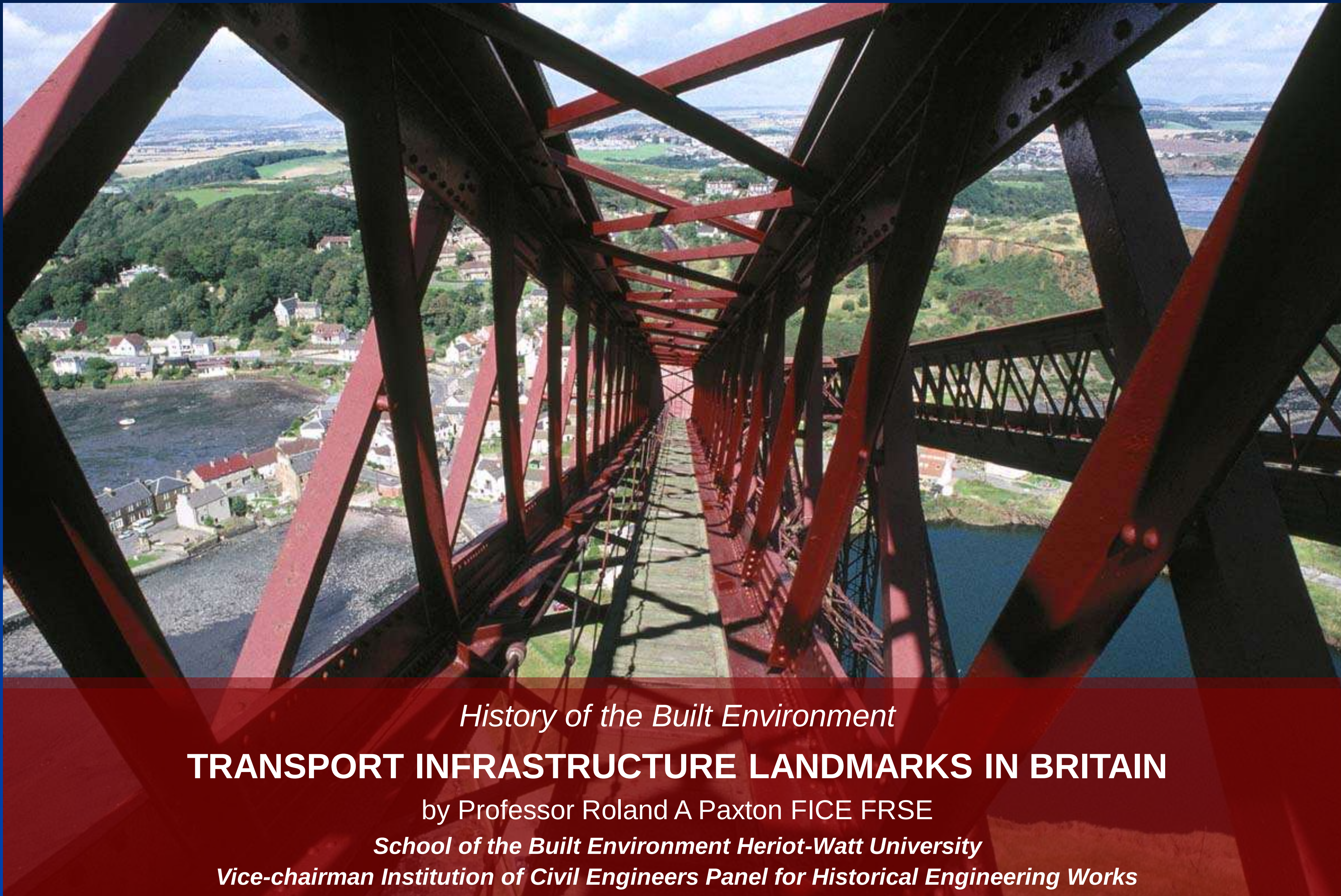


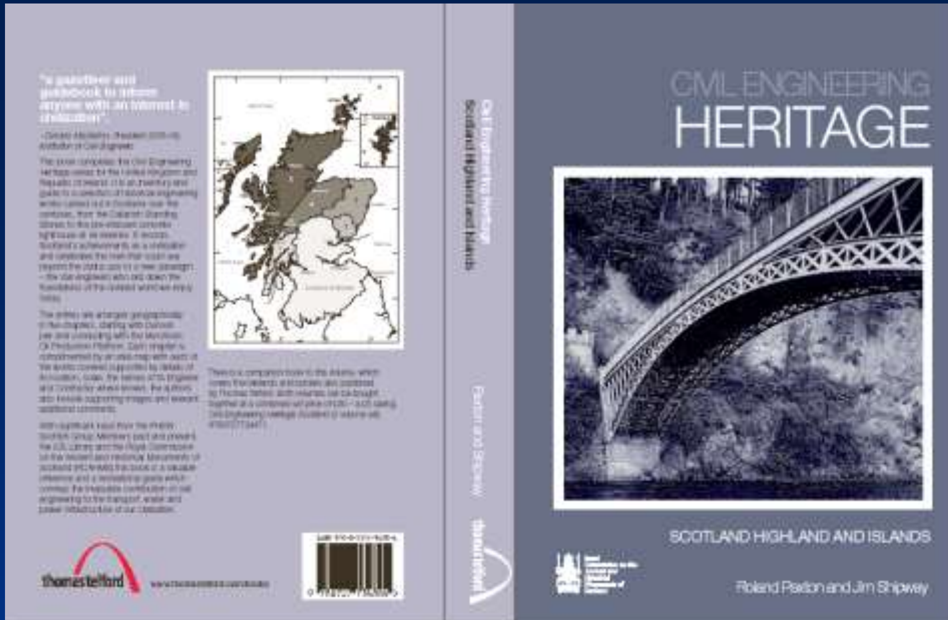
History of the Built Environment

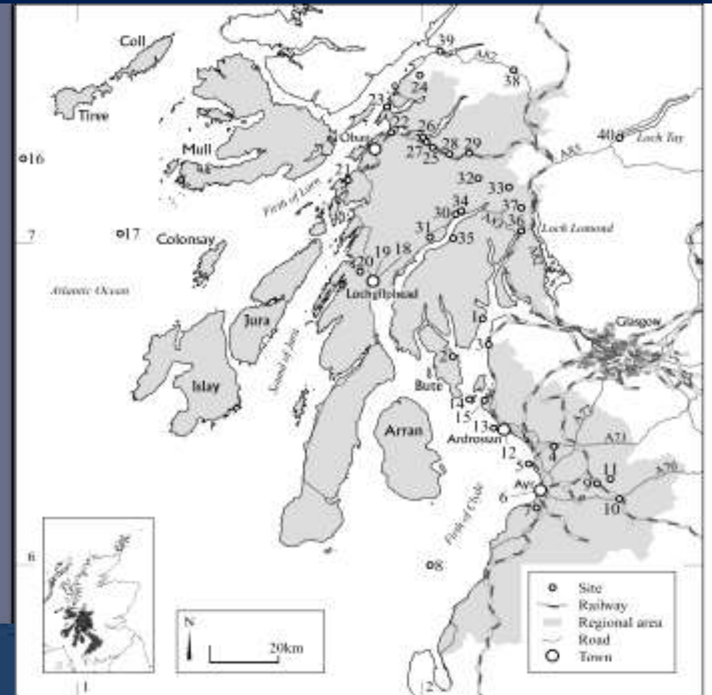
TRANSPORT INFRASTRUCTURE LANDMARKS IN BRITAIN

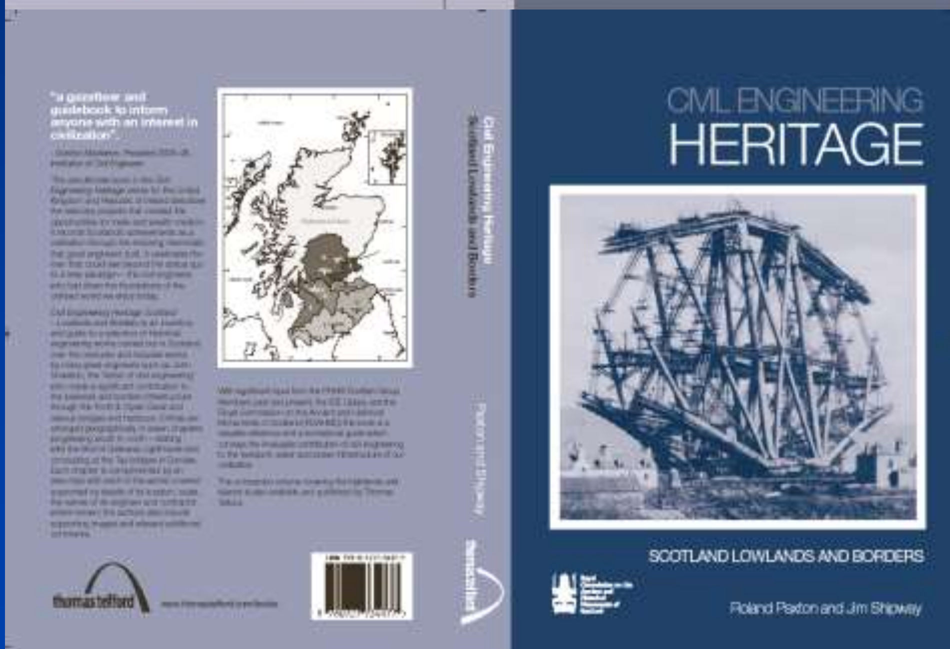
by Professor Roland A Paxton FICE FRSE

School of the Built Environment Heriot-Watt University

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







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

REMARKS

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 1823,

WITH EXTRACTS FROM THE EVIDENCE.

BY JOHN LOUDON M^cADAM, ESQ.

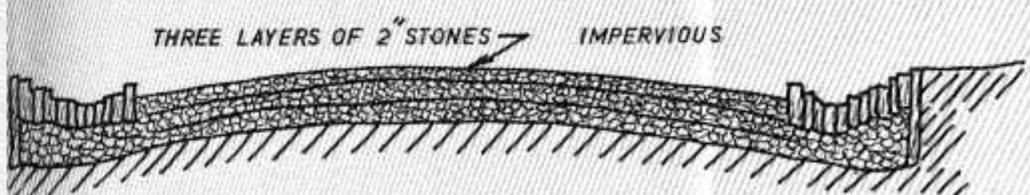
GENERAL SURVEYOR OF THE ROADS IN THE BRISTOL DISTRICT.

LONDON:

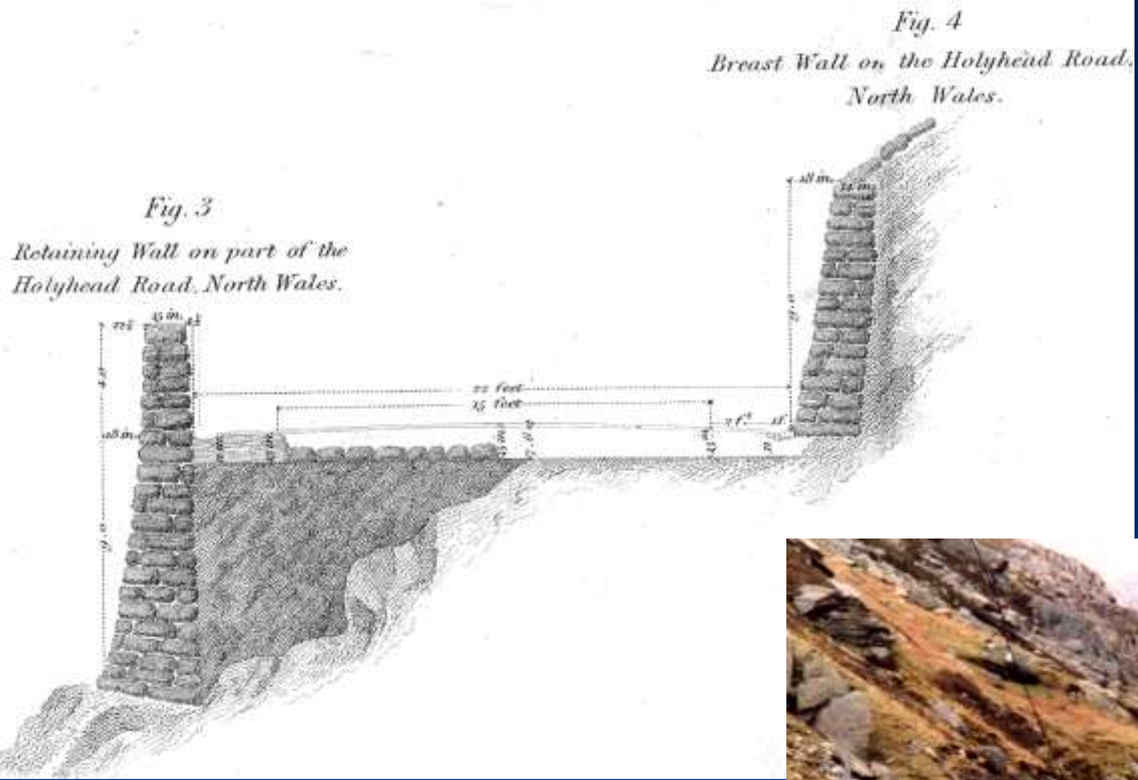
PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN, PATERNOSTER ROW.

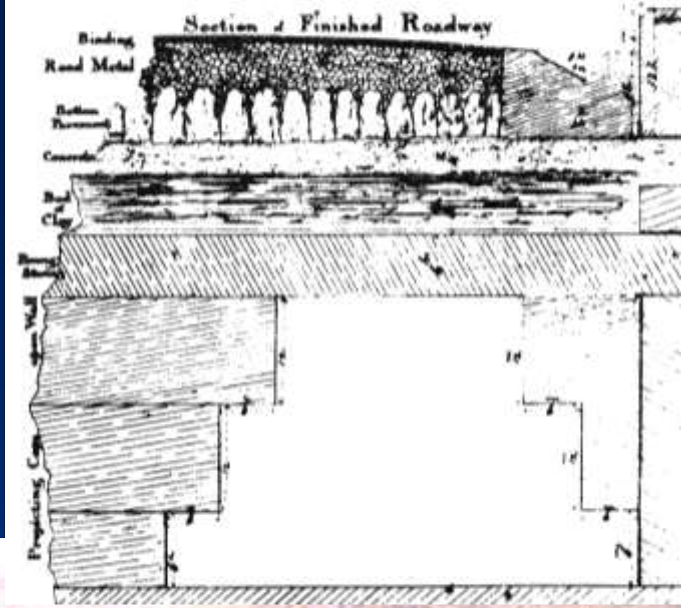
1823.

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.



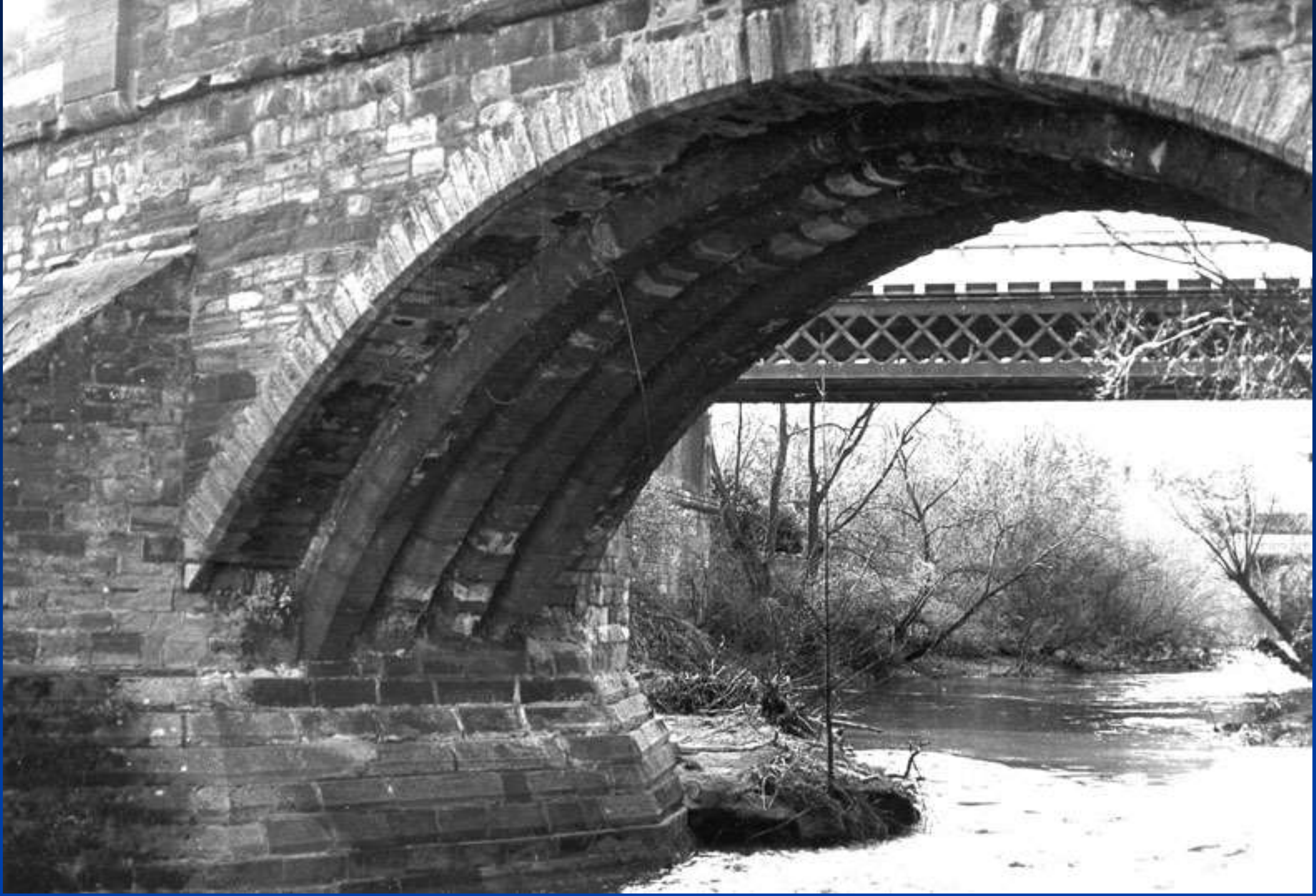
McAdam's principle of road making *was 'that it is the native soil which really supports the weight of traffic; while it is preserved in a dry state it will carry any weight without sinking'.*



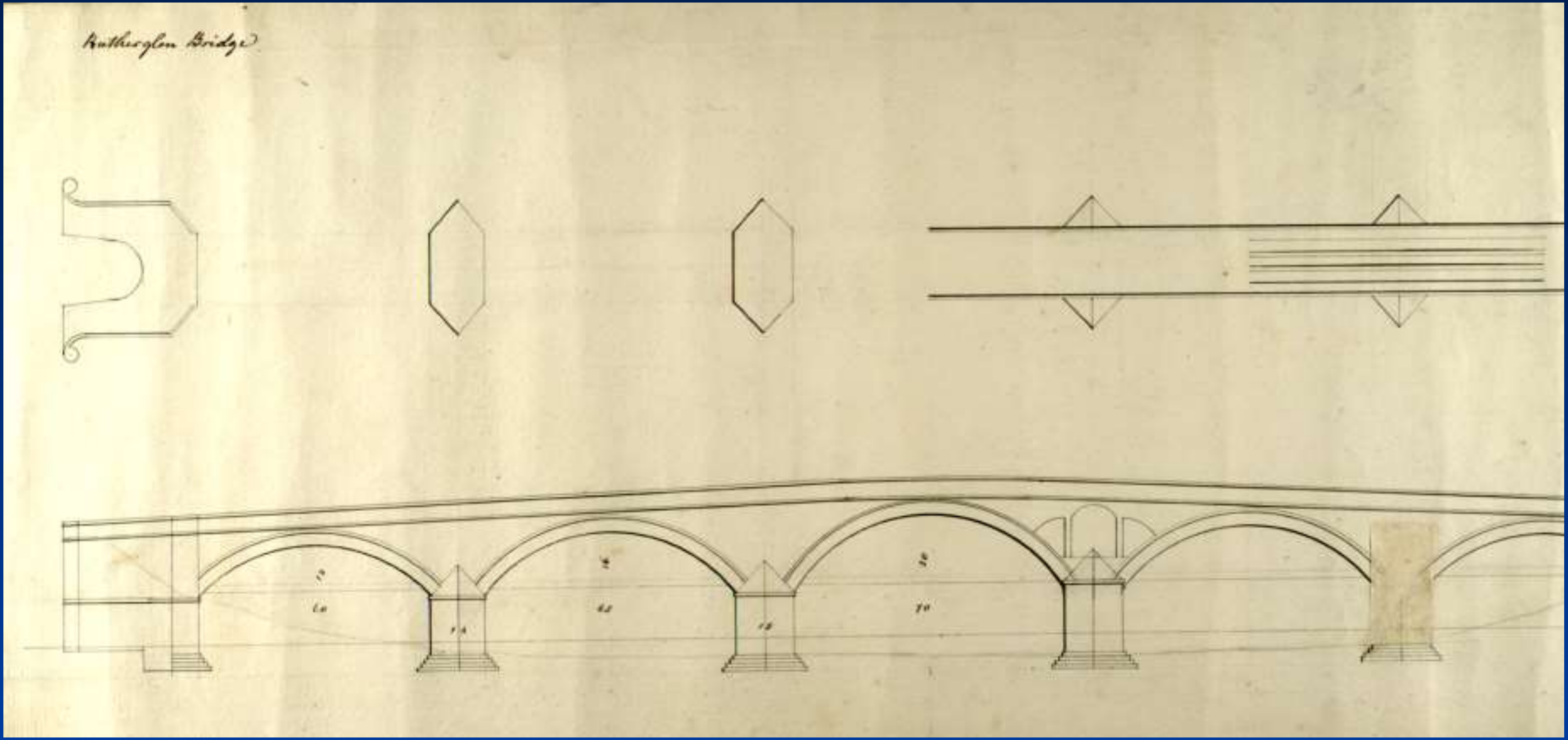


Telford’s road-making in North Wales in 1820s.
Dean Bridge top right.
Note stone foundation under the road metal

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



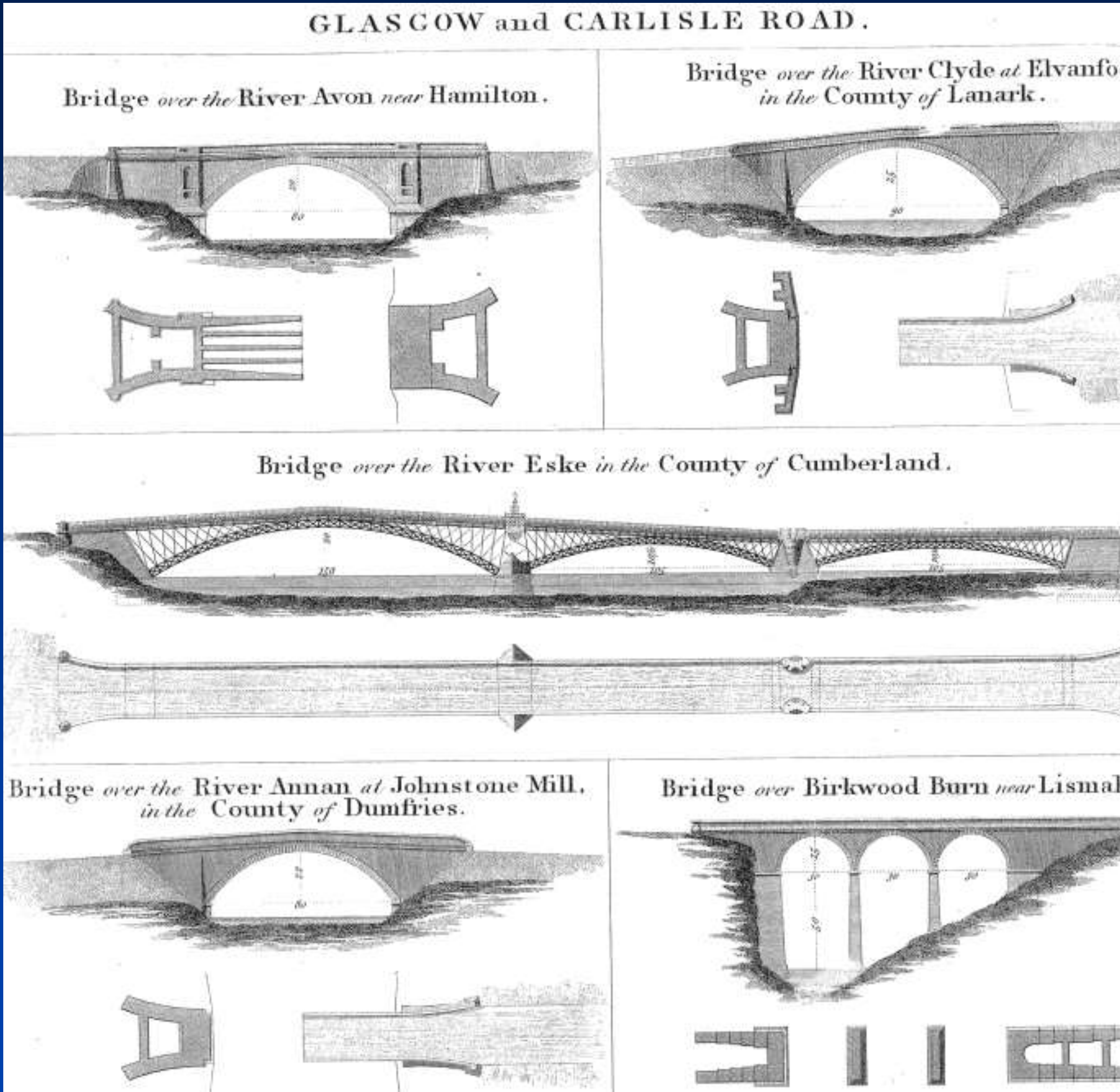
East Linton Bridges c 1550 and c 1870. Medieval bridges were narrow, of small stone (ribbed or plain) or timber spans.



Rutherglen Bridge, 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.

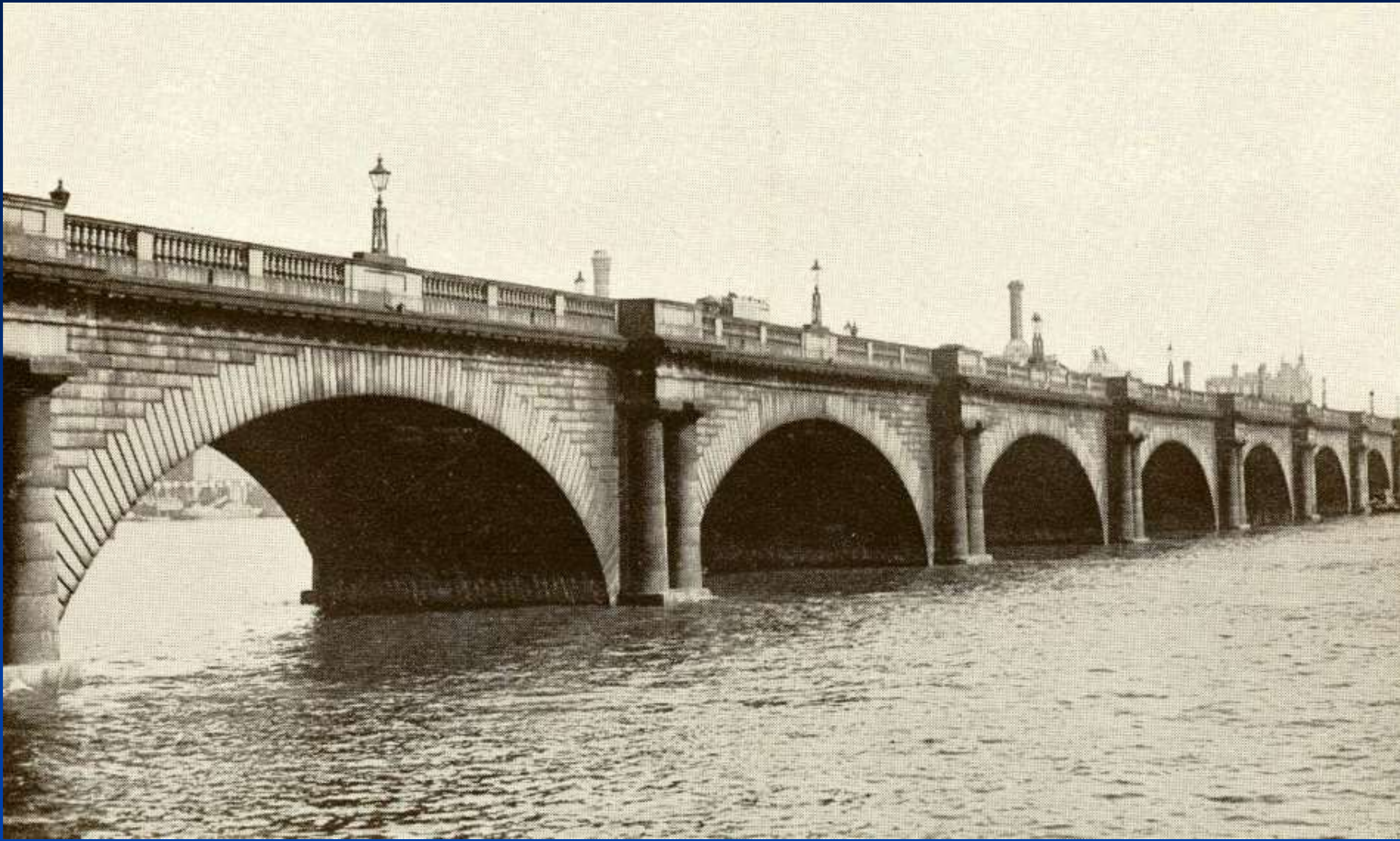


Glasgow and Carlisle Road Bridges [Telford] 1822

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).

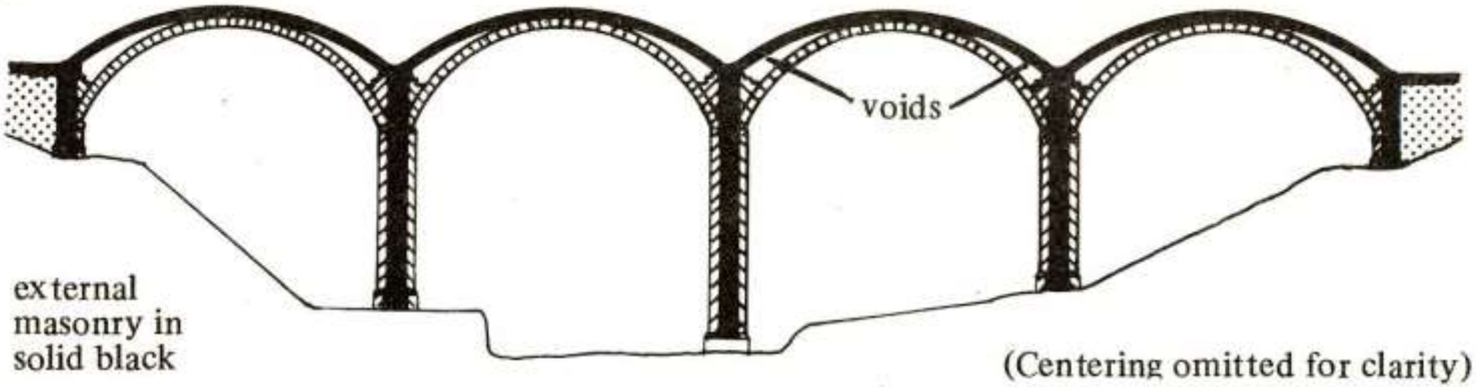
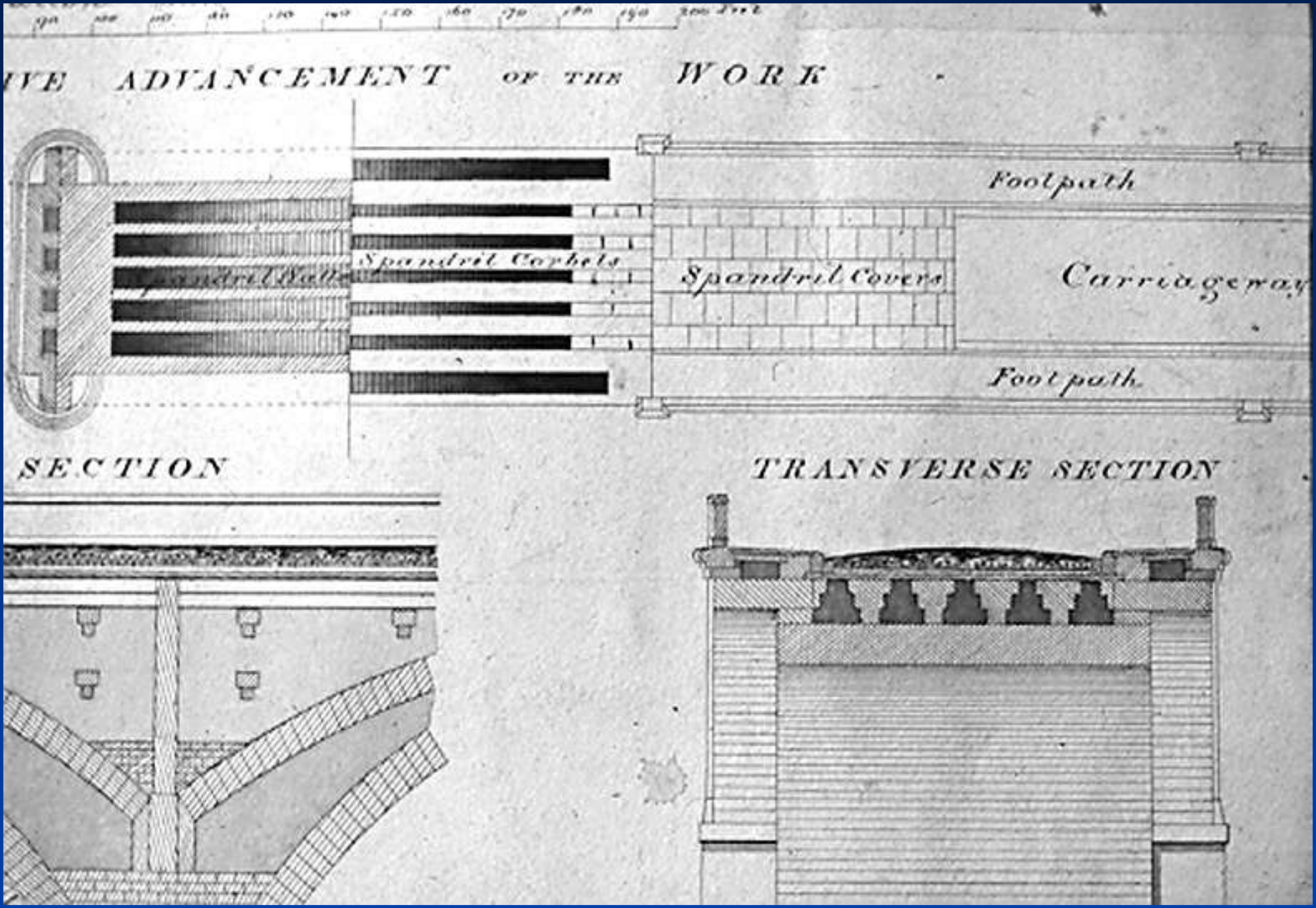
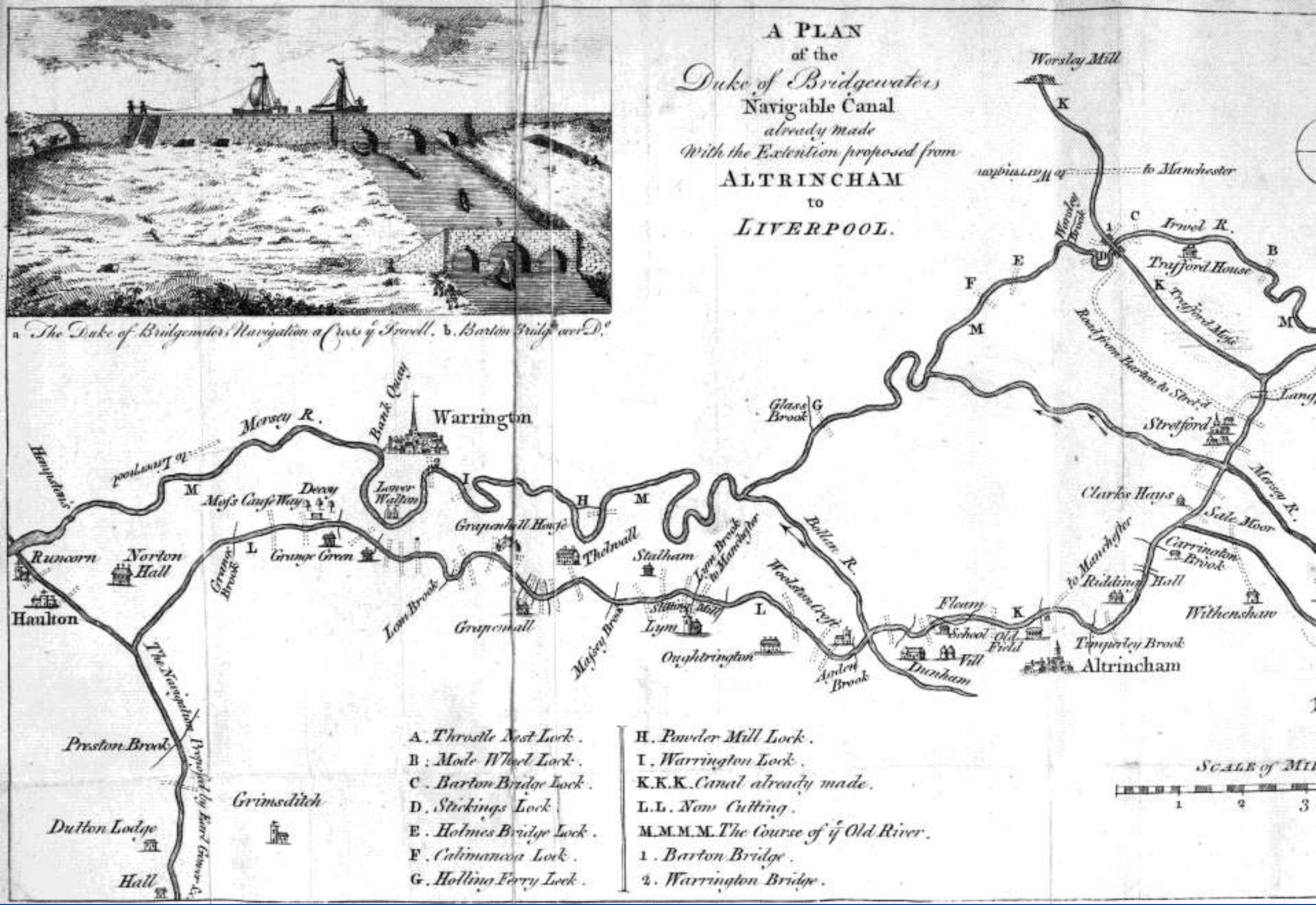


Fig 8A–Dean Bridge–Progress of masonry work on striking upper arch centering.

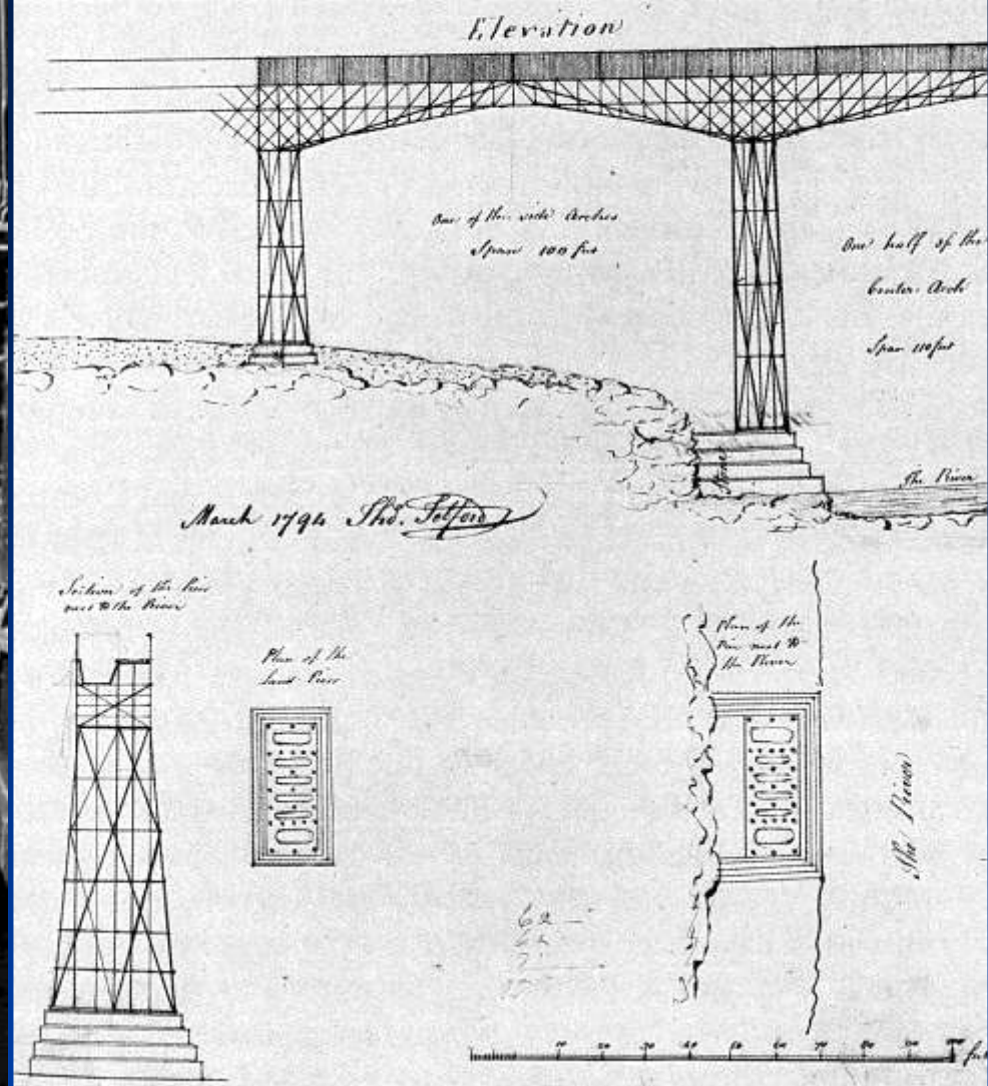
3. The high quality of the Craigleith stone masonry. The piers are particularly fine. Look for the close joints and nipper indentations on the ashlar blocks.



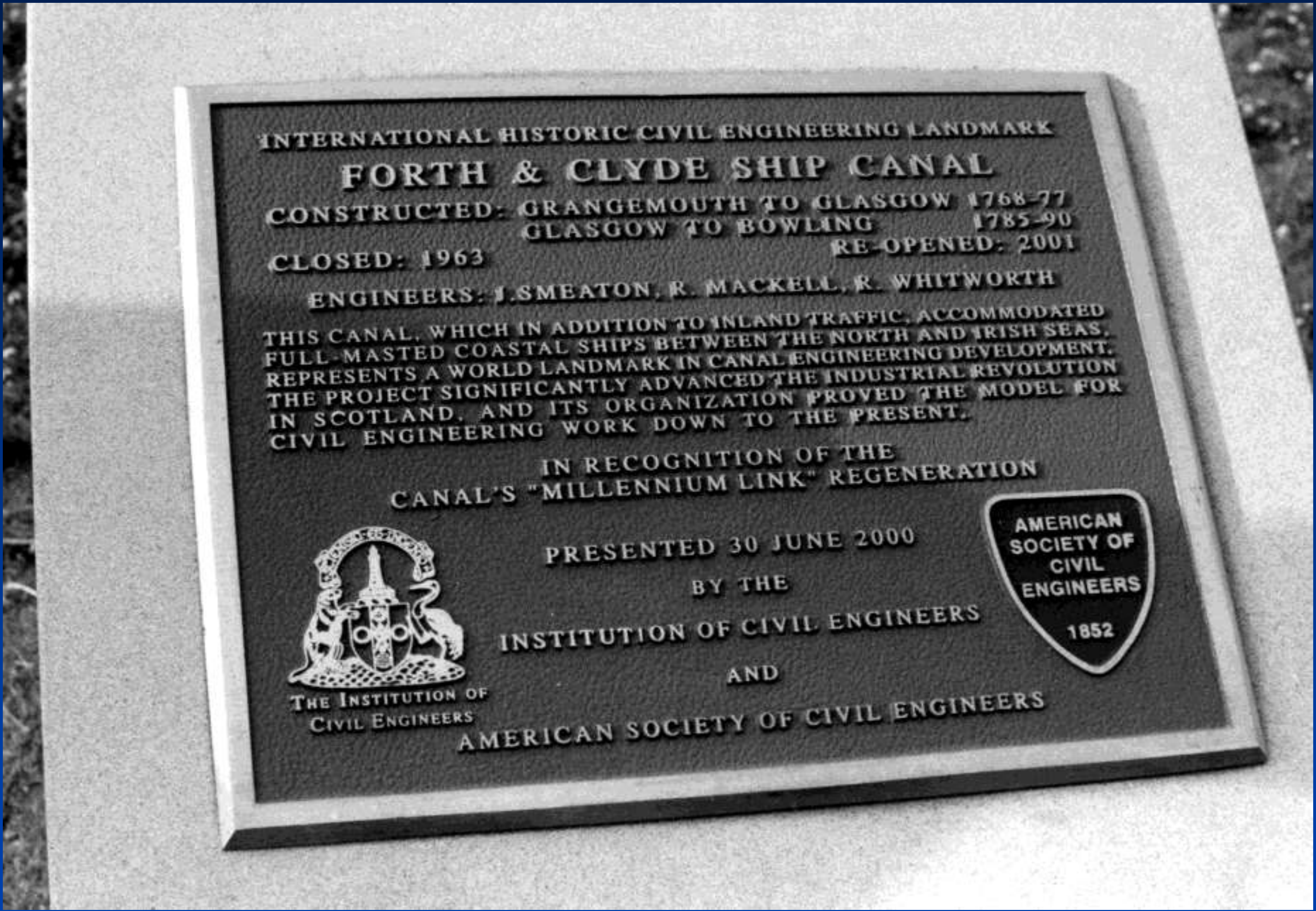
Dean Bridge Drawing 1832



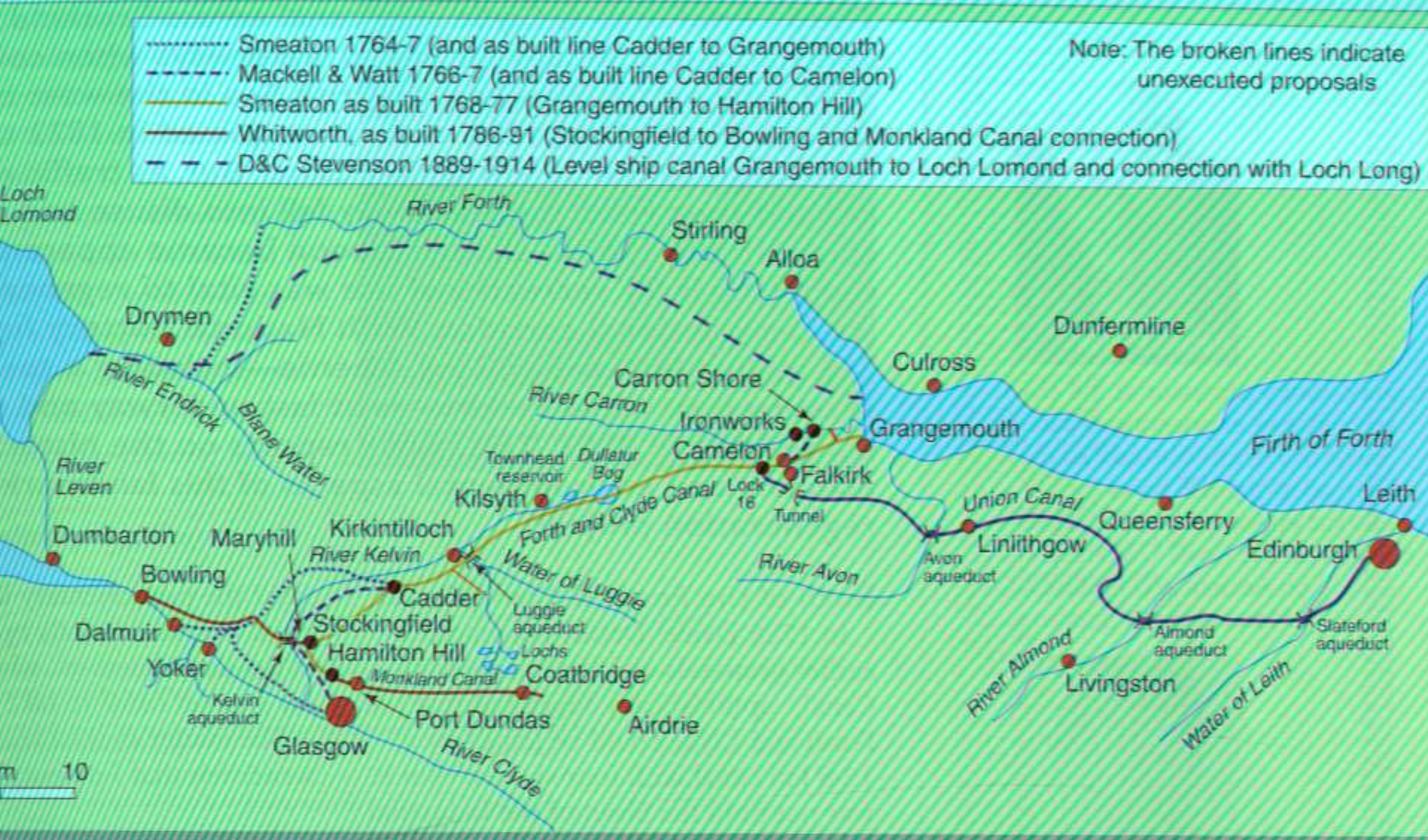
Bridgewater Canal 1761 – cheap coal from Worsley to Manchester



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

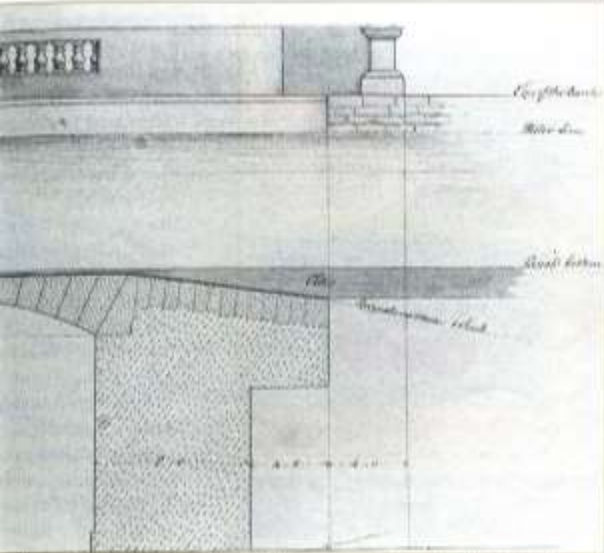


Forth & Clyde Canal Millennium Regeneration Plaque

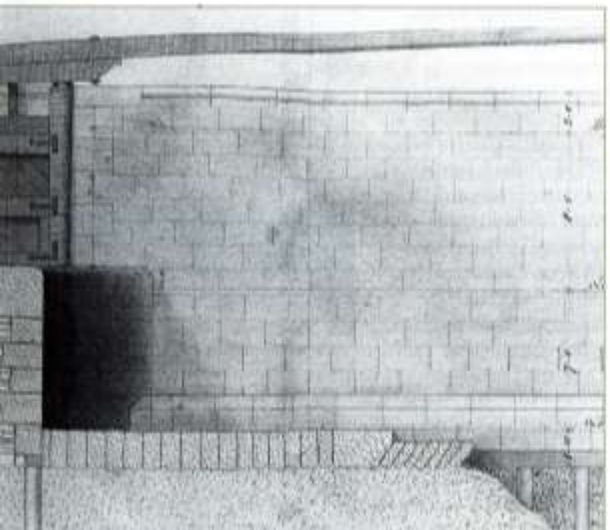


Forth & Clyde and Union canals as planned and constructed

Forth & Clyde Ship Canal plan



section of the Camelon aqueduct[29]—the road underpass with its decorative
d in the 19th century with a swing bridge



section of one the Forth & Clyde Canal's 39 locks showing timber piling[31]

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

Camelon aqueduct

At Camelon, the underpass of the Edinburgh to Stirling Great Road in 1772 (Fig. 5),[29] with a more decorative masonry façade[30] 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 Camelon, Smeaton designed the locks 'singly' so as to 'treasure up' a lockfull of water in 0·3 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. perpendicu-

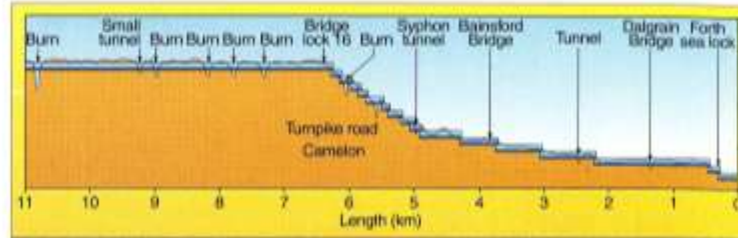


Fig. 7. Longitudinal profile of the east end of the Forth & Clyde Canal showing locks 1–16 requ
to rise about 38 m.[32] All bridges were drawbridges to provide unlimited head room

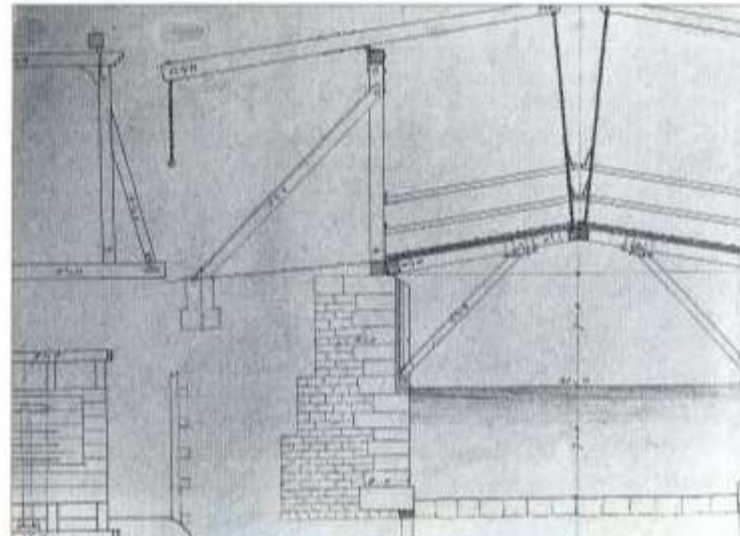
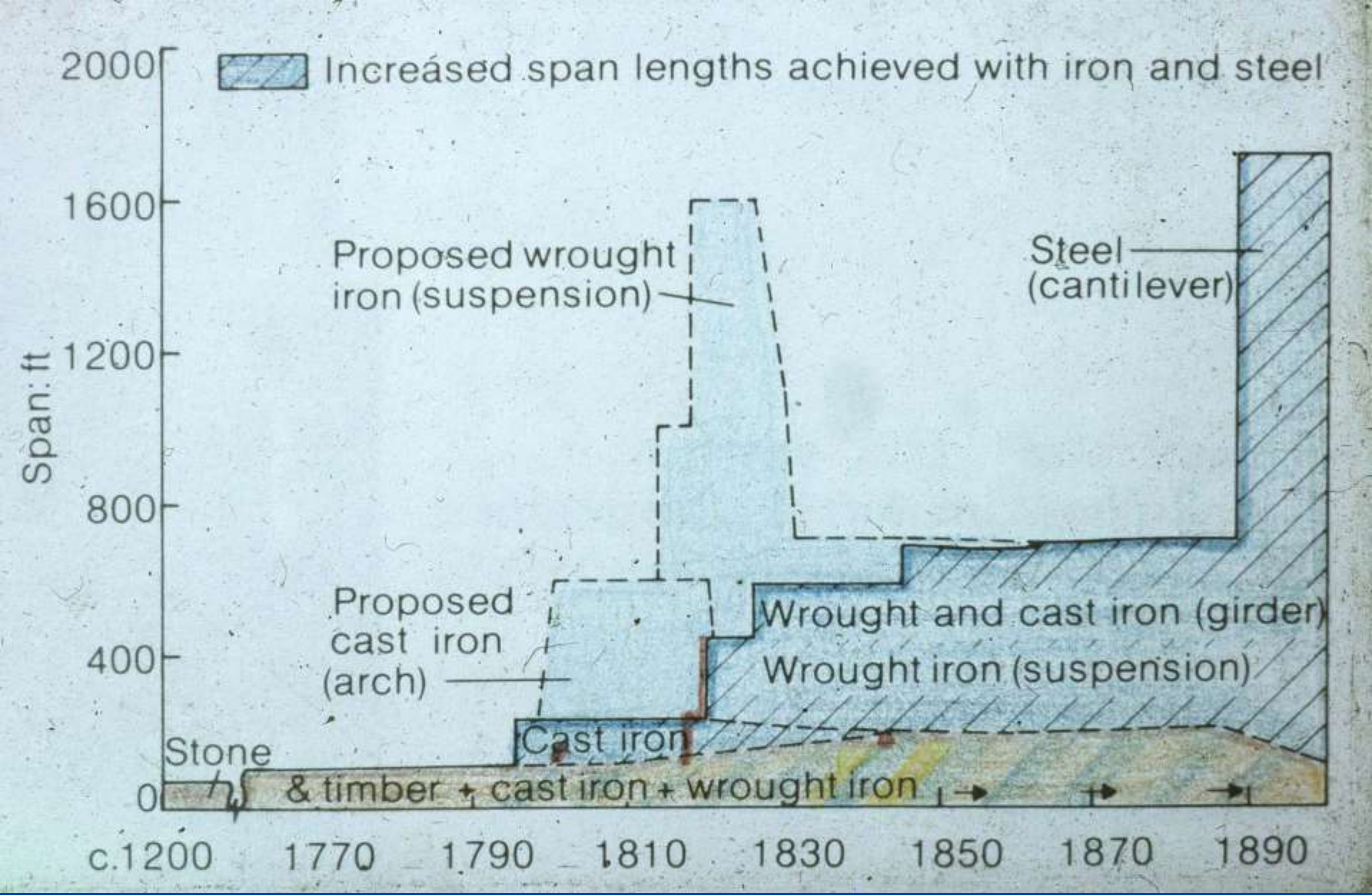


Fig. 8. Typical two-leaf drawbridge over the Forth & Clyde Canal.[34] None of the 33 original tim
bridges remain.

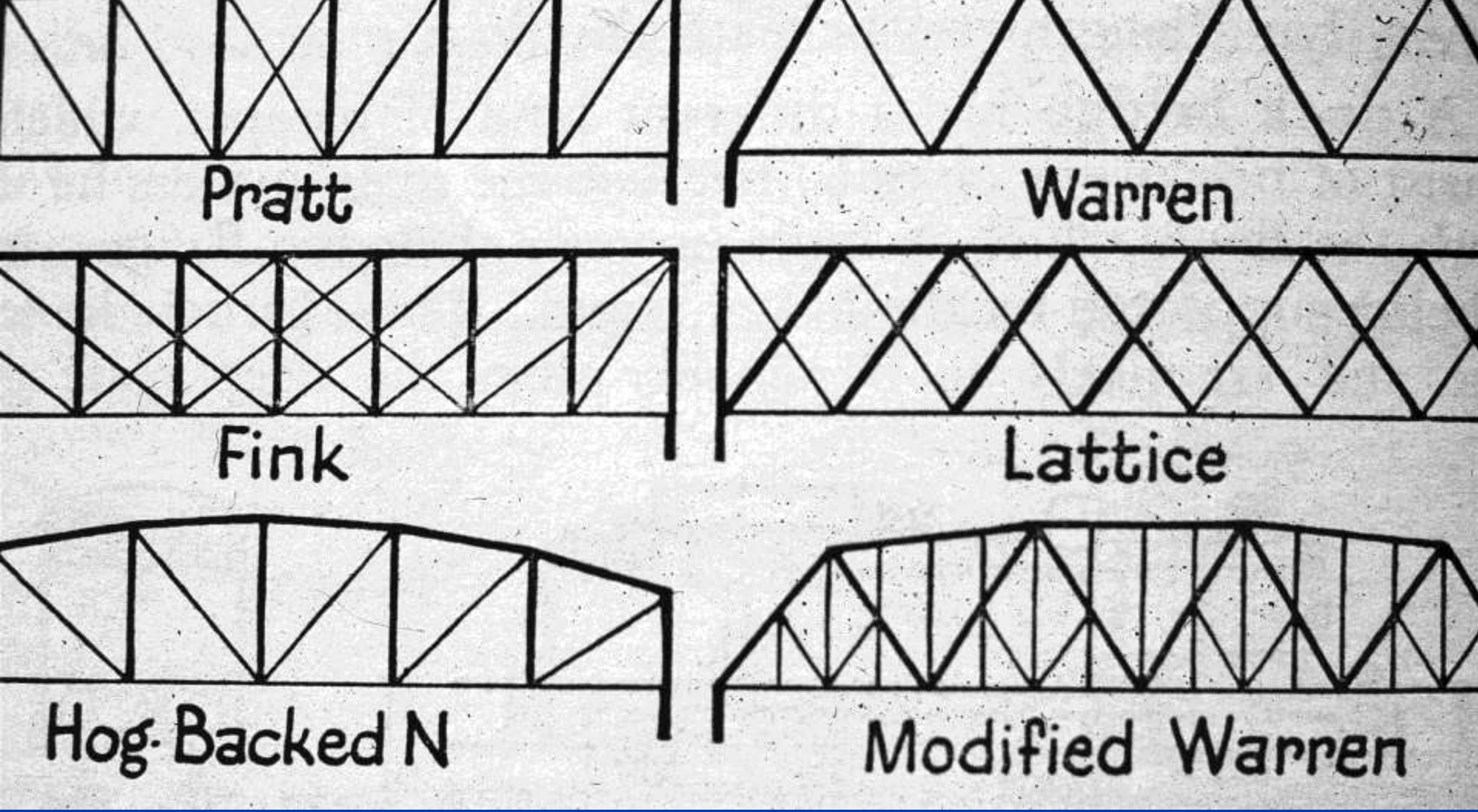
Forth & Clyde Canal 1768-90 – drawings and profile

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

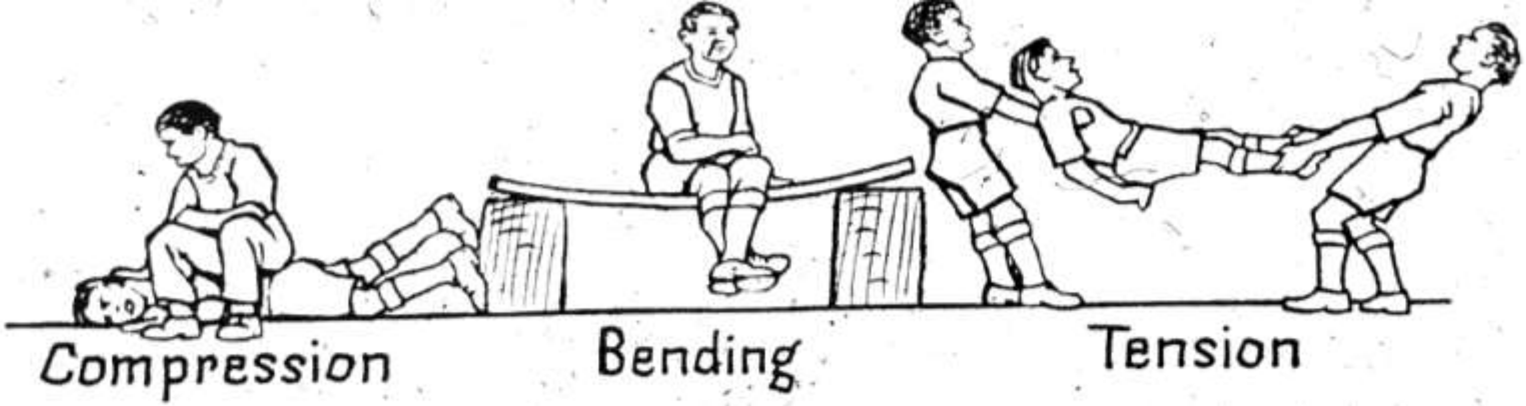
Ashiesteil Bridge 1848 (132 ft) (longest rubble masonry span in Scotland)



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



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

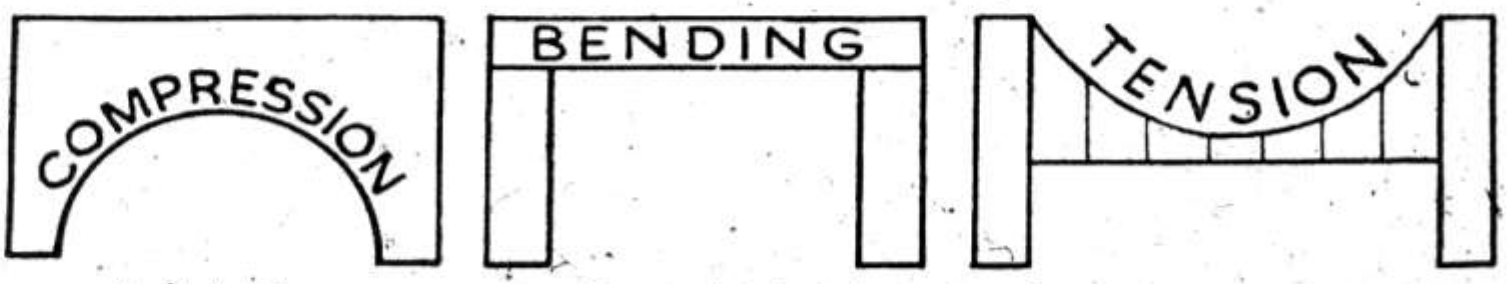


Compression, the force which presses or pushes things;

Bending; and

Tension, the force which pulls or stretches things.

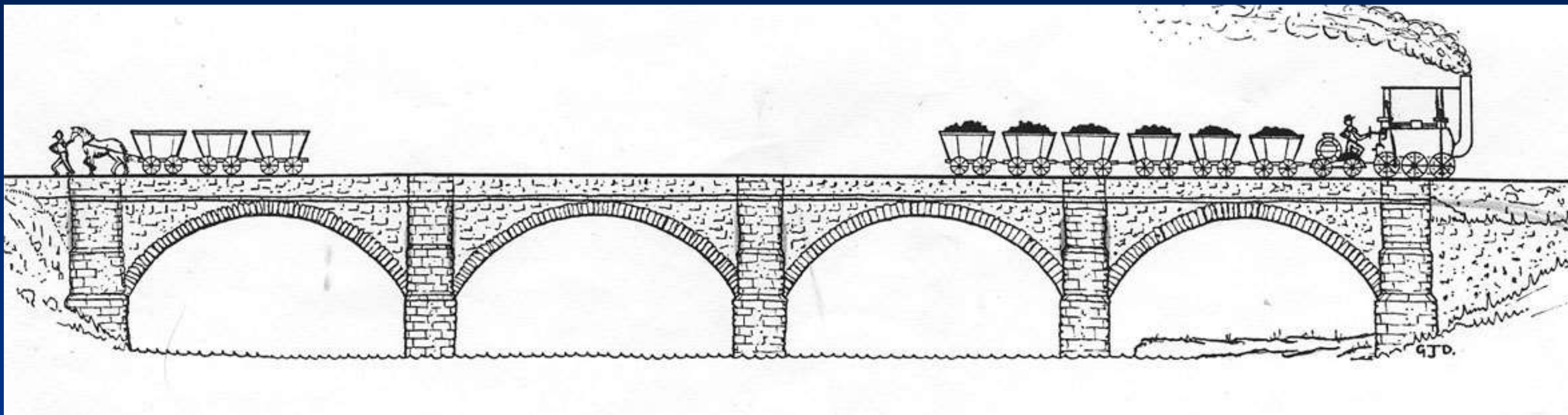
Bridges may be divided into three main types, each especially affected by one of these stresses. The *arch* bridge is subject to compression or direct thrust; the *beam* (or *girder*) bridge to bending, the *suspension* bridge to tension. Some materials are good at resisting one kind of stress, some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



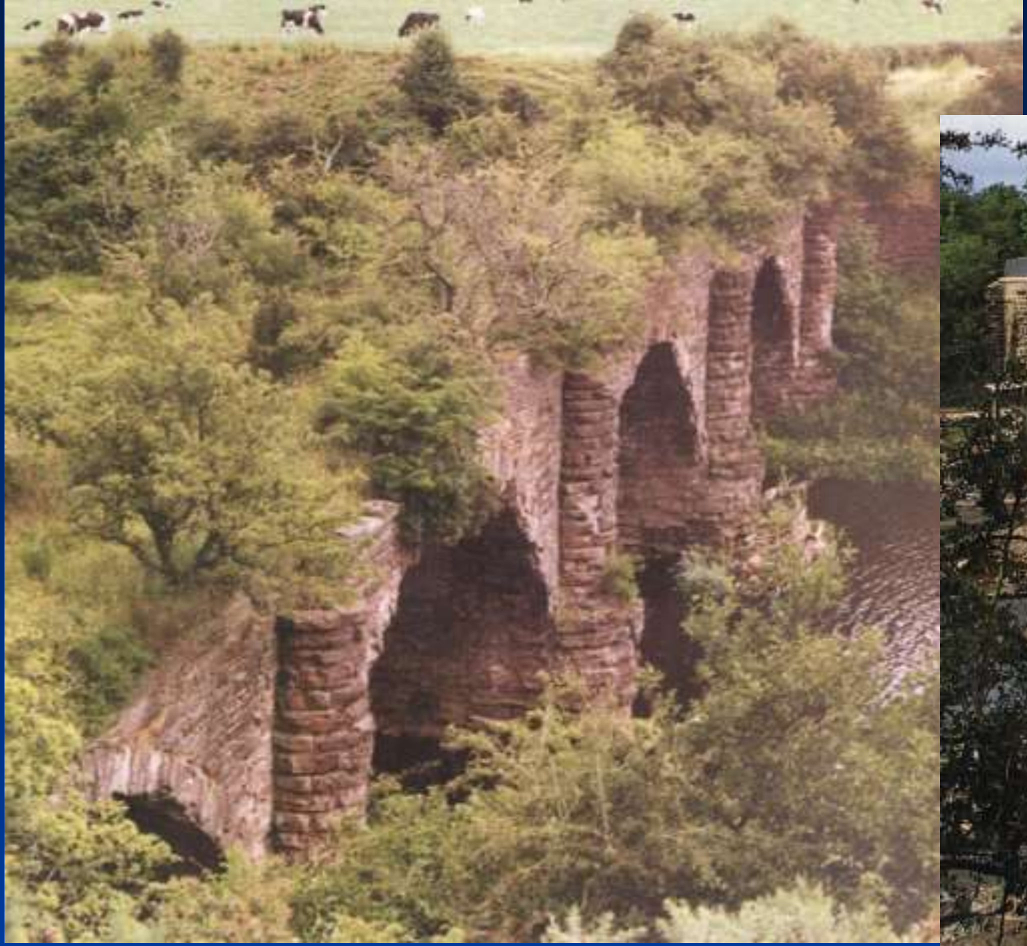
Arch bridge. *Beam bridge.* *Suspension bridge.*

The three main bridge types – arch, beam and suspension

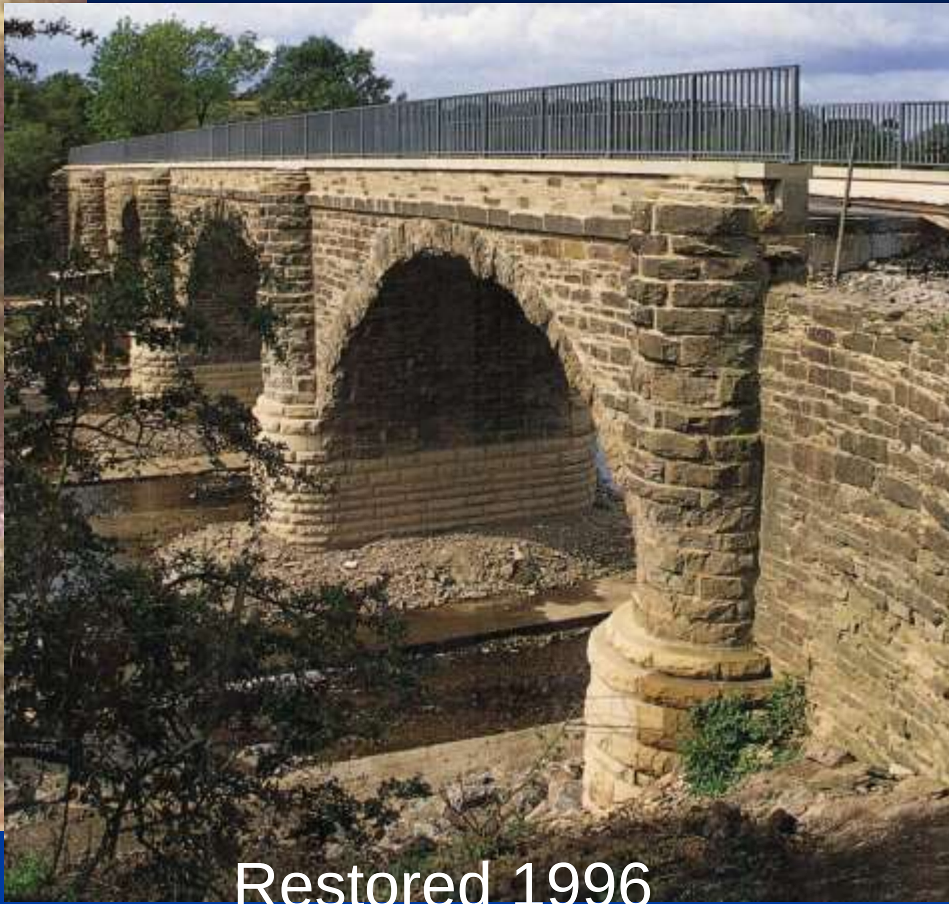
NORTH BRITISH RAILWAY MAP 1890



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



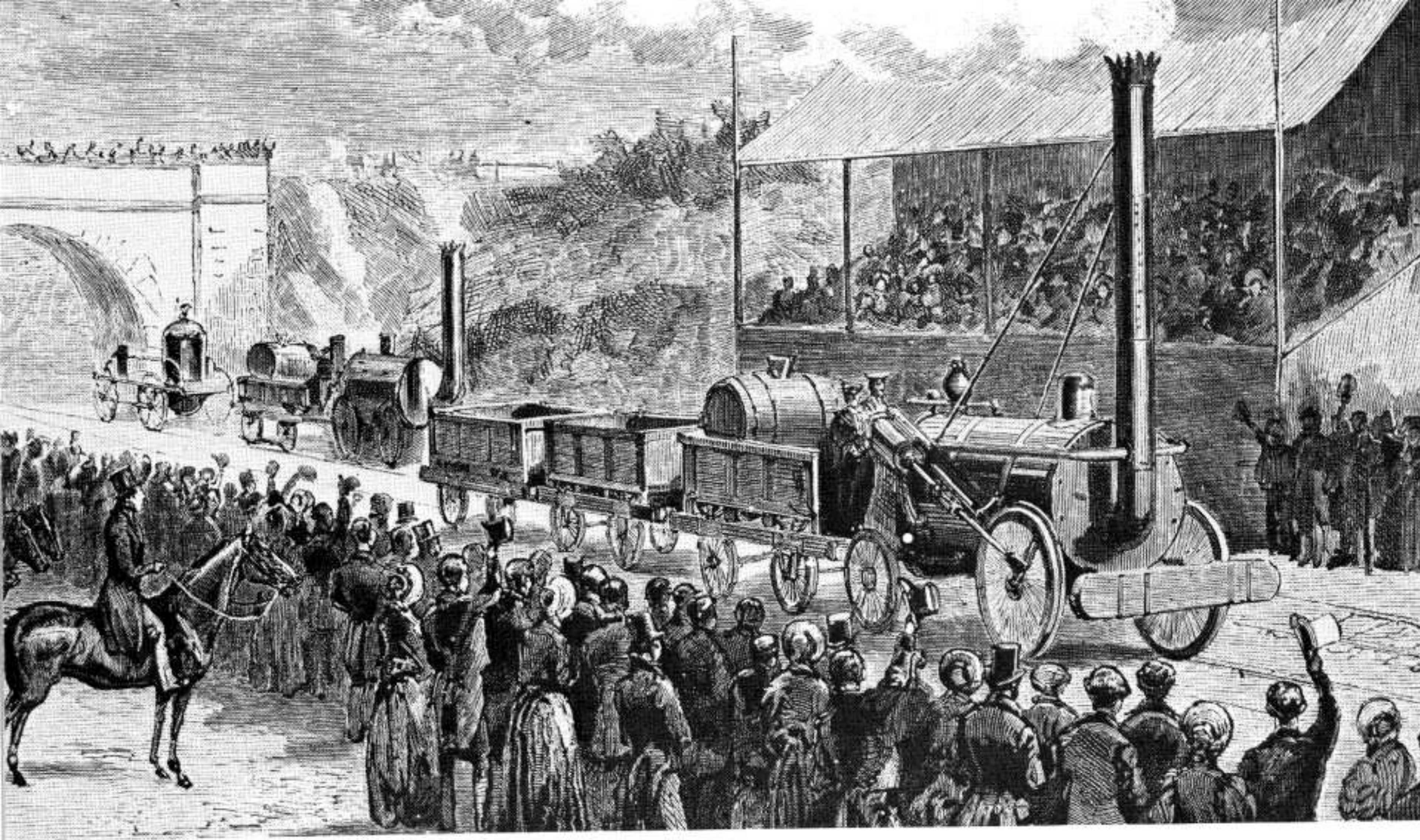
1995



Restored 1996

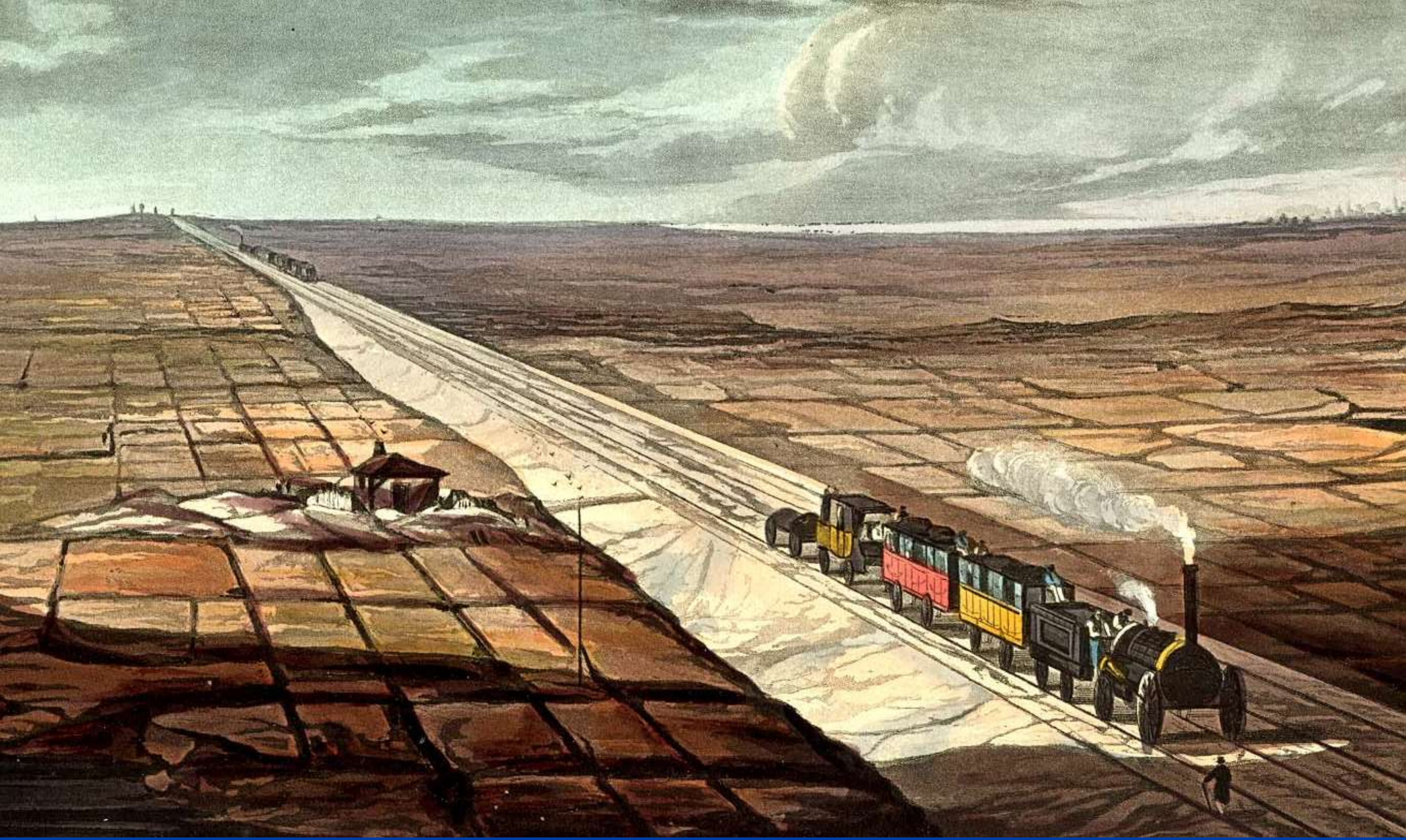
Laigh Milton Viaduct, Kilmarnock. William Jessop, Engineer. Opened 1811. Now a landmark as the earliest surviving viaduct on a public railway.

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

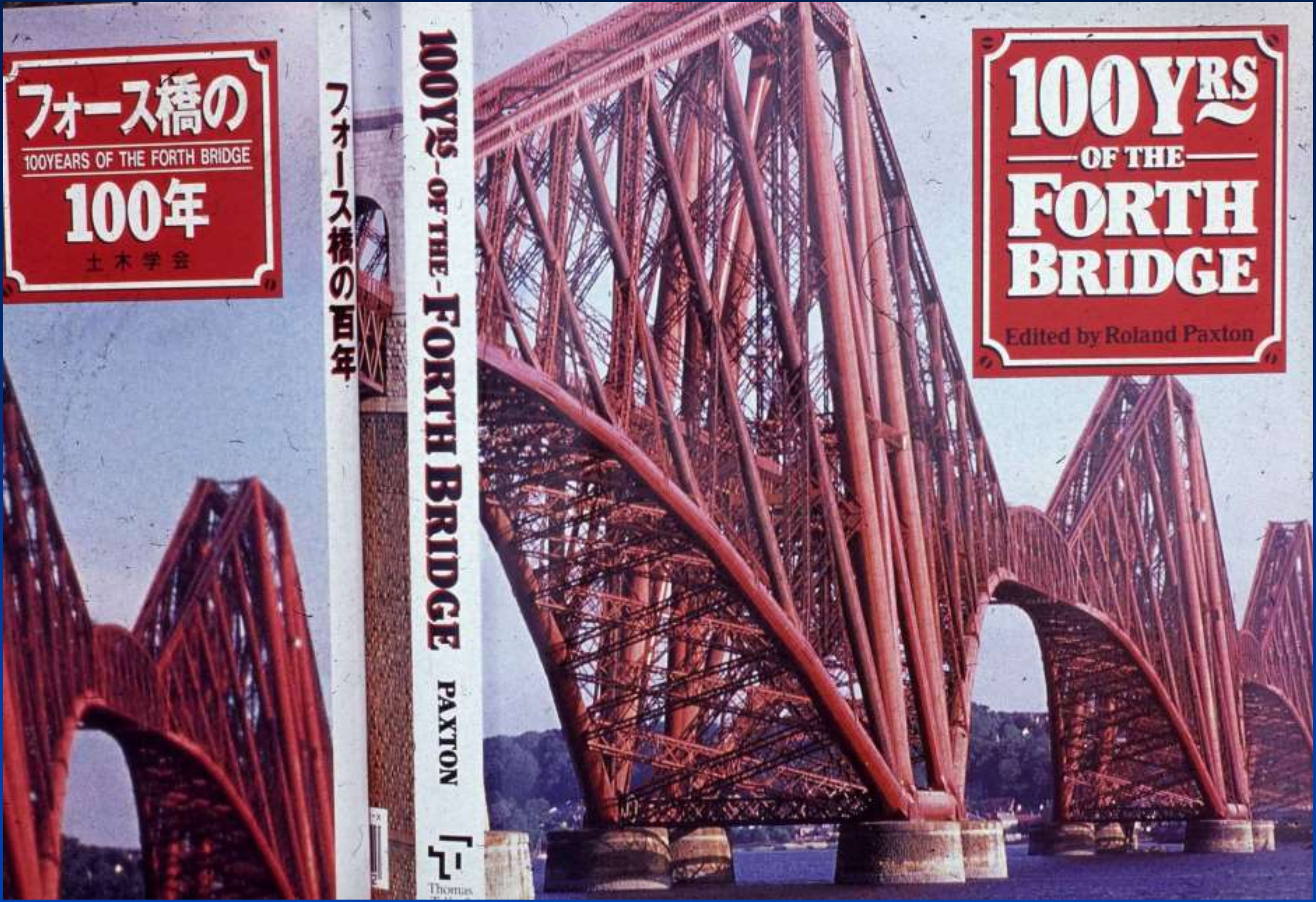
Bridge crossings at Conwy 1826 [Telford] 1848 [Stephenson]

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)

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

Tay Bridge after its fall on 28 December 1879



A landmark with gravitas – centenary tributes 1990

Forth Bridge – Thomas Bouch’s design 1873-81

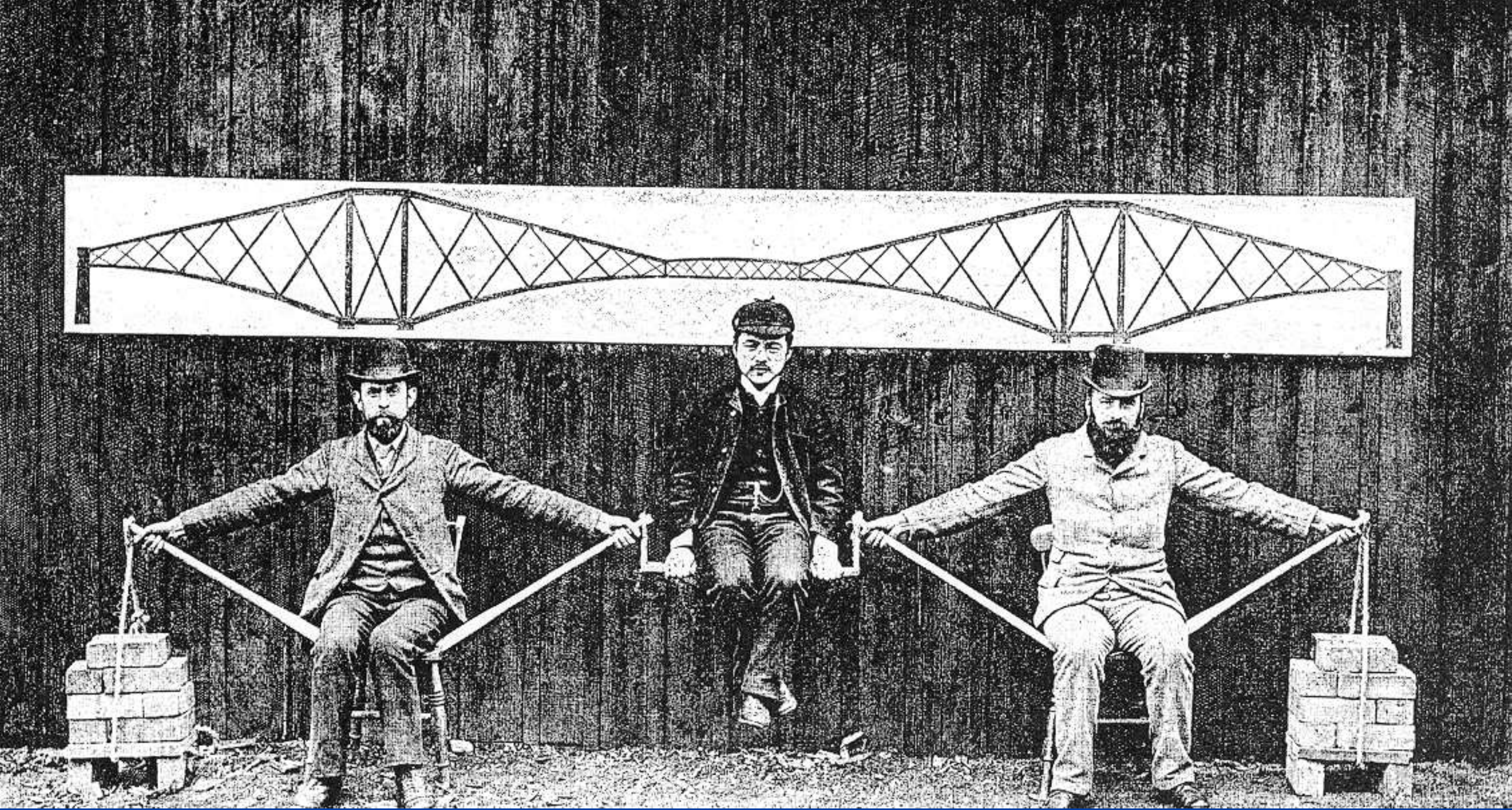
THE FORTH BRIDGE—THE LABOUR OF 5000 MEN (DAY AND NIGHT) FOR 7 YEARS.

ENGINEERS—SIR JOHN FOWLER & SIR BENJAMIN BAKER.

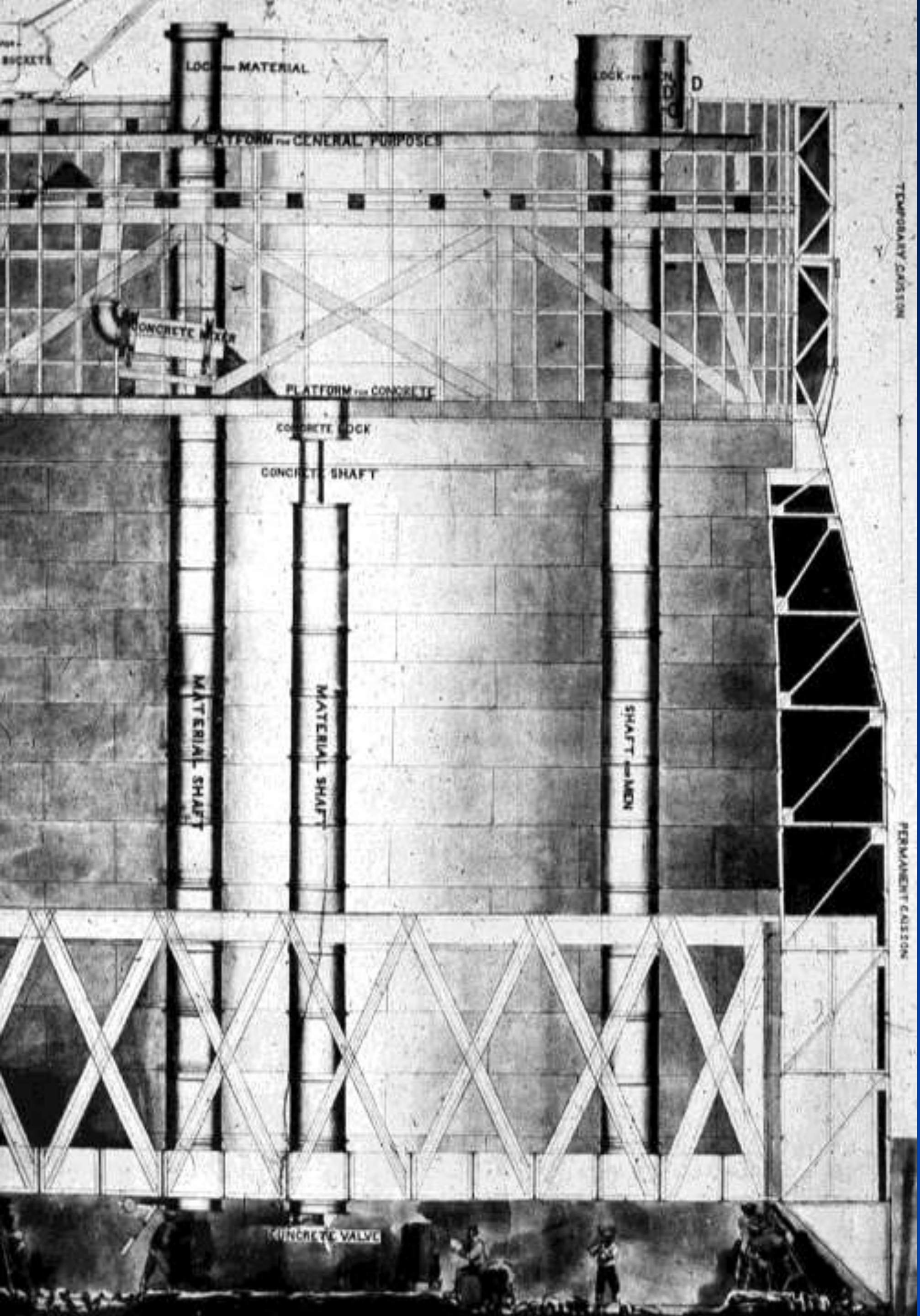
CONTRACTOR—SIR WILLIAM ARROL.

COST OVER £3,500,000.

Total length of viaducts over 1½ 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.**



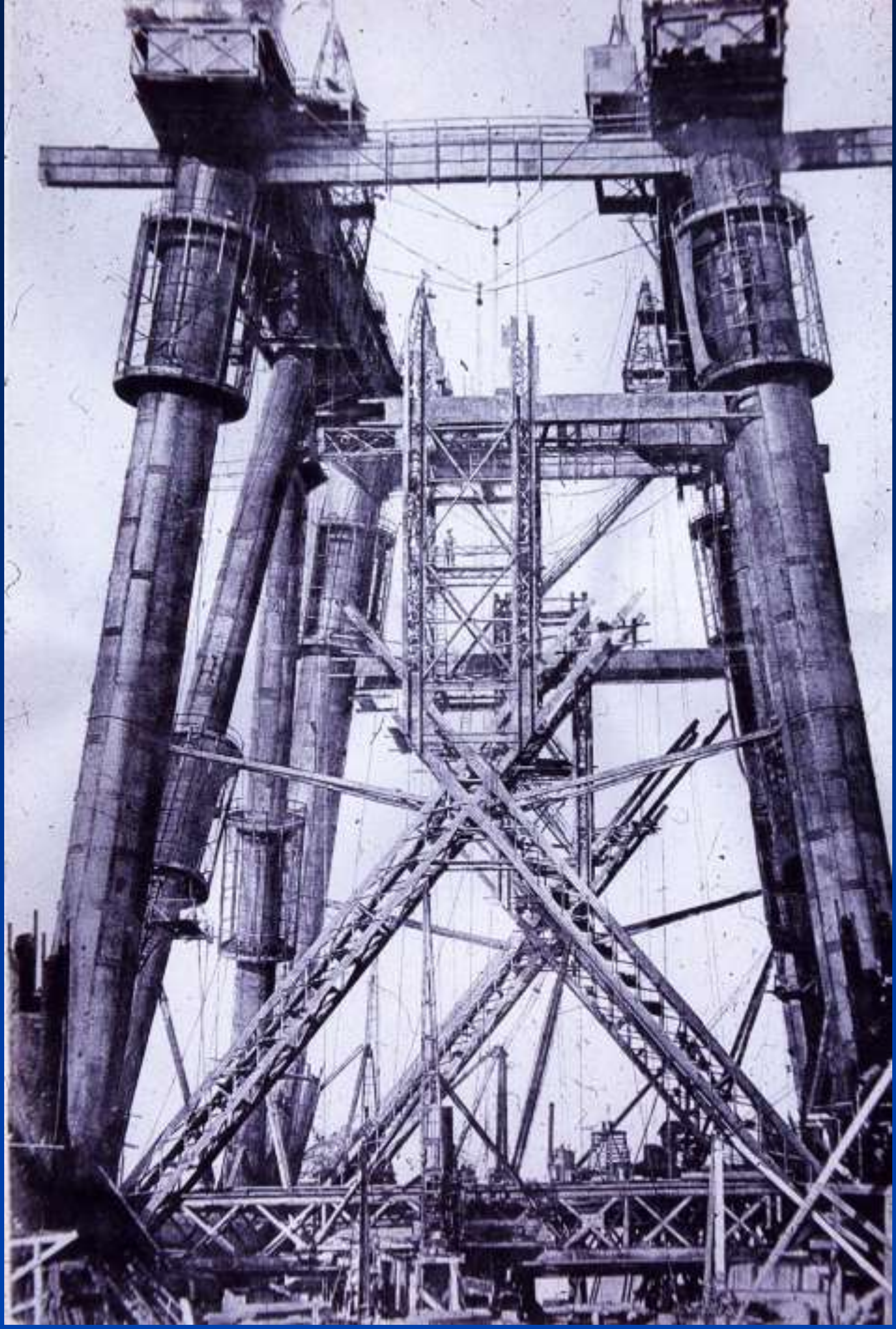
Forth Bridge – Benjamin Baker’s human cantilever model c.1884 demonstrating the structural engineering principle of the bridge. Arms in tension, struts in compression. Watanabe counter-balanced by bricks.



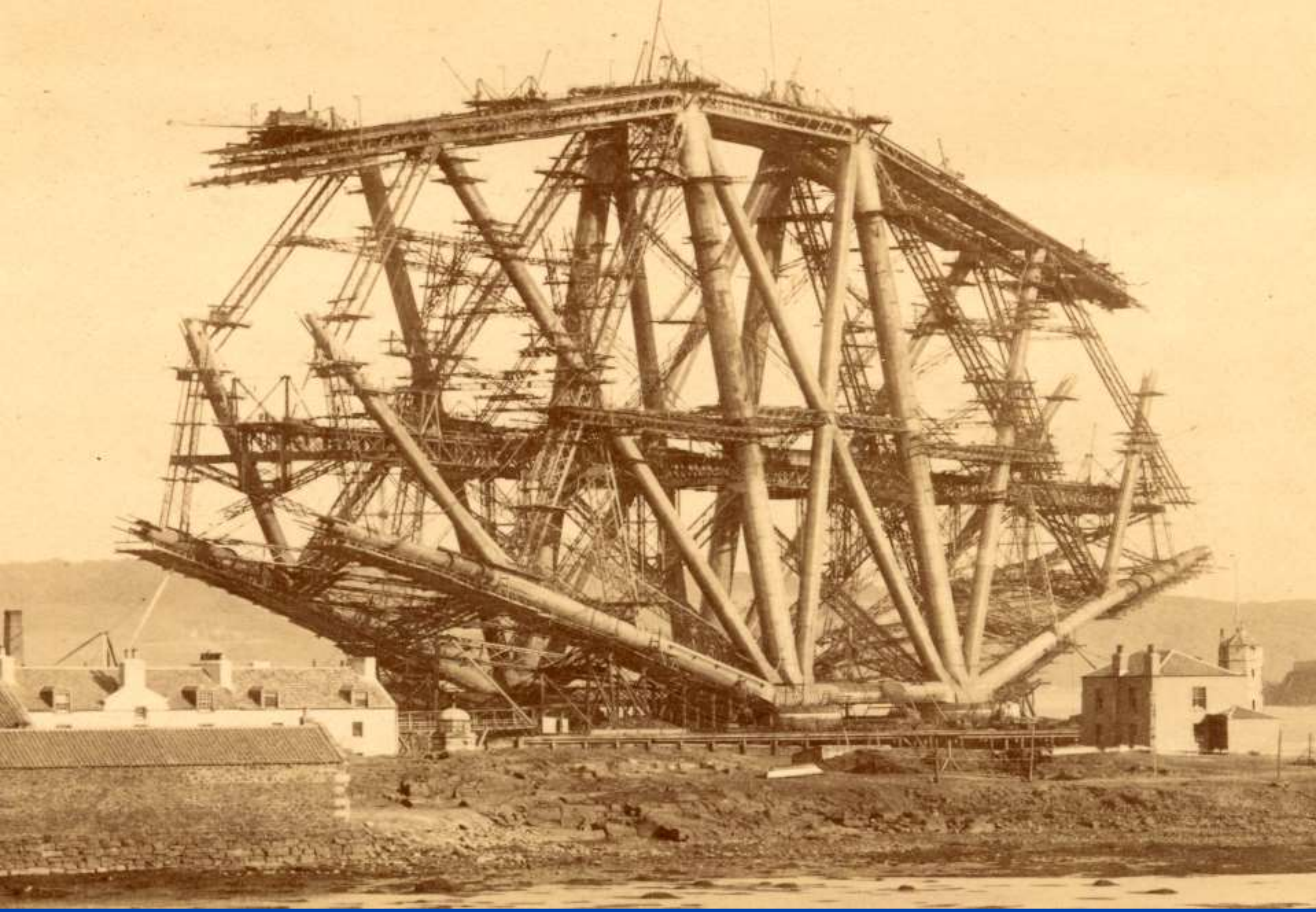
Forth Bridge Caisson
(6 in all)
70 ft diameter

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



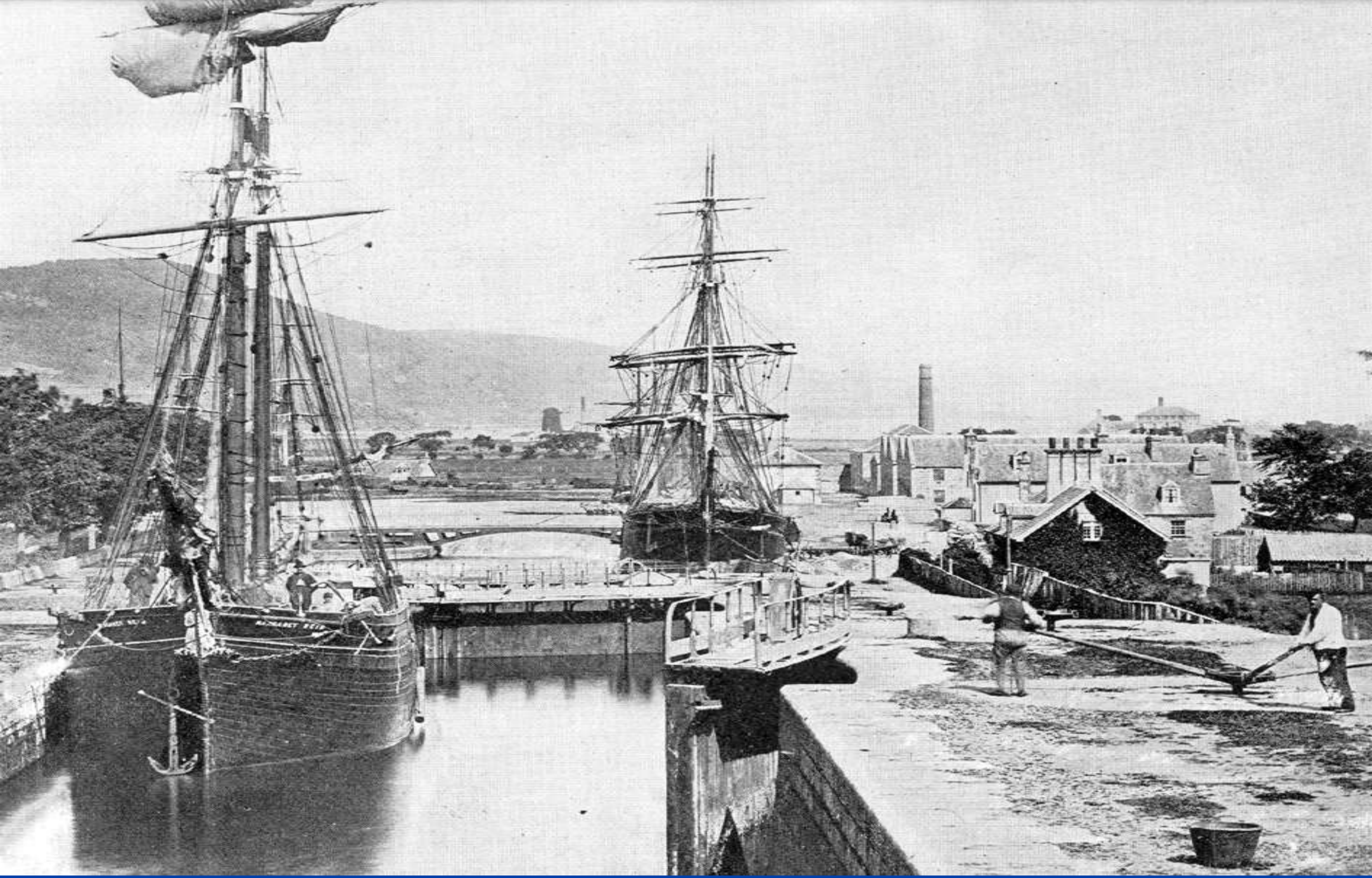
The Forth Bridge Tower under erection 1887 – height about 110m



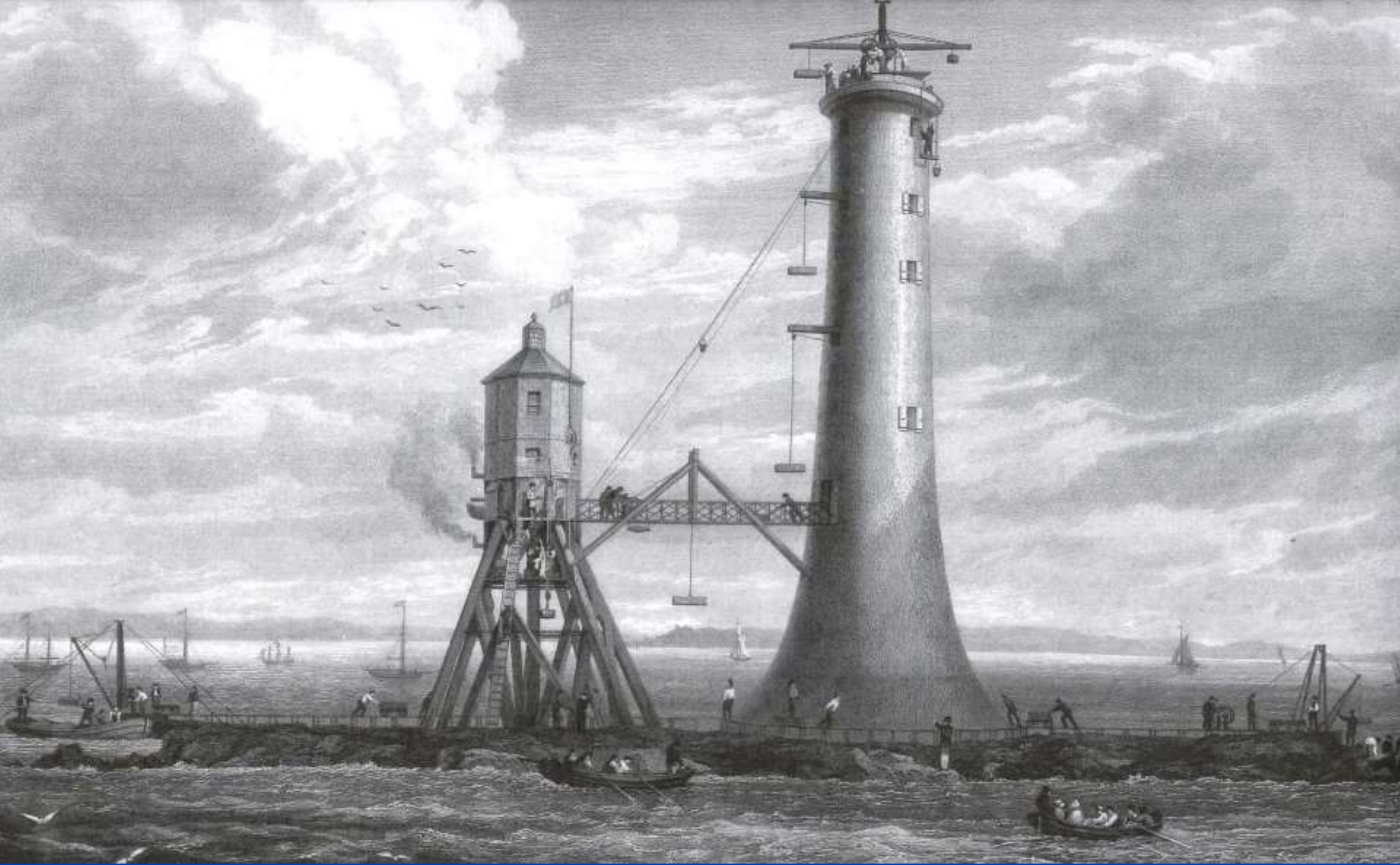
Forth Bridge 1888

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

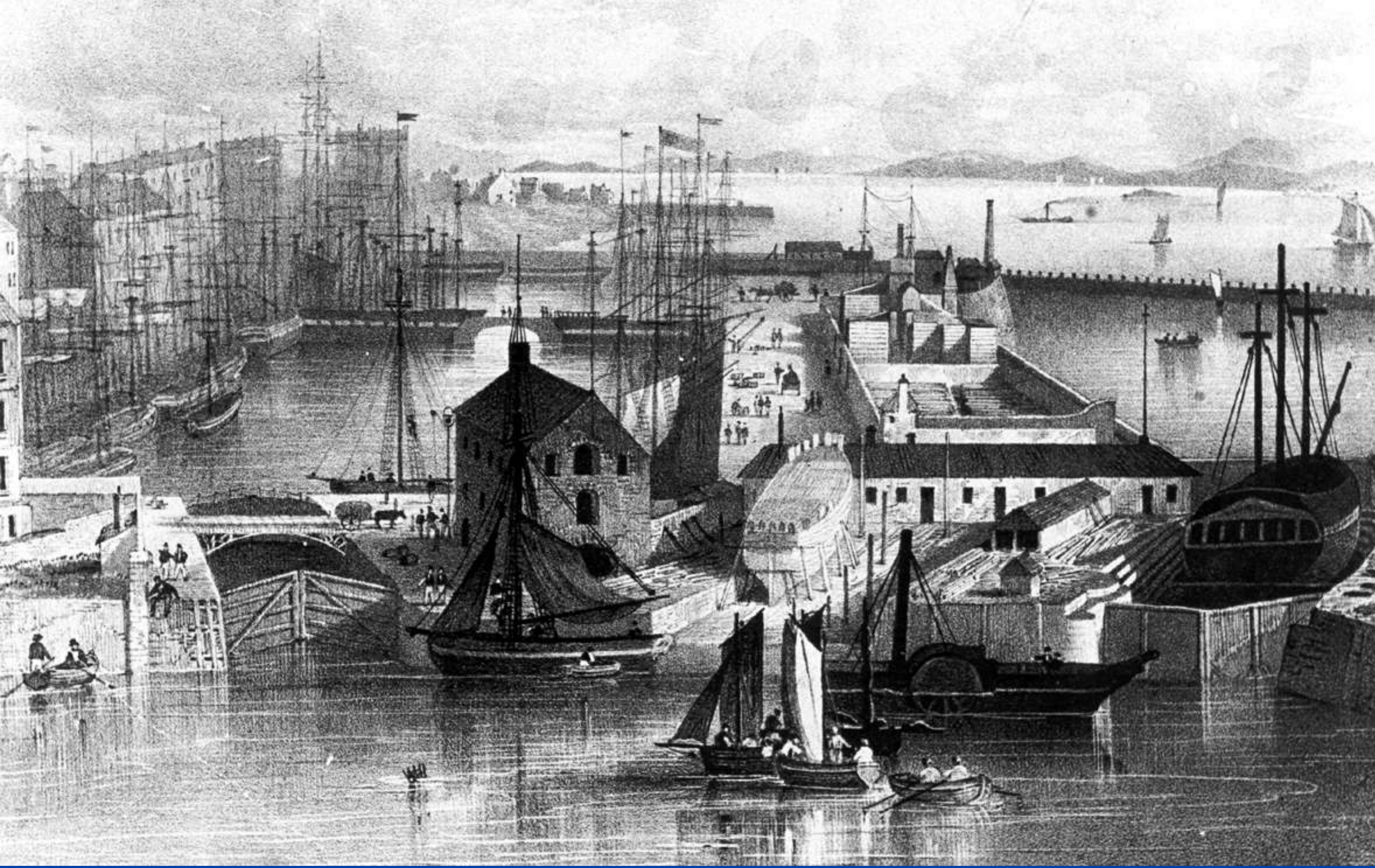


Bell Rock Lighthouse – view of works in July 1810. Chief Engineer: John Rennie, Resident Engineer Robert Stevenson

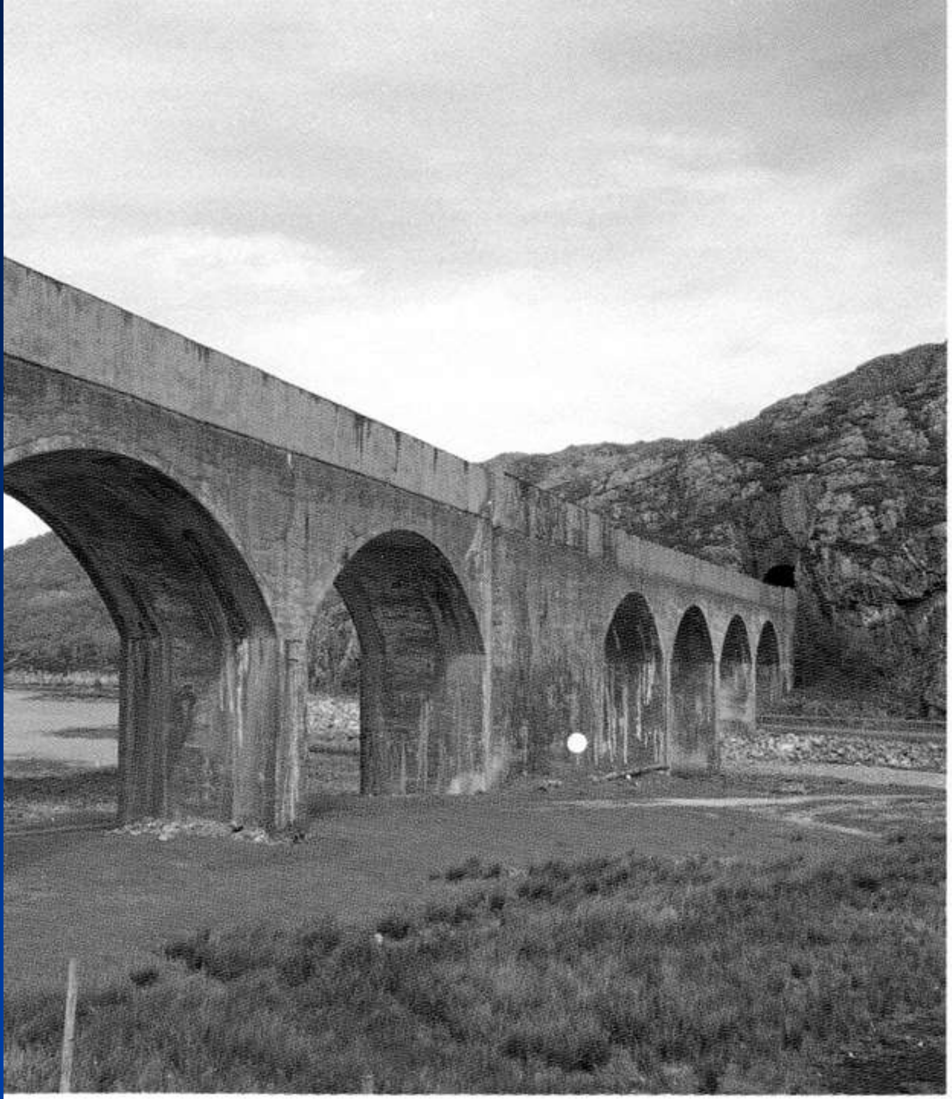
World's oldest sea-washed rock lighthouse still in service

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.

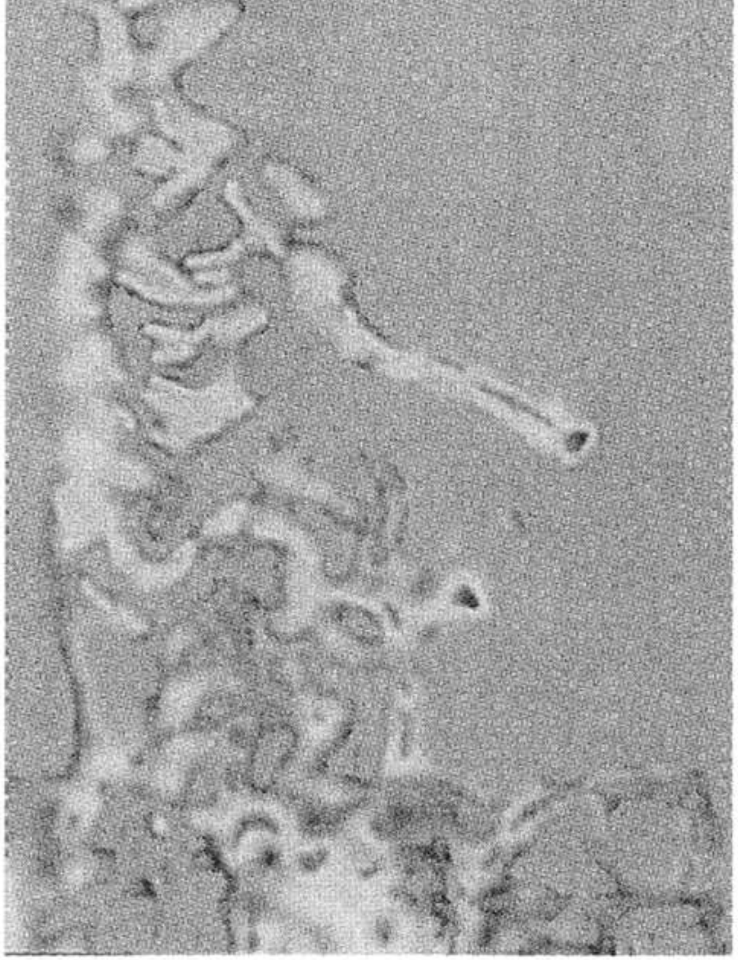
Menai Bridge (1819-26) today - Landmark as the world's first great suspension bridge which established the genre as the best means of achieving the longest spans. Link at H-W Univ. Made practicable by Cort's improvements in wrot iron making.



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