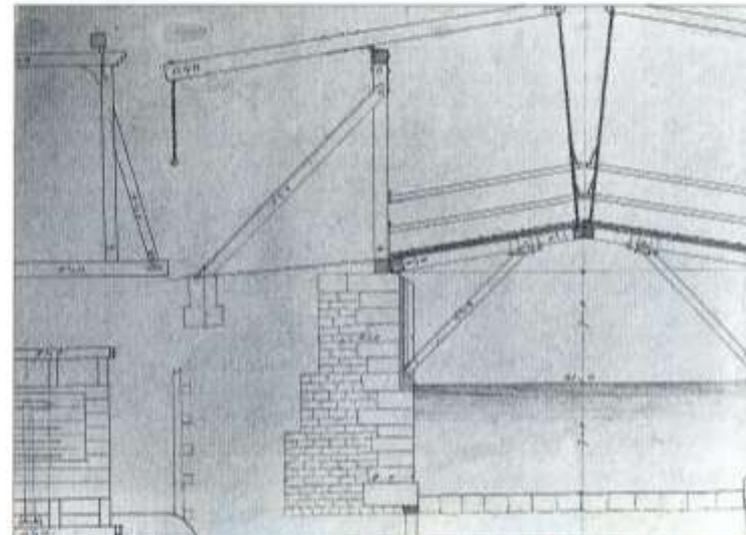


Fig. 8. Typical two-leaf drawbridge over the Forth & Clyde Canal.³⁴ None of the 33 original timber bridges remain.

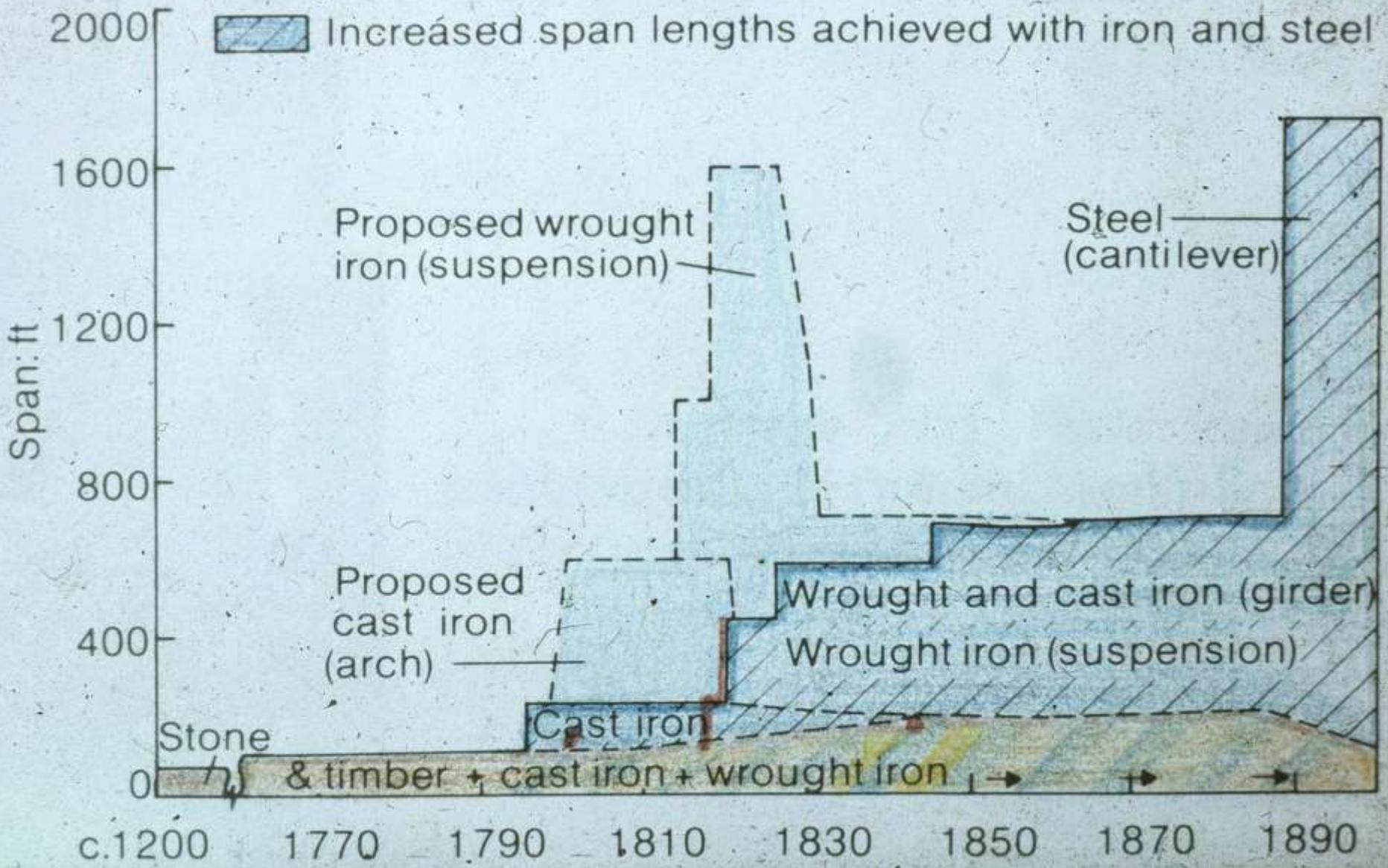




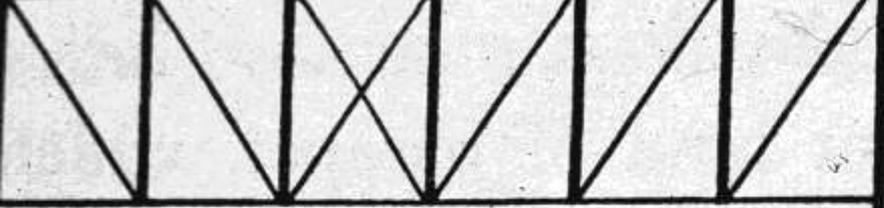
Forth and Clyde Canal. Luggie Aqueduct, Kirkintilloch
1774 (railway 1858)



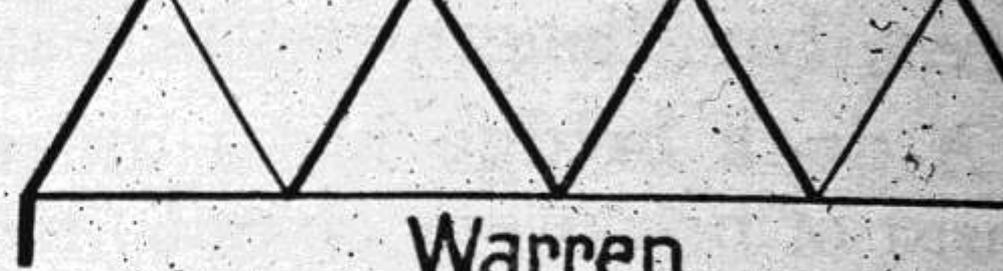
Ashiesteil Bridge 1848 (132 ft) (longest rubble masonry span in Scotland)



Development of bridge spans in Britain using stone, timber, iron and steel – c. 1200 to 1900



Pratt



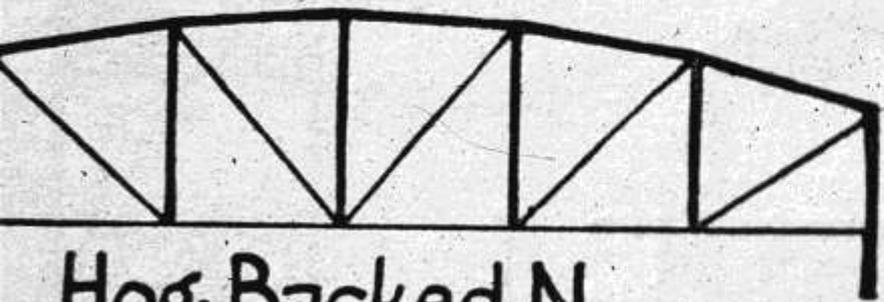
Warren



Fink



Lattice



Hog-Backed N



Modified Warren

After timber-lattice (and tubular iron beam bridges from 1848) more economical wrought iron and eventually steel trusses developed

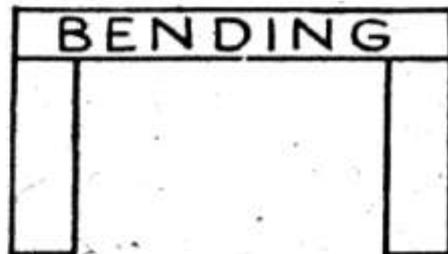


Compression, the force which presses or pushes things;
Bending; and
Tension, the force which pulls or stretches things.

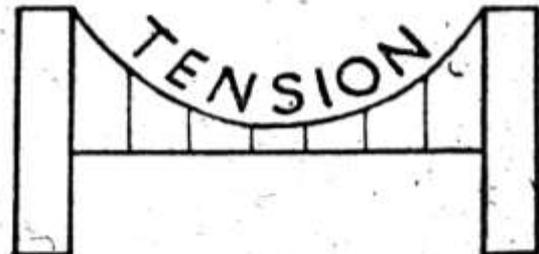
Bridges may be divided into three main types, each especially affected by one of these stresses. The *arch* bridge is subject to compression or direct thrust; the *beam* (or *girder*) bridge to bending, the *suspension* bridge to tension. Some materials are good at resisting one kind of stress, some at another; bricks resist compression, wires resist tension.



Arch bridge.



Beam bridge.

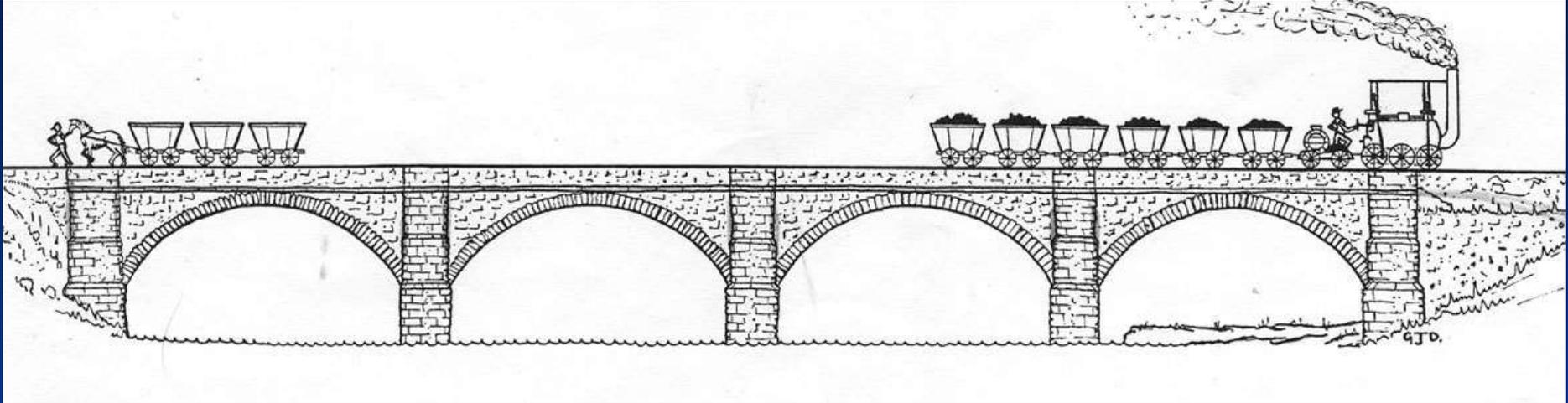


Suspension bridge.

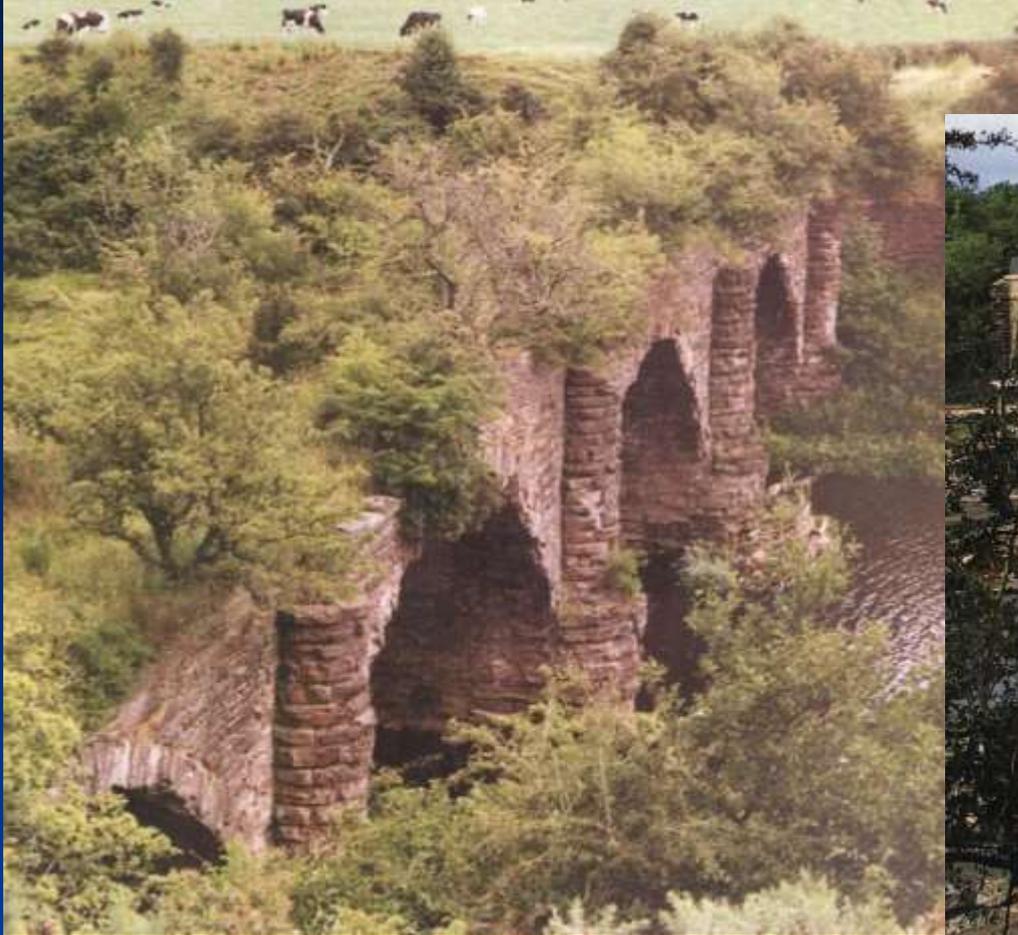
The three main bridge types – arch, beam and suspension



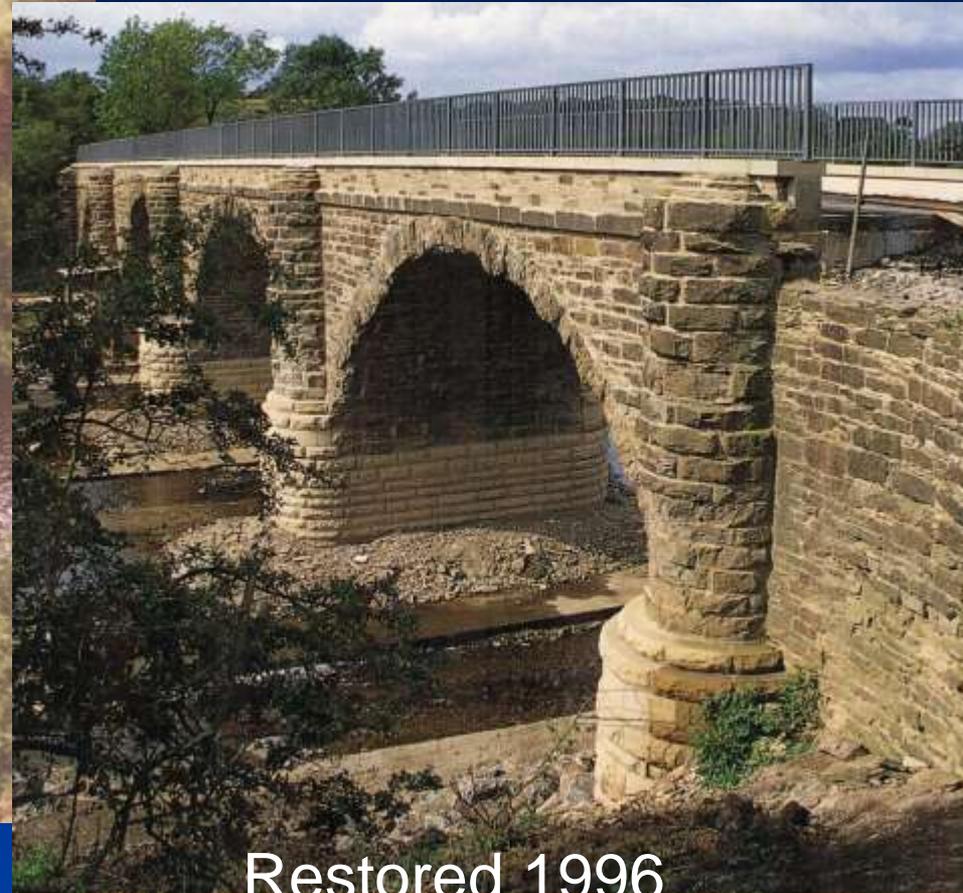
**NORTH
BRITISH
RAILWAY
MAP 1890**



Laigh Milton Viaduct, Kilmarnock, Ayrshire. Erected 1808-11.
In 1816 it carried a steam locomotive – nine years before the
Stockton & Darlington railway.



1995

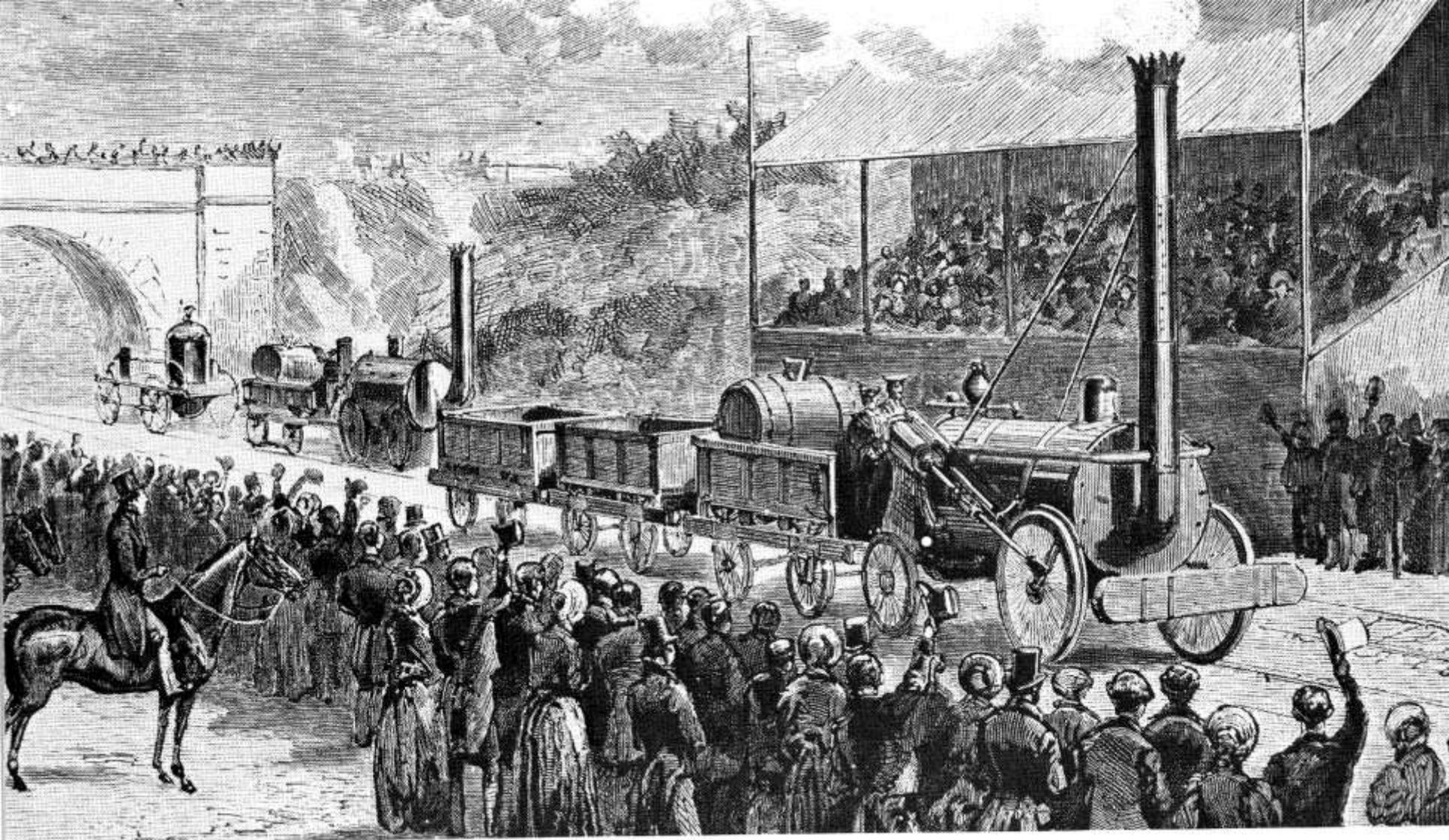


Restored 1996

Laigh Milton Viaduct, Kilmarnock. William Jessop, Engineer.
Opened 1811. Now a landmark as the earliest surviving viaduct
on a public railway.

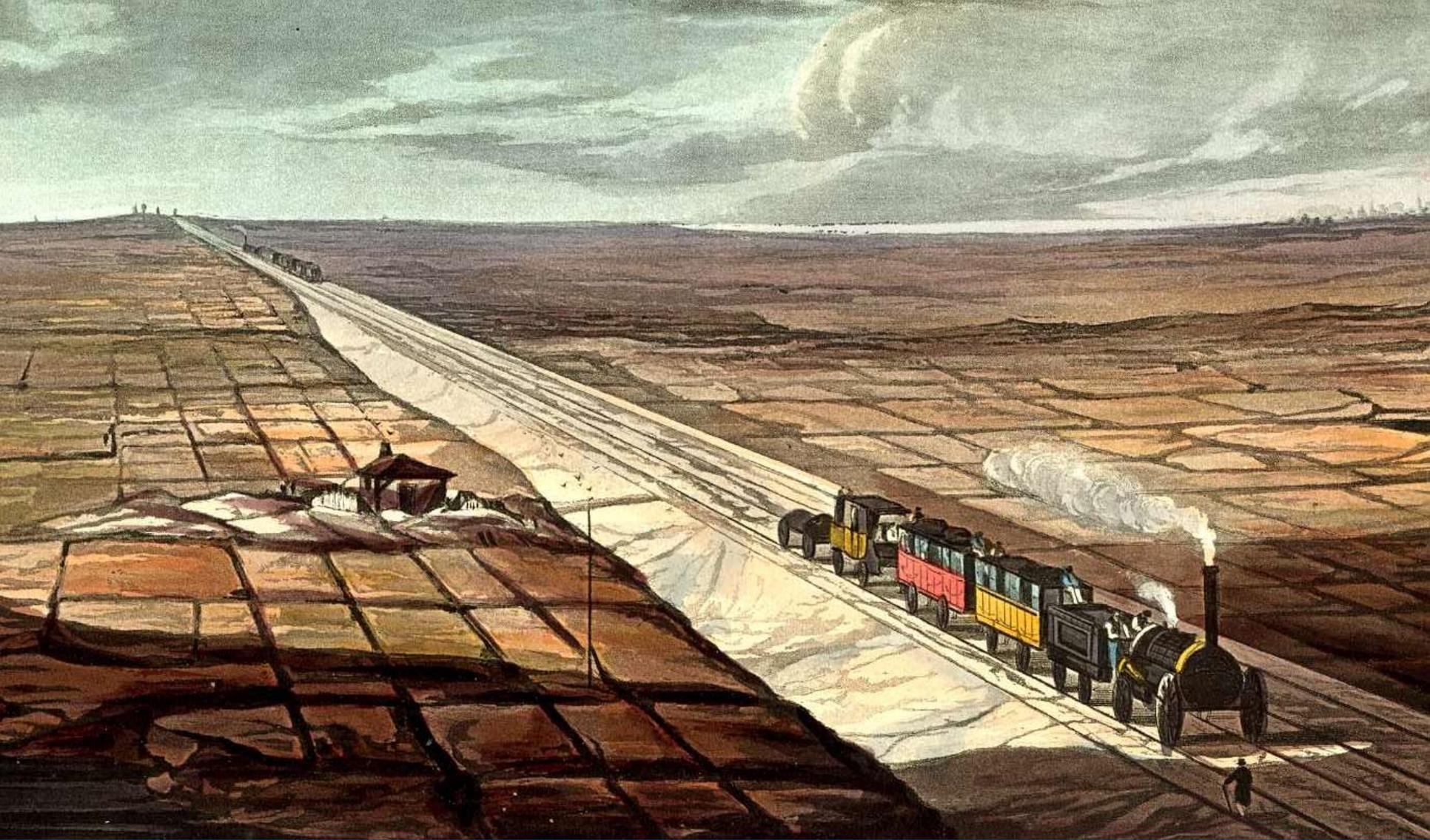


Edinburgh and Dalkeith Railway –Lifting
Braid Burn Bridge (1831) in 2001



The Rocket comes in first at the Rainhill trials

Liverpool & Manchester Railway- the world's first inter-city- Steam locomotion for railways was proved practicable at the Rainhill Trials in 1829 with speeds of 35 mph soon being achieved.



Liverpool & Manchester Railway – train crossing the soft ground at Chat Moss stabilised with brushwood. Rails rested on wooden sleepers instead of the usual stone blocks.



Liverpool & Manchester Railway 1830 – Liverpool Station



Uddingston Viaduct 1849 – traditional cast iron arches (now rare)



Conwy tubular bridge 1848 – Robt Stephenson and Wm Fairbairn



Bridge crossings at Conwy 1826 [Telford] 1848 [Stephenson]



Ballochmyle Viaduct 1848 (181 ft span; 164 ft high)
Landmark as largest of type in UK. Engineer, John Miller.



Queen's Street Station Roof, Glasgow 1879 (170 ft span)



N^o. 40. NEW TAY VIADUCT, NEW PIERS, SOUTH SIDE, JUNE 18th 1886.

Tay Bridge 1886 – note brick piers of 1879 failure behind new ones



Tay Bridge after its fall on 28 December 1879

フォース橋の
100YEARS OF THE FORTH BRIDGE
100年
土木学会

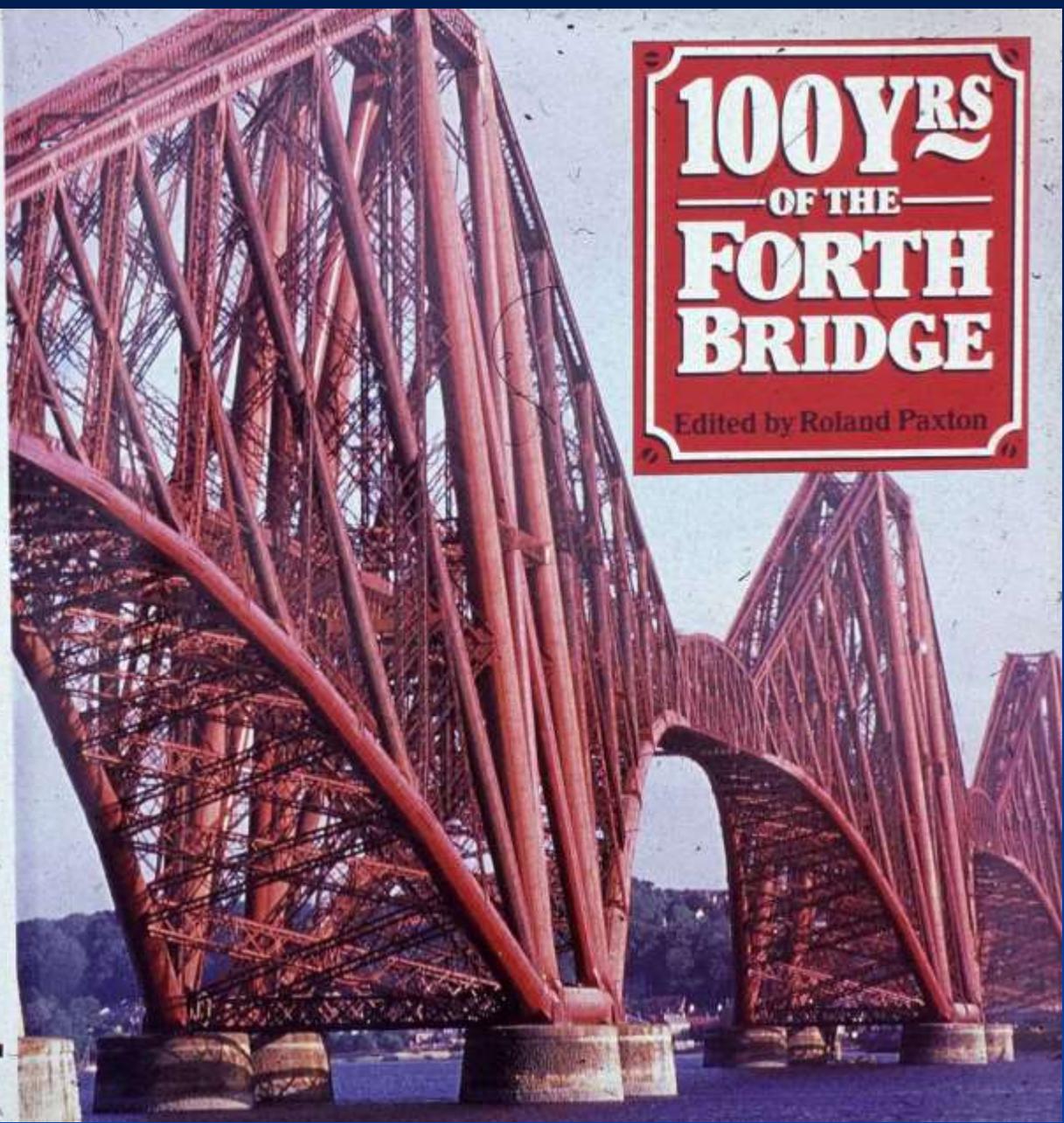
フォース橋の百年

100YRS - OF THE - FORTH BRIDGE

PAXTON



100YRS
— OF THE —
FORTH BRIDGE
Edited by Roland Paxton



A landmark with gravitas – centenary tributes 1990



Forth Bridge – Thomas Bouch's design 1873-81



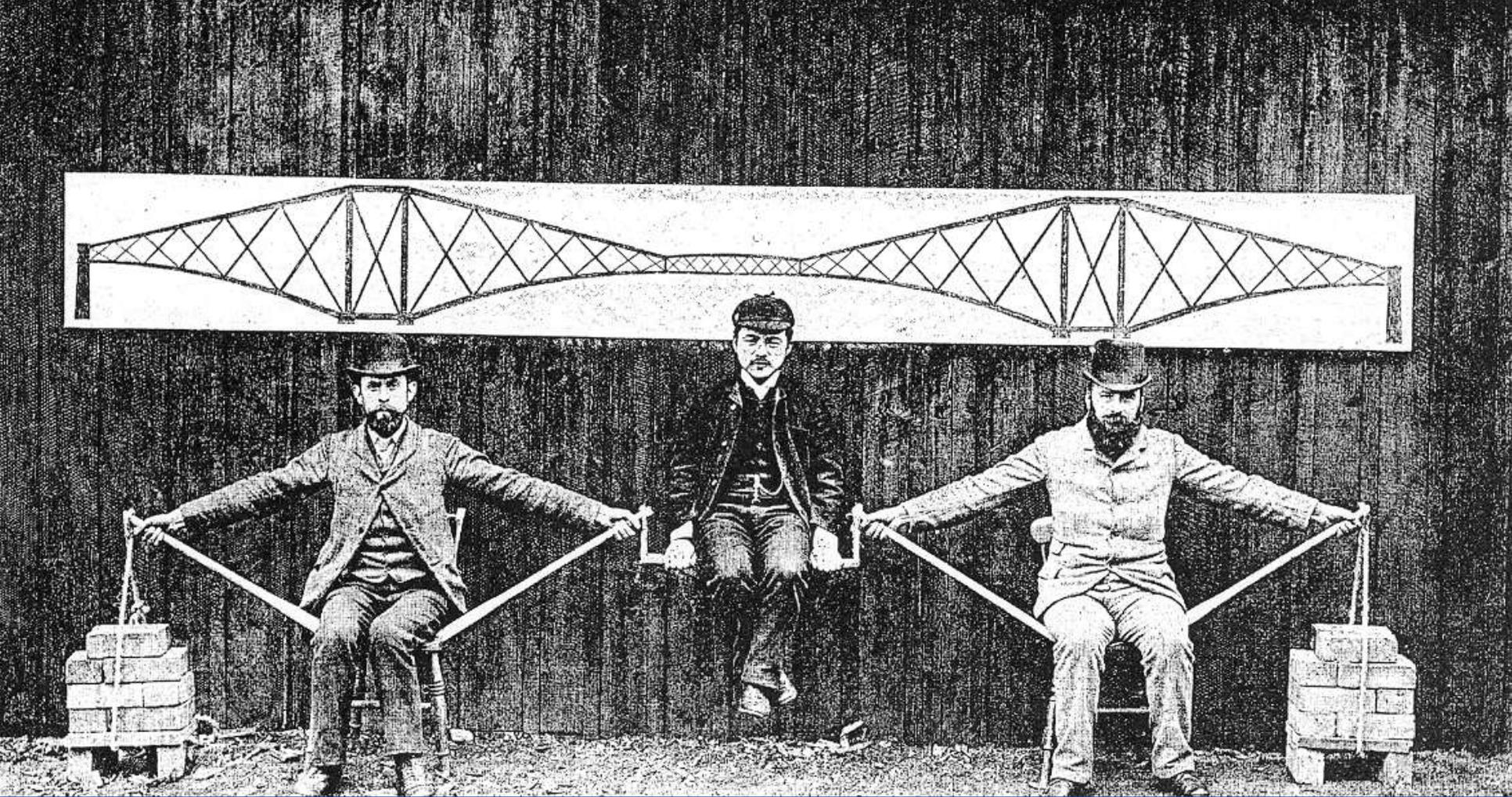
THE FORTH BRIDGE—THE LABOUR OF 5000 MEN (DAY AND NIGHT) FOR 7 YEARS.

ENGINEERS—SIR JOHN FOWLER & SIR BENJAMIN BAKER.

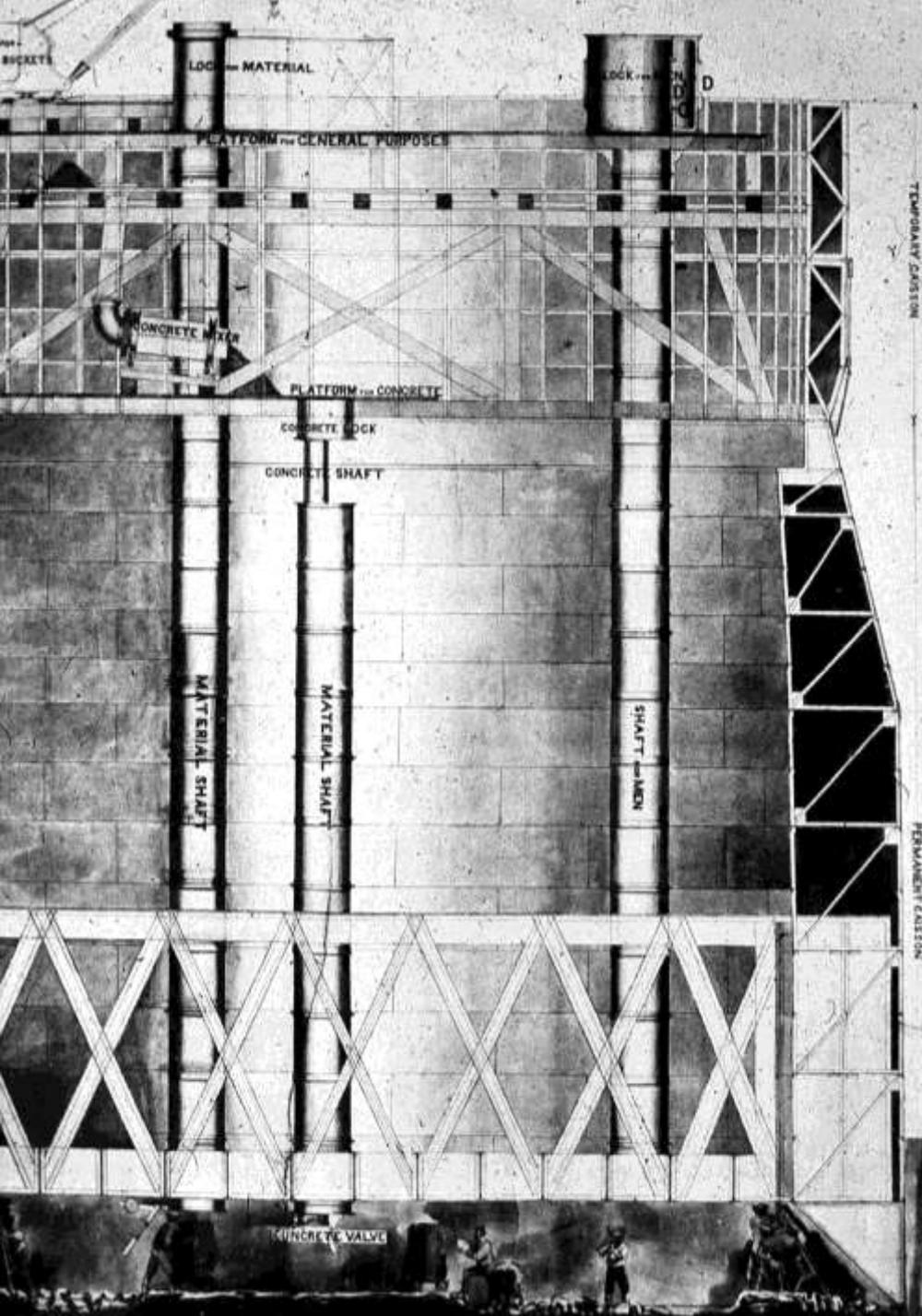
CONTRACTOR—SIR WILLIAM ARROL.

COST OVER £3,500,000.

Total length of viaducts over $1\frac{1}{2}$ miles, including approaches. Two clear spans of 1710 feet ea. Two spans of 680 feet ea. Highest part above high water level, 361 feet. Deepest foundation below high water level, 91 feet. Weight of steel used, 51,000 tons. Number of rivets 5,000,000.



Forth Bridge – Benjamin Baker's human cantilever model c.1884 demonstrating the structural engineering principle of the bridge. Arms in tension, struts in compression. Watanabe counter-balanced by bricks.

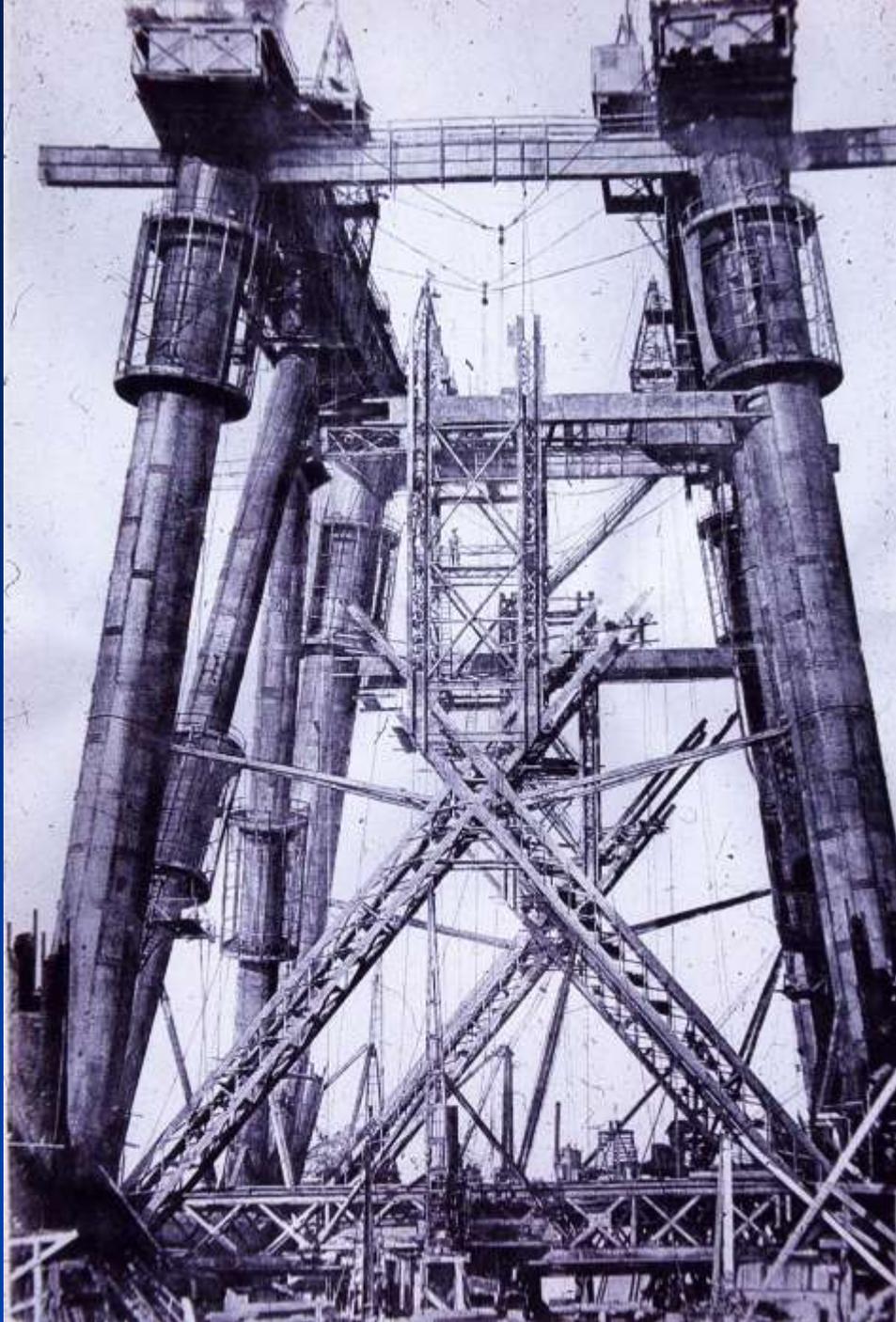


Forth Bridge Caisson (6 in all) 70 ft diameter

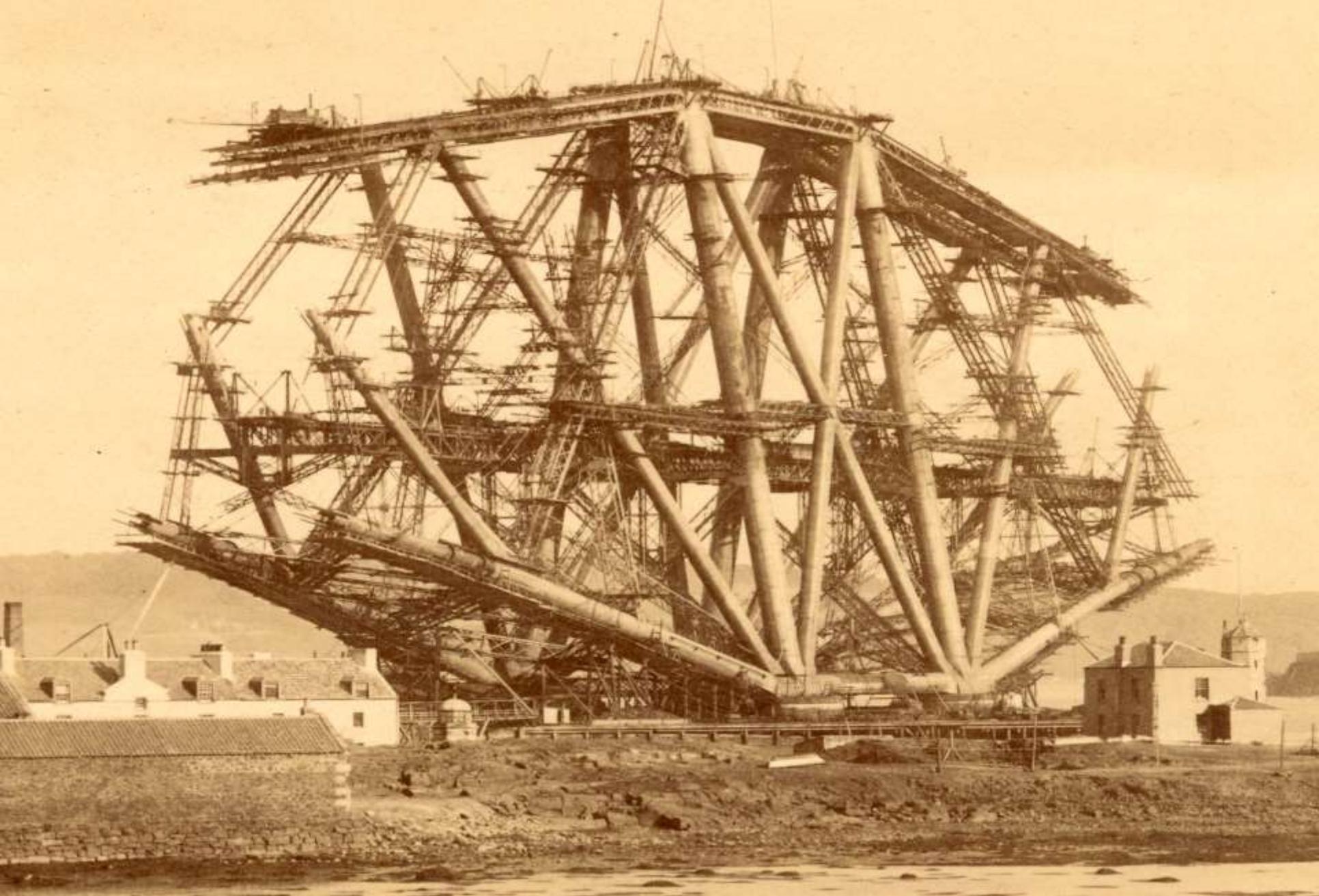
compressed air
chamber 7 ft high
within cutting edge
about 70 feet below
high water. Air
pressure 37 lbs sq in
maximum
at Inchgavie



Forth Bridge - fabricating 12ft tube 9 July 1885



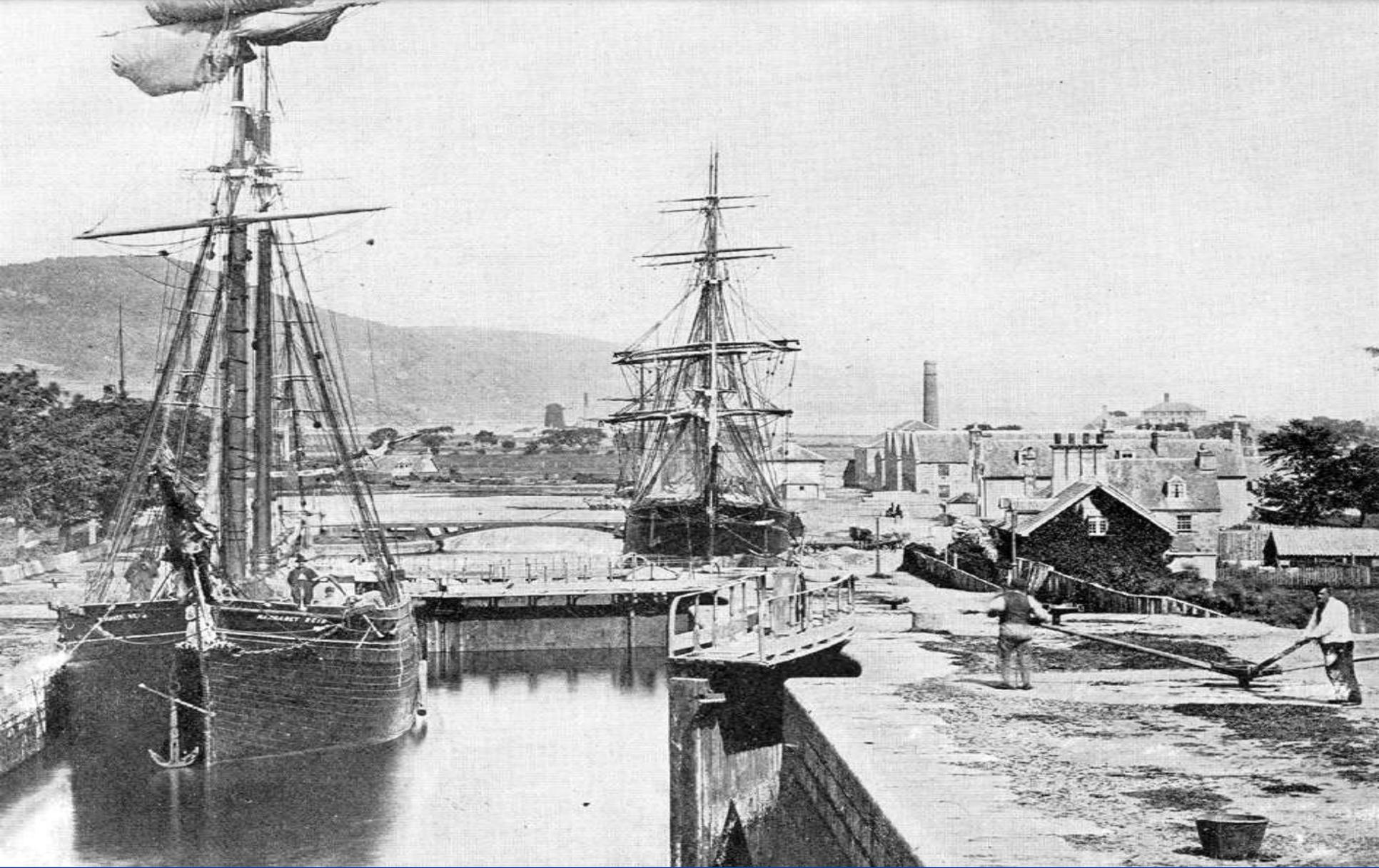
The
Forth
Bridge
Tower
under
erection
1887
—
height
about
110m



Forth Bridge 1888



Quebec Bridge 1917 –
world's longest
cantilever span - 27m
more than Forth Bridge
(right) 1st Quebec Bridge
collapse 1907



Caledonian Canal (1804-22) – world-scale landmark
View showing Muirtown Locks & Swing Bridge in 1890



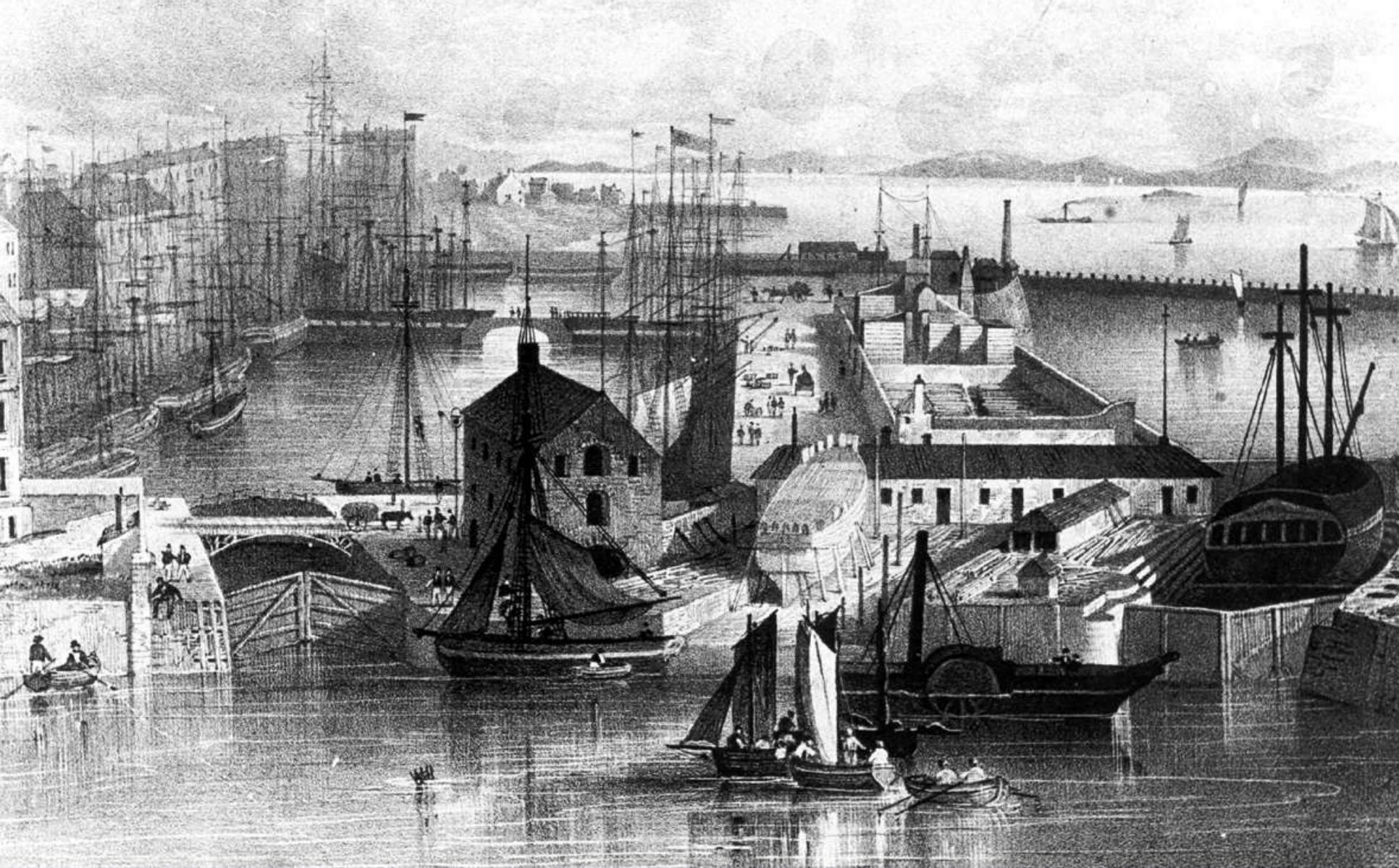
Bell Rock Lighthouse – view of works in July 1810. Chief Engineer: John Rennie, Resident Engineer Robert Stevenson
World's oldest sea-washed rock lighthouse still in service



Union Bridge, Paxton – World's longest span carrying carriages when opened in 1820. Landmark for this reason and also as the world's oldest suspension bridge still carrying vehicles.



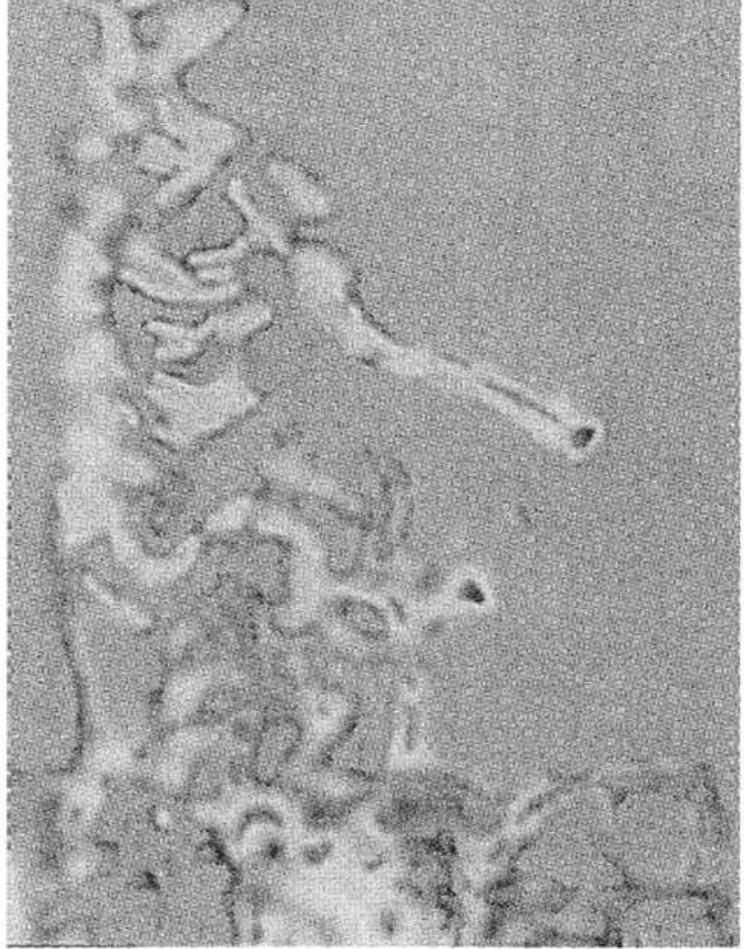
Menai Bridge (1819-26) today - Landmark as the world's first great suspension bridge which established the genre as the best means of achieving the longest spans. Link at H-W Univ. Made practicable by Cort's improvements in wrought iron making.



Leith 'floating harbour' landmark [Rennie 1806] in 1838 – identical entrance lock to his London Docks c.1800 – bridges and dry-dock



indicates the location of the horse and cart. (RCAHMS: D48255/CN)



Loch nan Uamh Viaduct; radar scan of remains of horse and cart within central pier. (Courtesy of Radar World)

Loch-nan-Uamh Viaduct c1899 – This and other bridges on the West Highland Railway were the earliest large-scale use of the mass concrete genre on a railway. Horse & cart remains found.



Early reinforced concrete bridge, Saughton Park
Edinburgh – Mouchel 1907 – 30 ft span



Bernera – Lewis Bridge 1953 – 1st prestressed concrete bridge in UK