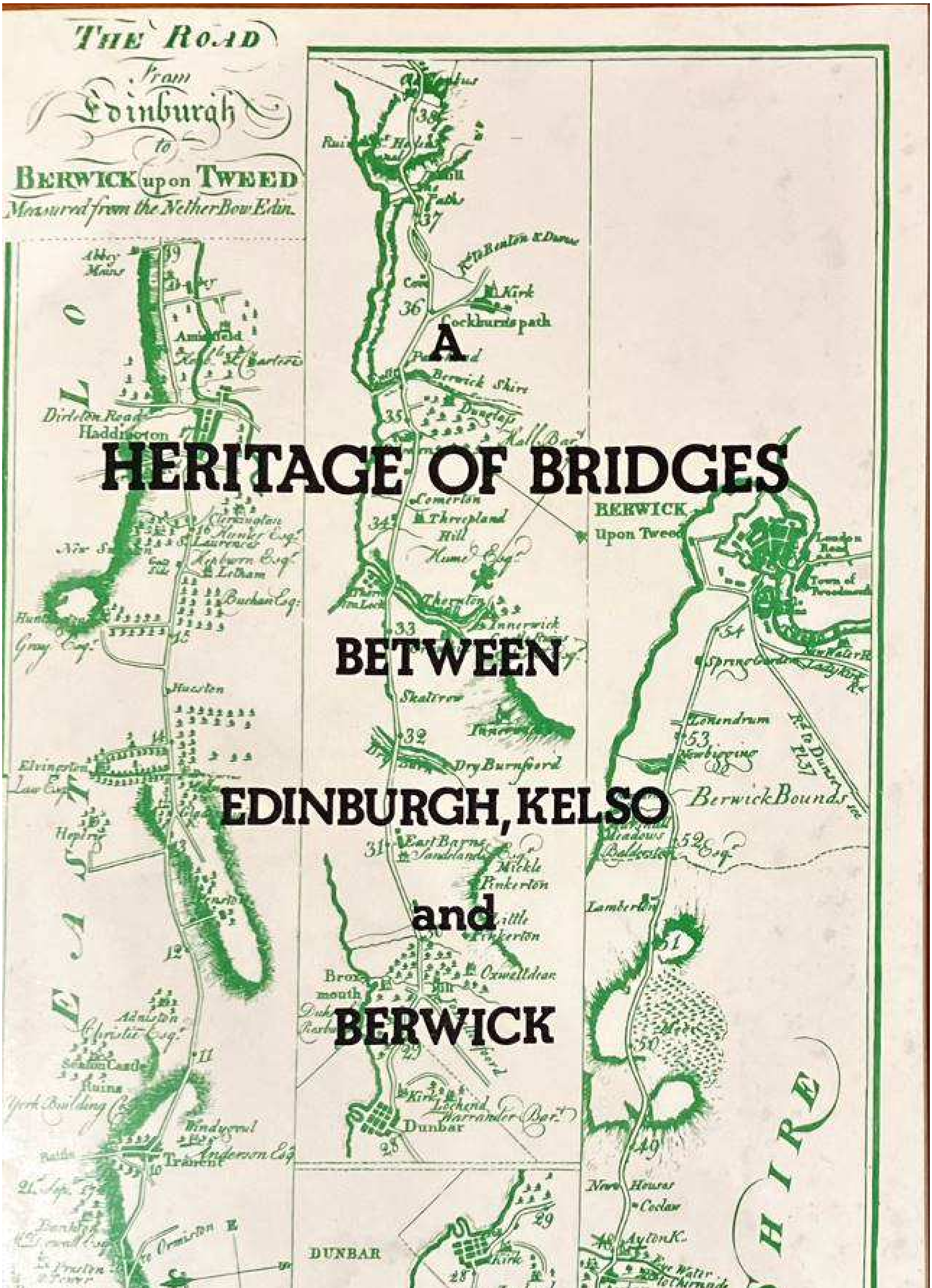
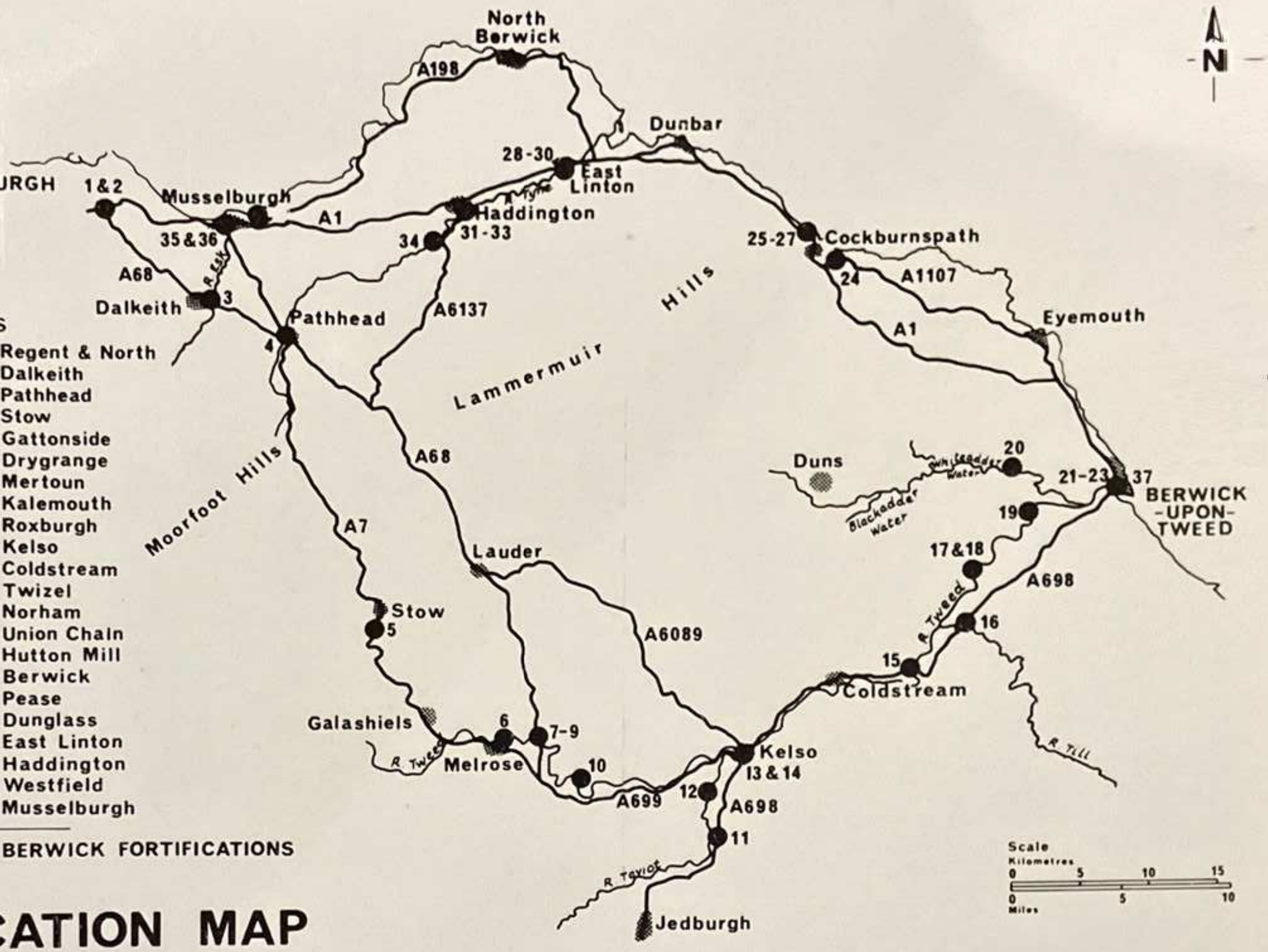
A HERITAGE OF BRIDGES BETWEEN EDINBURGH, KELSO and BERWICK





BRIDGES

1 & 2	Regent & North
3	Dalkeith
4	Pathhead
5	Stow
6	Gattonside
7 – 9	Drygrange
10	Mertoun
11	Kalemouth
12	Roxburgh
13 & 14	Kelso
15	Coldstream
16	Twizel
17 & 18	Norham
19	Union Chain
20	Hutton Mill
21 – 23	Berwick
24	Pease
25 – 27	Dunglass
28 – 30	East Linton
31 – 33	Haddington
34	Westfield
35 & 36	Musselburgh
37	BERWICK FORTIFICATIONS

LOCATION MAP

Copies of this booklet can be obtained, price £1.50 post free, from the Association's Hon. Secretary, D. Haldane, Department of Civil Engineering, Heriot-Watt University, Riccarton, Currie, EH14 4AS.

THE INSTITUTION OF CIVIL ENGINEERS

Edinburgh and East of Scotland Association

A HERITAGE OF BRIDGES

BETWEEN

EDINBURGH, KELSO and BERWICK

by

ROLAND PAXTON, M.Sc., C.Eng., M.I.C.E.

and

TED RUDDOCK, M.Sc., C.Eng., M.I.C.E.

with 44 illustrations

EDINBURGH

FOREWORD

This publication complements *"Our Engineering Heritage–Dean Bridge, Leith Docks, Forth Rail Bridge"* published last year, and aims at bringing to the notice of the public the achievements and significance of another aspect of our engineering heritage. Once again it has been possible to include some little known and previously unpublished material and it is hoped that the reader will be encouraged to take to the field and appreciate the work of past engineers, many of them well-known names, at first hand. On this occasion the main theme is to illustrate the development of bridge design and practice by a selection of examples, mainly in the Lothian and Borders Regions which can be readily visited from the main routes indicated on the map, but to introduce a little more variety, Berwick Fortifications have also been included.

I should like to thank the many people who have contributed to the booklet, in particular, my co-author Ted Ruddock, a leading authority on historic arch bridges; Mr Francis Cowe, the well-known Berwickshire local historian for the interesting and informative article on Berwick Fortifications; and David Haldane and the Committee for their continuing encouragement and generous support for the aims and work of the Panel.

ROLAND PAXTON
Member of the Institution of Civil Engineers Panel
for Historical Engineering Works

ACKNOWLEDGEMENTS

In addition to the above-mentioned, the authors would like to thank the following for their interest and support:- A. S. Crockett, Director of Highways Lothian Region; R. Hill, Director of Roads Borders Region, B. Arthur, County Surveyor Northumberland County Council and Surveyor to the Tweed Bridgès Trust, J. A. M. Mackenzie, Chief Road Engineer Scottish Development Department and members of their Bridge Sections; Members of Staff of the Scottish Record Office and the Royal Commission for Ancient Monuments of Scotland; D. Small, Blyth & Blyth; G. Duncan, Director of Physical Planning East Lothian District Council; Hawick Public Library; W. Hamley; Douglas McBeth, John Munro and other members of PHEW local group; M. Hutchison; Mrs Margaret Young and, for photographic reproductions Alan Laughlin and John McGovern.

COVER

The cover is reproduced from "Taylor & Skinner's Survey and Maps of the Roads of North Britain" which was the first publication of its kind relating to Scotland. At this time coach travel on the road between Edinburgh and Berwick took a full day and the single fare was 15 shillings and fivepence (1778).

CONTENTS

NOTES ON BRIDGE TYPES AND MATERIALS – 1200 to 1973

Superstructures

In all centuries except the twentieth there were many timber bridges, but until almost 1800 AD arches of masonry provided the only long-lived bridges. In Scottish bridges the shape of the arches varied; there were always some semicircles and segments of circles and before 1600 some pointed arches. Just after 1760 John Adam introduced the semi-ellipse in estate bridges at Inveraray and Cumnock and it was afterwards used quite frequently, for instance in Rennie's Kelso Bridge.[14]

In the early centuries long arch spans occurred only in single-arch bridges, where they made it possible to found the bridge on rock above water level; Twizel Bridge[16], of 26.5m span, is a good example. From 1200 onwards some masons built each arch of several separate ribs, apparently using the same falsework for each rib and covering the gaps between ribs with flat stones to support the rest of the superstructure; Twizel Bridge also illustrates this technique, which was common in Scotland from 1500 to 1550. In bridges of several arches the spans were commonly 35-55ft (11-17m) until about 1765 when John Smeaton and others began to build arches of 75-100ft (23-33m) span; for example the old Drygrange Bridge[7]. These resulted in larger spandrels over the piers at the same time as piers were being made narrower, and so methods had to be devised for lightening the spandrels and reducing the lateral pressure of filling materials on the outer walls. One method was cylindrical arched voids through the spandrels (as in Pease Bridge[24]) which had been used by architects of the Roman Empire for extra flow in times of high flood. Another was to build each spandrel of four or five longitudinal walls with voids between them, bridging over the voids by stone slabs or small arches to form a base for the road; this was done first by Smeaton in Perth Bridge in 1770 and soon became almost universal practice in large bridges, for example Drygrange[7], Kelso[14] and Musselburgh[36]. (See Coldstream Bridge[15] for a photograph).

In the 1790s cast iron arches became a practical possibility and in the nineteenth century girder bridges were introduced, made first of cast iron, then of wrought iron, for example at Roxburgh[12] and Hutton Mill[20] and finally from c.1880 of steel, for example the North[2] and Victoria[33] arch bridges and East Linton cantilever[30]. The modern composite structure of steel box girders and reinforced concrete deck at Drygrange[9] has been included for comparison with its counterparts of a century and two centures earlier[7, 8]. By 1850 metal girder bridges could span much further than masonry arches, but for spans of 250ft (80m) and more suspension bridges had already been built of wrought iron from 1817 onwards. Union Bridge[19] was the first really successful large suspension bridge in Britain. About the turn of the present century reinforced concrete was introduced and arches were again built of separated ribs, Berwick Bridge[22] being one of the largest in the country and contrasting in size with Westfield Bridge[34] which is an early example of a beam footbridge in this material.

From c.1825 onwards in the last century the advent of effective wood preservatives notably Kyan's patent corrosive sublimate, encouraged the construction of timber truss bridges and although probably none now survive, examples existed at Norham[18], East Linton[29], and Mertoun[10].

Foundations

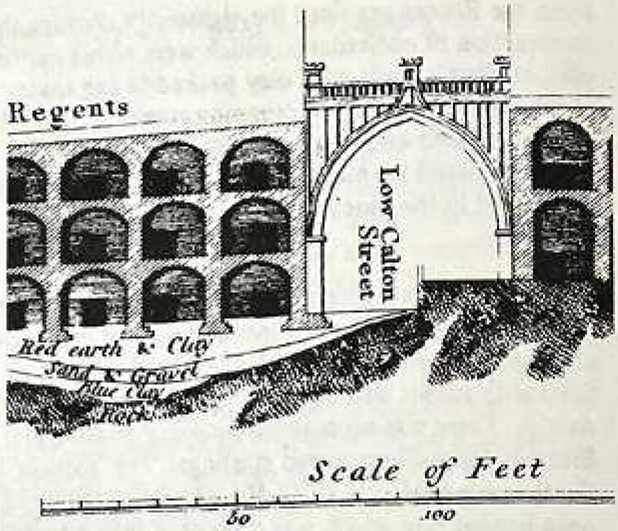
From the Roman era until the eighteenth century there was little change in the construction of cofferdams, which were either earthen bunds, single walls of timber piles, or double walls with clay packed in the space between them. Towards the end of the eighteenth century pumping power was greatly improved by the application of water wheels and steam engines and in the nineteenth century compressed-air working opened up much greater possibilities. Iron and steel piling were also introduced in the nineteenth century but the use of timber piles has never entirely stopped.

Before these developments two other methods had been used to found masonry bridges in deep water. The method of 'starlings' was in use at least as early as 1200: a wall of piles was driven with their heads above low-water, the interior space was filled with rubble and compacted, usually with further piles, then the pier was built on top. There was no coursed masonry at all below low-water. The old Berwick Bridge[21] has well-preserved starlings. The 'caisson' method was invented for use at Westminster Bridge in 1737-40: the first courses of a pier were built in a floating open-topped box which was then sunk into a prepared excavation in the river-bed and the sides of the box removed, leaving the bottom as a permanent sole or platform under the masonry. When piers were founded in cofferdams it was usual to lay a similar thick platform or 'grating' on the river bed, often on top of bearing piles and with a surrounding wall of sheetpiles driven 5-10ft (1.5-3m) into the bed for protection against scour under the pier (see the drawing for Coldstream Bridge[15]).

N.B. The bridge reference numbers above refer to the main entry numbers.

HISTORICAL REFERENCES

Many of the facts concerning masonry bridges on the Berwick-Edinburgh (A1) route are derived from A. Graham, "Archaeology on a great post road", Proceedings of Society of Antiquaries of Scotland XCVI (1962-3), 318-347, or sources noted therein. For many of the masonry bridges T. Ruddock, "Arch bridges and their builders 1735-1835" (Cambridge University Press, 1979) gives extra information and names the primary sources. For these bridges and also for those constructed in timber, iron, steel and reinforced concrete, some main references are given after each description.

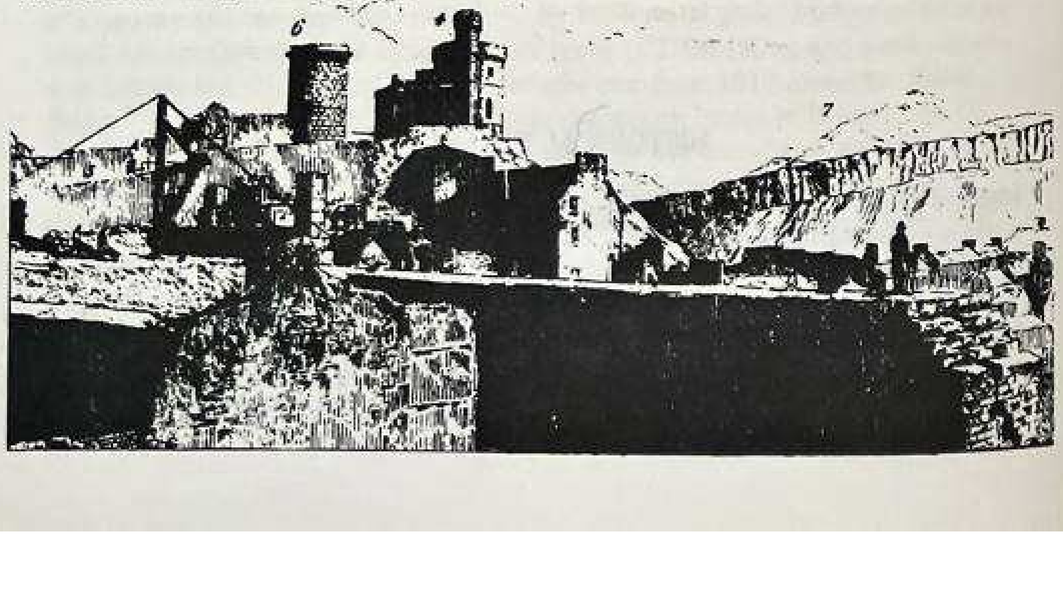


1. REGENT BRIDGE or ARCH (sometimes WATERLOO BRIDGE) (NT 260741)

Regent Bridge consists of a single semi-circular arch of 50ft (15.2m) span, the crown of which is 42ft 6 in (13.0m) above the surface of Lower Calton St. It is constructed of ashlar masonry and the arch ring is 3ft (0.9m) thick. The engineer for the road improvement scheme, which included the bridge, was Robert Stevenson (grandfather of Robert Louis Stevenson) and the contractors were Thomas & Henderson. The architect for the overall project, which also included adjoining buildings, was Archibald Elliot. The foundation stone was laid on 9 September 1815 and the bridge was eventually completed in 1819 after encountering various difficulties not of an engineering nature. The bridge provides an early example of an integrated road improvement and building development.

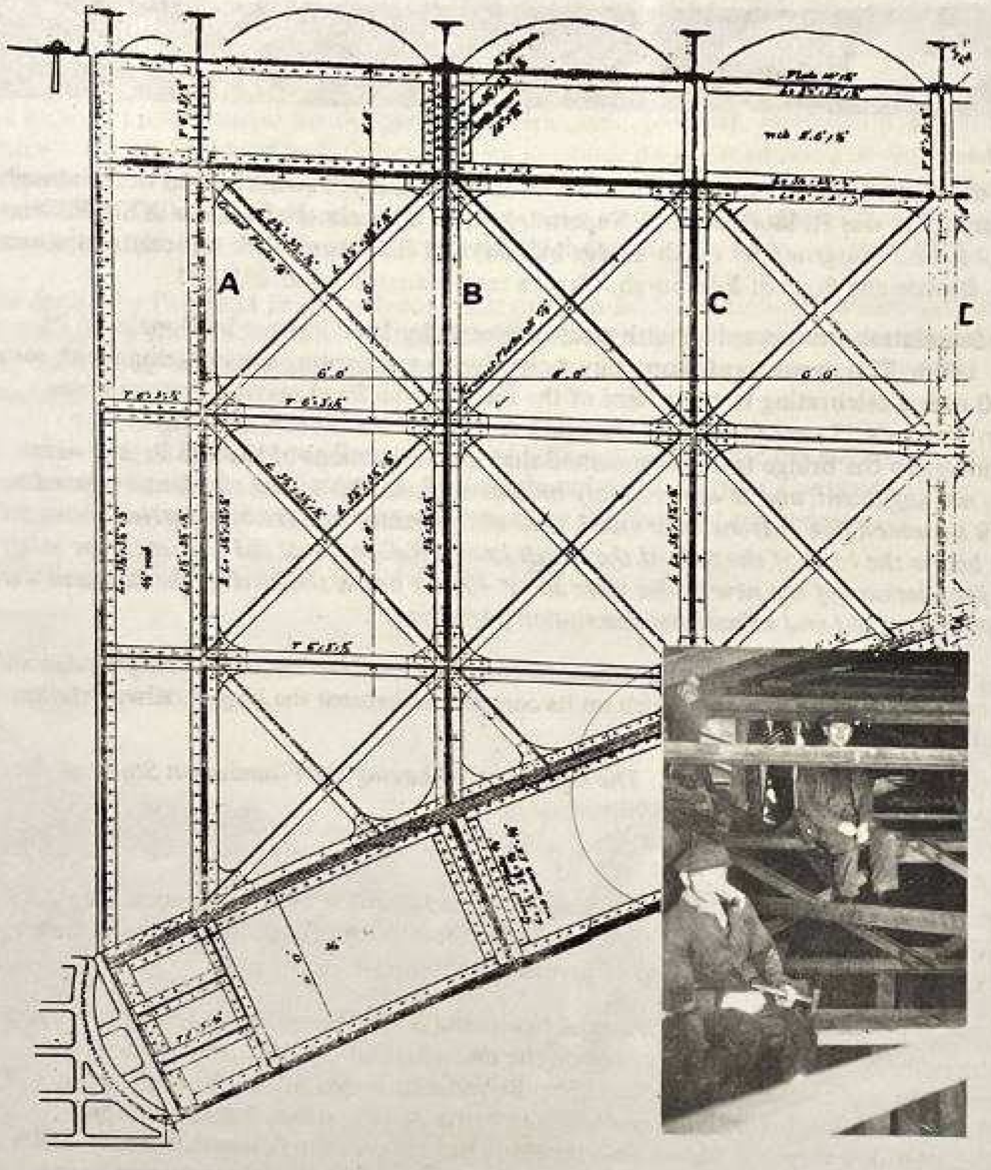
Stevenson wanted to have the term "Engineer" in the foundation stone inscription *"as it was very desirable to have the profession recognised,"* but an appropriate word could not be found in classical latin and he had to be satisfied with the style "architect".

Ref. Note: For further information see Youngson, A. J. The Making of Classical Edinburgh 1750-1840, and the sources referred to therein. The illustrations show the 1814 and 'as built' designs compared and construction in 1817.

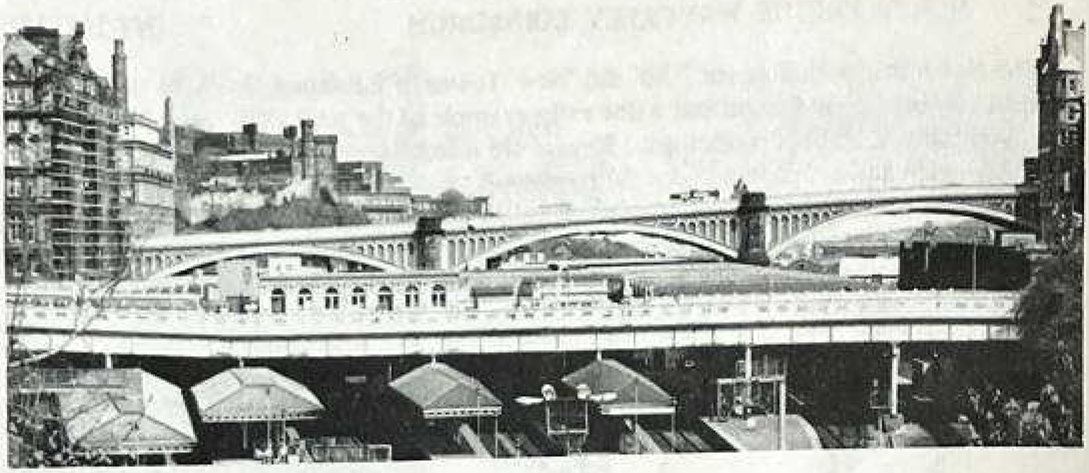


2. NORTH BRIDGE, WAVERLEY, EDINBURGH (NT 258739)

The North Bridge linking the 'Old' and 'New' Towns of Edinburgh is one of the largest span city bridges in Britain and a fine early example of the steel arch form of construction. It was built in 1894-7, replacing a 130-year old masonry bridge. The roadway is 75ft (23m) wide and supported by a steel framework under which there are 4ft (1.2m) deep plate girders (see Fig) in three segmental arches of 175ft (53m) span and 22ft (6.7m) rise. The abutments and piers are of masonry, the piers being 18ft (5.5m) thick. There are six plate-girders to each opening and the bridge facades are of cast iron to a traditional cast iron bridge elevation.



NORTH BRIDGE—part of the original contract drawing signed by Wm. Arrol 1895 and Men at work in 1933.



The engineers for the bridge were Messrs. Cunningham, Blyth and Westland of Edinburgh: the architect was R. Morham, City Superintendent; the main contractor was Sir William Arrol & Co., Glasgow (the Forth Bridge builder) and the mason work sub-contractor was Wm. Beattie and Sons of Edinburgh. Arrol's tender amounted to £81,894.

The foundation stone was laid with great ceremony by Lord Provost McDonald on 25 May 1896. This event was followed by a civic lunch and evening conversazione with some 5000 guests celebrating to the strains of the Black Watch Band playing Festival Music from Wagner's "Tannhauser". At the lunch Benjamin Hall Blyth*, replying for the Engineers to the bridge toast, commented that the foundations of the Old Bridge were *". . . not sufficient, and it was probably on that account that a fatal accident occurred in 1769 by which five citizens were killed. The old foundations were only carried about 20 feet below the level of the rails of the North British Railway, and did not reach the solid; the foundations of the new bridge were about 40 feet below the level of the rails and were of the most solid and substantial description (Applause)".*

Blyth and Westland were also the engineers for the reconstruction of Waverley Bridge and Waverley Station in 1895-99 which on its completion became the largest railway station in Britain.

Ref: Edinburgh Town Council. The Ceremony of Laying the Foundation Stone of the New North Bridge, 25th May 1896.

3. DALKEITH BRIDGES

Newmills Bridge (NT 336671) is a puzzling mixture of construction at several dates. Two main phases of building are recorded on the parapets, both designed by James Jardine and the second dated 1839. The date of first construction is thought to be 1756.

There is a cluster of old bridges over the North and South Esk within a few miles. Three in the policies of Dalkeith House include the medieval Old Cow Bridge and the grand Montagu Bridge (NT 334682) designed by Robert and James Adam and built about 1793. On the golf course, formerly grounds of Newbattle Abbey, stands Maiden Bridge (NT 336666), a very fine ribbed arch probably built late in the fifteenth century, and a bridge of two pointed arches stands disused beside the B703 near the entrance to the Abbey (NT 332657). Lugton Bridge (NT 329676) was built in 1767 and widened in 1814.

** President of the Institution of Civil Engineers in 1914.*

4. PATHHEAD or LOTHIAN BRIDGE (NT 391645)

This fine bridge over the Tyne Water at the north end of Pathhead village was designed by Telford in 1827, built by James Lees and opened in 1831. In Telford's own words the bridge *"consists of five arches, each 50 feet in span and 25 feet rise from their springing, which is at 49 feet above the bed of the river; the shaft of each pier is 8 feet in thickness, and is not solid masonry, the side and cross-walls being 2 feet in thickness; the longitudinal section of each shaft or pier, across the bridge, is 24 feet, with projections of 2 feet (at each end) 4 feet broad, at 19 feet above the springing of the main arches, and showing an equal breadth of soffit. The finished driving-way is 22 feet in width, with a footpath on each side of 2 feet, making the width between the parapets 26 feet; and, with the exception of the backing of the outer and cross-walls in the abutments, the whole bridge consists of square sand-stone."*

The local turnpike trustees for the part of the Newcastle, Morpeth, Coldstream, Edinburgh main route from Pathhead to Edinburgh could not agree on the road line and requested the government to make a survey and recommendations. Telford was instructed by the General Post Office on 19 March 1827 to carry out a survey and he immediately prepared drawings for the first mile north of Pathhead which includes the ravine of Tyne Water.

The design for Pathhead Bridge preceded that of Dean Bridge, Edinburgh which has basic similarities by about two years. Telford introduced the supplemental, or as he termed it, the "ascititious" or "external" shallow arches to give the structure an appearance of slenderness.

Note and ref: A search at the Scottish Record Office and elsewhere has not so far yielded any details of costs for the bridge but Sir John Hamilton Dalrymple, Convener of the Turnpike Trust, played a prominent role in making the financial arrangements.

Telford, T. Life of . . . edited by J. Rickman, 1838, 201-2, Pl. 63.

5. STOW OLD BRIDGE (NT 458444)

Stow Bridge, built in the mid-17th century, spans the Gala Water immediately west of the church at the south end of Stow village and can be readily seen from the main road (A7). The bridge, a scheduled ancient monument, is now disused except for pedestrians, mainly visitors. The overall length of the structure, which is partly a causeway, is about 125ft (38m) and it includes three arches increasing in size from 10ft (3m) span at the west side to the main span of 47ft (14.3m) at the church side. The clear width of the bridge between the side walls, which no longer exist, was about 6ft 6in (2m). The main arch ring consists of thin, undressed stone about 2ft (0.6m) deep and is of segmental shape with a 12ft (3.7m) rise at mid-span. The pier between the main and middle arches is protected from flood effects by a triangular cutwater.

The AA Road Book of Scotland refers to this bridge as the best example of a pack horse bridge in Scotland. In fact, the bridge was not built to facilitate commerce, being erected, between 1654 and 1655, by the Kirk Session for the convenience of worshippers who dwelt on the west bank of the river. The bridge was no doubt used by pack horses as, before about a century and half ago, the Edinburgh-Hawick-Carlisle road ran along the west side of the river and the bridge was the main means of access to the village on a cross road to Lauder.

6. GATTONSIDE SUSPENSION FOOTBRIDGE (NT 545347)

This bridge over the River Tweed was built in 1826 to form a direct link between the village of Gattonside and the burgh of Melrose, a journey which previously entailed a 2½ mile (4km) detour by road or an often hazardous fording of the river. The need for a convenient and reliable crossing had long been felt, especially to allow easier access to the parish church in Melrose.

The work was promoted by a specially formed Chain Bridge Co. and part, at least, of the cost was raised by public subscription. The designer was Mr J. S. Brown of Redpath and Brown, Edinburgh, the firm which provided and erected the metalwork of the bridge. The masonwork was done by John Smith of Darnick who had earlier built Abbotsford for Sir Walter Scott.

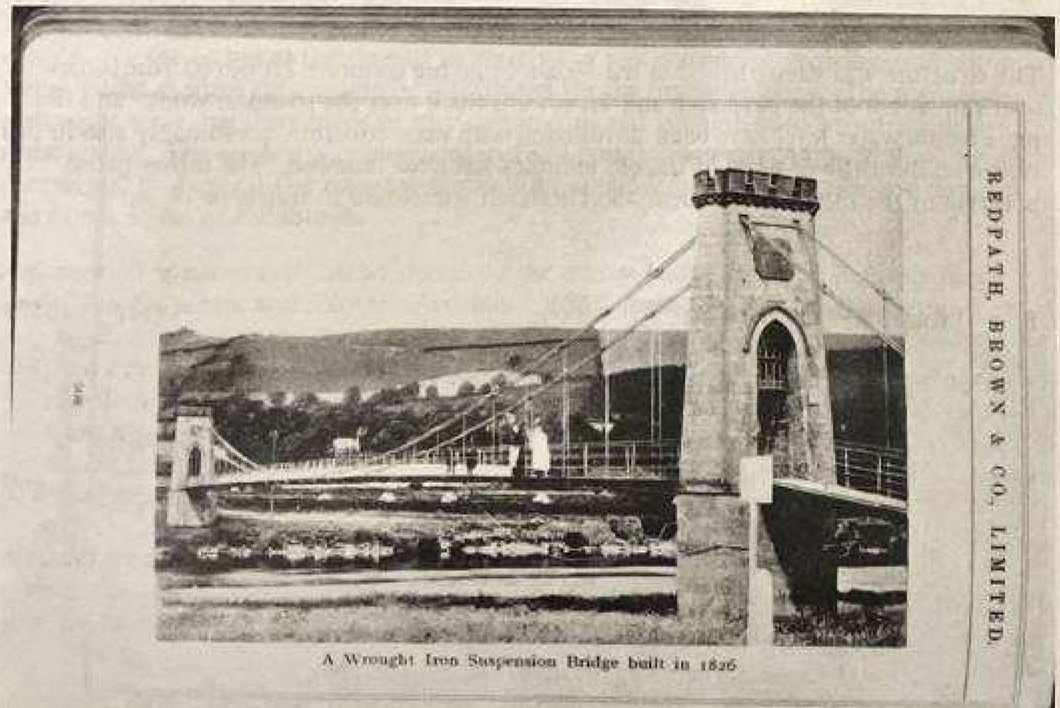
A masonry tower on each bank rises 38ft (11.6m) above low water level and is stayed on either side by 1½in (38mm) diameter bars. These support 4 suspending chains (2 on each side) over a span of 296ft (90.2m). The chains consist of 1¾in (44mm) diameter iron bars 10ft (3.0m) long connected by single 7in (178mm) links. The 4ft (1.2m) wide deck of 2in (51mm) planks on 6 x 4½in (152 x 114mm) timber joists, is suspended from the chains by single 1in (25mm) diameter iron bars at 10ft (3.0m) centres.

A contemporary account says, "it is intended chiefly for foot passengers although it is also calculated to admit horses". At the south end of the bridge a house was built for the collector of pontage (toll) which was one penny for foot passengers. The toll has long since been abolished and the bridge belongs to the local authority.

This bridge is the oldest example of the work of Messrs Redpath Brown still in use and in recognition of this fact the Company, in 1928, carried out repairs and refurbishing free of charge.

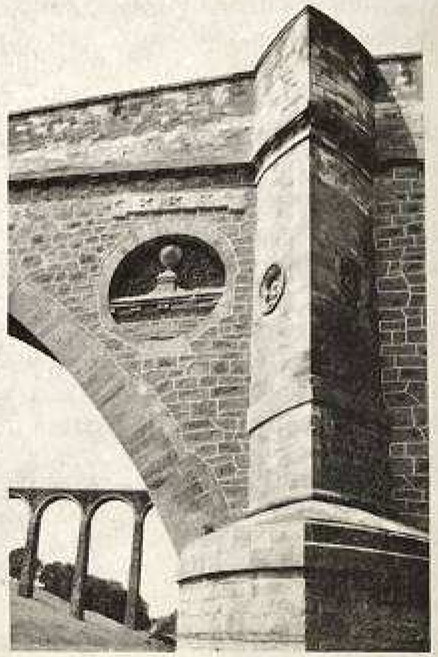
Refs:

John Bower, "Description of the Abbey of Melrose", 1827.
D. M. Hood, "Melrose 1826", Melrose Historical Association 1978.
"A Short History of Redpath Brown", 1964.
"Southern Reporter and Border Standard", 26 October & 4 November 1976.



A Wrought Iron Suspension Bridge built in 1826

7. DRYGRANGE OLD BRIDGE (NT 575346)



Drygrange Bridge was a product of the turnpike system of road management. All road users paid tolls to provide both for maintenance and for the repayment of borrowed capital, but local gentlemen sometimes made voluntary subscriptions towards the capital cost of a bridge. This was the case with Drygrange Bridge. The Trustees of Roxburghshire Turnpikes contracted with Alexander Stevens in 1778 to build the bridge for £2,100. The foundations, piers and abutments were constructed in 1779 and the superstructure in 1780.

It was Stevens' most daring design, having two side arches of 55ft (16.8m) span and 26½ft (8.1m) rise and a middle arch 105ft (32m) span and 34ft (10.4m) rise. The thickness of the large arch was only 2ft 6 in (0.76m) at the crown, increasing to 4ft (1.22m) at the springings, both remarkably small for such a large span. Three longitudinal voids were formed in each spandrel. The pier foundations were of large hewn stones all joined by cramps and laid directly on rock; the cutwaters are of the curved *and* pointed shape preferred by French engineers, but still very new to Britain in 1780. The roadway was 16ft (4.9m) wide between parapets.

The structure was strengthened in the 1920s by laying concrete 2ft 6in (0.76m) thick over the crown of the large arch and 1ft (0.3m) thick over the spandrel voids; and the piers below water level have been surrounded with mass concrete, presumably also in this century. But little or none of the old masonry has been renewed. The rather garish pointing of the facades dates from the 1960s. It was closed to traffic in 1974.

8. LEADERFOOT VIADUCT (NT 574347)

This was the major structure on the Berwickshire Railway which ran from Duns by Earlston to Ravenswood Junction on the Edinburgh–Galashiels–Hawick line. It was opened on 2 October 1865. The engineers were Charles Jopp and Messrs Wylie and Peddie. An early design proposed three arches of 150ft (46m) span but the structure which was built has 19 arches each 43ft (13.1m) in span. The arches are of brickwork 2ft 6in (0.76m) thick, with abutments, piers and walls of rustic-faced sandstone. The height from water level to soffit of arches is 123ft (37.5m). The line was closed (at least to passengers) after flood damage to other bridges in 1948, but the problems of the viaduct have been on the valley sides where several ties and buttresses have been added.

The viaduct can be seen in the background of the photograph.

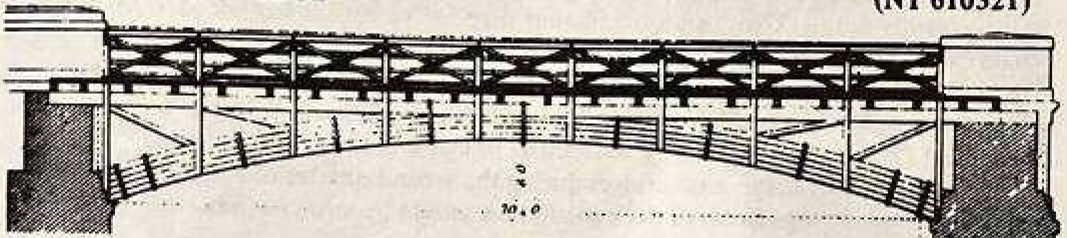
(Dimensions, etc., supplied by British Rail).

9. DRYGRANGE BRIDGE (NT 576347)

This is a composite structure of steel box girders and reinforced concrete deck. The river is bridged in a single span of 57m (187ft) and subsidiary spans bring the total length to 195m (640ft). The twin box girders measure 3.7 x 1.5m (12ft x 5ft) over the piers and 1.5 x 1.5m (5ft x 5ft) at midspan with curved soffit profile; they were fabricated in lengths of 11 and 14.25m (36 and 47ft) and assembled on site by friction-grip bolted splices. A slight longitudinal curve of the bridge was obtained by skew ends of the pre-fabricated units. The carriageway is 7.3m (24ft) wide, with two 1.9m (6ft) verges. Most of the piers and abutments are founded on rock, with some on piles. It was designed by Sir Alexander Gibb and Partners and built by Miller Construction (Northern) Ltd., with steelwork by Clarke Chapman Ltd. (Sir Wm. Arrol Branch) in 1971-3.

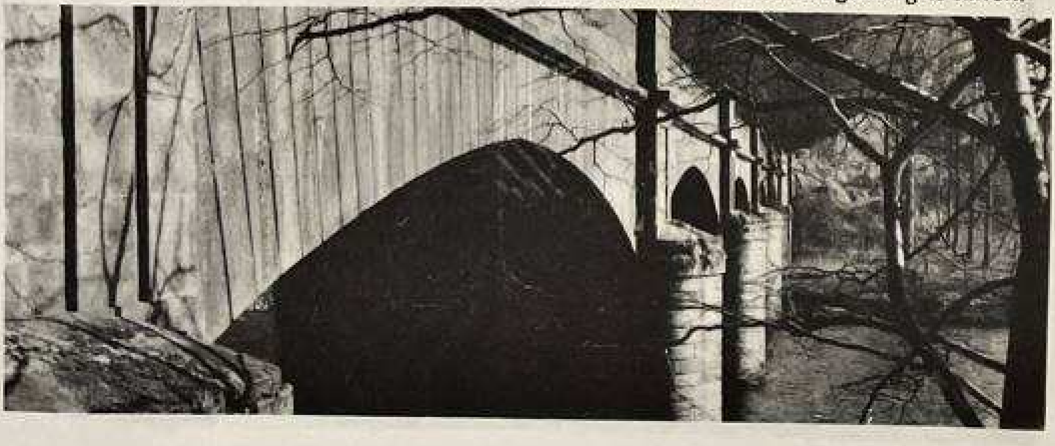
Ref: 'Drygrange Bridge', Acier-Stahl-Steel 4 (1975), 137-140.

10. MERTOUN BRIDGE (NT 610321)



Mertoun Bridge consists of five arches, each 70ft (21.34m) span erected on stone abutments and piers. Originally each arch consisted of three laminated rib-beams each formed of five thicknesses of 12in x 6in (305 x 152mm) half logs of timber (see fig.). The bridge was intended originally to be entirely of stone and although timber was adopted for the arches at the time of its erection, it was considered probable that stone arches might at some future date be substituted for the timber framing. The piers and abutments were therefore made of such dimensions and strength as to be sufficient for stone arches. The work was commenced in 1839 and finished in 1841 by William Smith, contractor, Montrose. The masonry arches were added later. The engineer and designer was James Slight of Edinburgh.

Ref. note: The above and further details of the timber bridge are given in James Newlands "The Carpenter and Jointer's Assistant", *1860, from which the engraving is taken.*



11. KALEMOUTH SUSPENSION BRIDGE

(NT 708274)

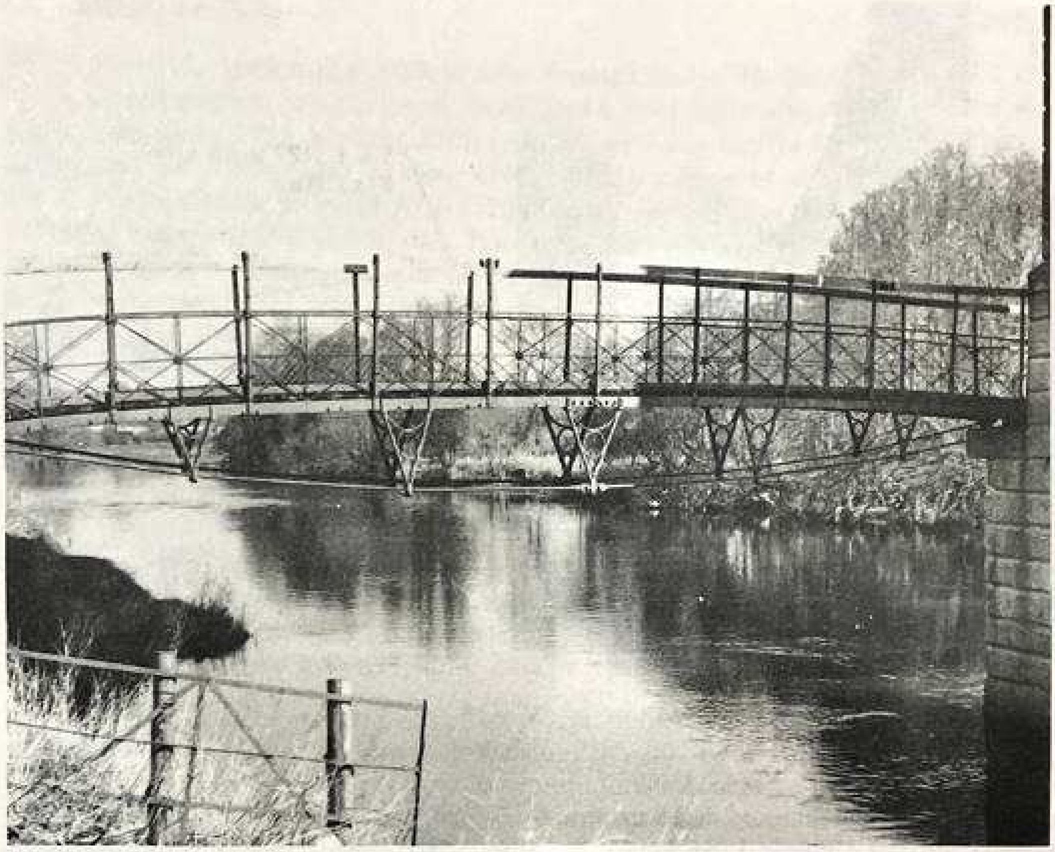
A wrought iron rod-chain suspension bridge with timber deck, erected over the River Teviot near Kalemouth c.1835 (to within five years). The bridge spans 186ft 7in (58.9m) between points of suspension and its clear width at the suspension pillars is 8ft 8in (2.6m). The four main chains, a pair at each side of the bridge, consist of 2in (50mm) diameter rods about 10ft (3.05m) in length with hand forged eyes (see photograph for these and other details.)The chains are suspended from four individual masonry pillars of obeliscal shape, an unusual feature of this type of bridge, through which they pass at about 16ft (4.9m) above road level.

This structure, a later example of the work of the chain cable manufacturer, Captain Samuel Brown, R.N. (1776-1852), the builder of Union Chain Bridge[19], is not only of considerable historical interest *per se* as one of the earliest surviving carriage suspension bridges, but also, by comparing the details of the two bridges, the development of the practice over the intervening period of one of the leading early suspension bridge engineers can be readily appreciated. A more efficient shape of curvature was adopted for the main chains and the link ends are cross-bolted, with the hangers terminating at the short inter-connecting links (see photograph and compare with Union Bridge photograph). Both these features were basically similar to those adopted by Telford at Menai Bridge from 1821-26.* The deck is stiffened by substantial timber cross-braced side railings which became a feature of suspension bridges during the second quarter of the 19th century to counter the damaging effects of deck-oscillation caused by strong winds.

The masonry work was carried out by William Mather of Kalemouth and the bridge was built at the expense of William Mein of Ormiston (about half a mile (0.8km) south-west of the bridge). The pontage c.1845 was ½d per foot passenger, a horse and cart 3d, a gig 6d and a chaise one shilling.

The Borders Regional Council plan to re-condition the bridge where necessary in 1983-5.

** For a comparison of the Suspension Bridge practice of Capt. Brown and Telford see Paxton R.A. "Menai Bridge (1818-1826) and its influence on Suspension Bridge Development." Trans. Newcomen Society, Vol. 49 (1977-8), 87-110.*



12. ROXBURGH VIADUCT FOOTBRIDGE (iron truss) (NT 702304)

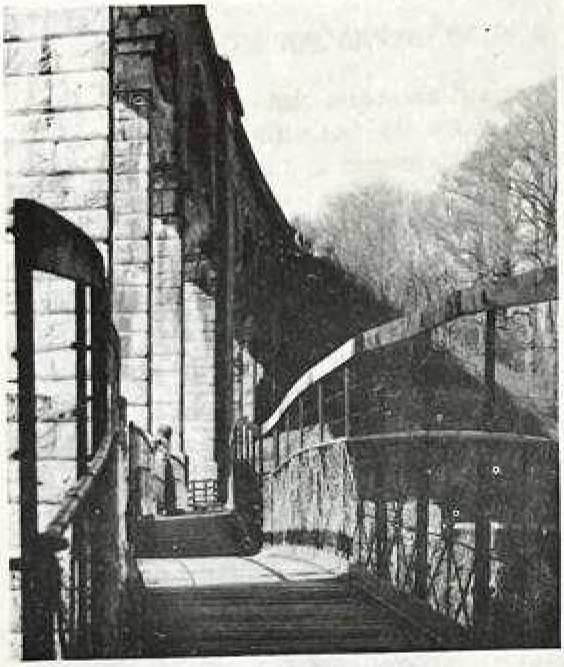
Roxburgh Viaduct is a fine example of a large masonry viaduct built on a curve with skew arches. It crosses the River Teviot at a height of about 70ft (21.3m) and consists of 14 arches, six main spans of about 47ft 6in (14.5m), measuring more on the skew, and flanked by four 30ft (9.1m) spans on each side. It was opened by the North British Railway in 1850 and connected the main line at St Boswells with the outskirts of Kelso. The line was closed in 1964. The resident engineer for the viaduct was G. Glennie.

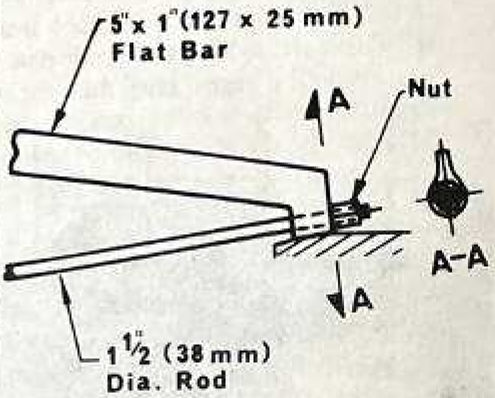
On the north side of the viaduct, four piers are extended at a low level to support an iron truss footbridge on a principle of construction of which, although fairly common in the 'railway mania' period of 1840-50, very few examples have survived.

The footbridge which probably also dates from c.1850, is 178ft (54.3m) in overall length with three clear spans varying from 49-52ft (14.9-15.8m) and is 5ft (1.5m) wide. The footway follows the curve of the upper truss-member. Details of the truss, which is mainly wrought iron are shown in the photograph and sketch. The truss, which is simply supported at the piers, is 4ft (1.2m) deep at mid-span and kept in shape vertically by cast iron 'V' elevation spacers. Sway bracing was not provided.

Other bridges of this type formerly existed at Hutton Mill[20] and Abbey St Bathans (NT 7662).

The footbridge is maintained by the Borders Regional Council.



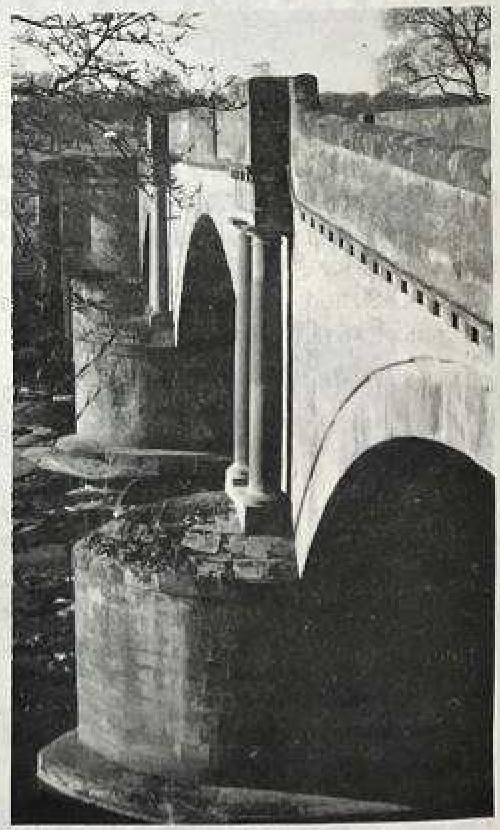


SKETCH OF TRUSS END.

13. TEVIOT BRIDGE (NT 720336)

Alexander Stevens submitted designs and estimates for this bridge in 1784 and 1788, and, although the actual builder in 1794-5 was William Elliott of Kelso, the form and ornament suggest very strongly that it was built to Stevens' design. The twin columns up each spandrel were first introduced by Robert Mylne in Blackfriars Bridge in London (1760-9). John Rennie was very critical of the architecture of Teviot Bridge and of its position at a bend of the river when he visited Kelso in 1798, but he built twin columns with a more generous entablature on several of his own bridges including the bridge over the Tweed nearby.

The bridge was founded on rock inside cofferdams. The side arches are of 53½ft (16.3m) span and 12ft (3.66m) rise, the middle arch 64½ft (19.7m) span, 15ft (4.65m) rise, and 2ft 6in (0.74m) thick. The clear width between parapets is 21½ft (6.5m). The cutwaters are curved and pointed like those of Drygrange Bridge. The cost of construction was about £2,000.



14. KELSO BRIDGE (NT 727336)

This is one of the finest bridges built to John Rennie's design. He designed it in 1799 for the local road trustees, to replace a six-arch bridge a short distance upstream. The former bridge, built about 1755, provided 320ft (97m) of waterway but the foundations were shallow and were undermined by scour which caused a collapse of part of the bridge in 1797. Rennie's design provided 360ft (110m) of waterway, in five elliptical arches of 72ft (22m) span and 19ft (5.8m) rise. The foundations were all sunk at least 7ft (2m) into bedrock, in cofferdams pumped dry by the power of a water-wheel set in a mill-race on the south bank of the river. The width between parapets is 24ft (7.32m). It was built by Messrs Murray and Lees between 1801 and 1804 and cost £12,876. The resident engineer was John Duncan.

The architectural details are correct and bold. Notice the wide projecting cornice, the entablatures and columns perfectly proportioned, the V-jointed arches and the rusticated cutwaters semi-circular in plan. The steep rise of the ground at the south end required a high bridge there and Rennie therefore chose a horizontal line of road and parapets to obtain a symmetrical elevation. An approach embankment was necessary at the north end.

Full repointing and some strengthening were carried out in 1921. A small increase of width was suggested in 1965 but the Fine Art Commission made strong objections–because cantilevers would destroy the architectural system–and no change was made.

An accident during the construction of the bridge might have deprived the country of one of its greatest mechanical engineers, Sir William Fairbairn. He was the eldest son in a Kelso family and as his parents were in poor circumstances, he went to work at the bridge as a labourer when only fourteen years old. Stones were carried to their place on the bridge on 'handbarrows' between two men and young William staggered under the weight of a stone which fell on his leg and caused an injury which threatened to make him a permanent cripple. Happily he recovered after nearly three months.

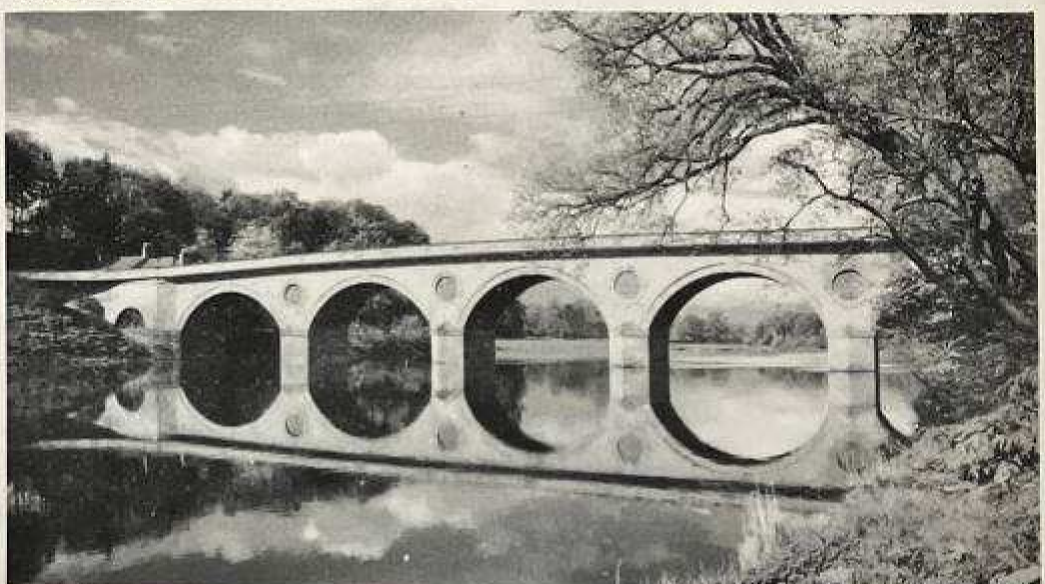
In order to preserve the bridge the Borders Regional Council plan to carry out remedial works in 1980-82 estimated to cost £60,000-£70,000. These works include replacing several modillions, taking down the parapets, sealing the stringer course beneath with sheet lead and rebuilding the parapets, replacing damaged or worn masonry.

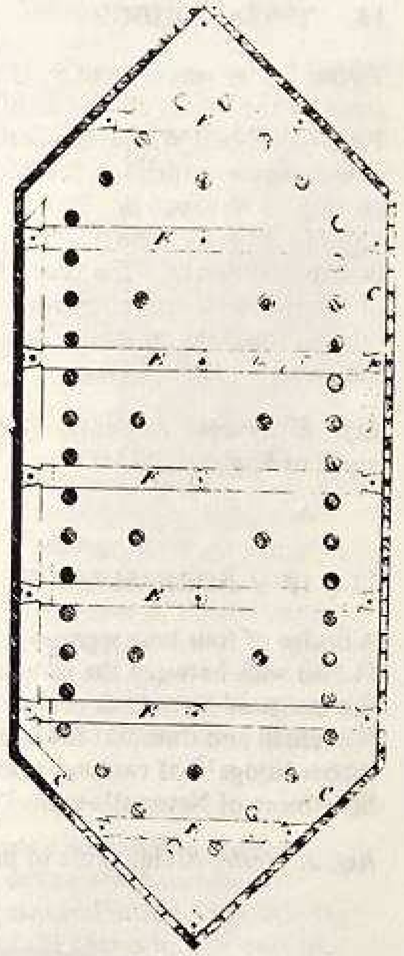
15. COLDSTREAM BRIDGE (NT 848401)

An Act of 1760 empowered local road trustees to build a bridge at Coldstream, but in 1762 they had to return to Parliament for financial assistance because their annual income from road tolls was less than £280 and they could not build a bridge for less than £2500. As military officers argued strongly that the route was necessary for troops and supplies moving from Newcastle to Edinburgh and Parliament had often financed roads and bridges in Scotland for military use, a grant of £4000 was made. In fact the bridge cost at least £2000 more, which was raised by borrowing from local gentlemen and Edinburgh banks, and the tolls collected were never enough to pay off the debt. The bridge was started in 1762 and finished in 1767 but not freed of tolls until some years after 1826.

The trustees employed John Smeaton as engineer and Robert Reid of Haddington as overseer on the site, the bridge being built by direct labour. The striking feature of a large ring on every spandrel was first drawn by Reid and later adopted by Smeaton, but it was Smeaton's own idea to build the arches all of the same radius so that one set of centres would do for all the main arches, while a small variation of spans (from 58ft to 60ft 6in, or 17.7 to 18.5m) created acceptable gradients down to the river banks. This elevation was the prototype for Smeaton's other large bridges at Perth, Banff and Hexham.

Ground conditions varied across the river, but rock was nowhere more than 10ft (3m) below the river-bed and both Smeaton and Reid hoped to place all the foundations on rock. This was done for both abutments and the first pier at the south end; for the two middle piers leakage into the sheet-pile cofferdams was too fast and the masonry had to be founded on bearing piles and a grating laid about 3ft (1m) below the bed (see fig.). At the position of the northmost pier the river-bottom was bare rock, so sheet piles could not be driven and the pier up to water level was built in an open-topped caisson. All these foundations, however, proved insecure in violent spates of the Tweed and protection from scour has been a regular task of the bridge's engineers. There has been a cauld (or dam) downstream since 1785 and protective 'starlings' round all the piers from an early date, first of rubble stone and now of concrete.





The spandrels were filled originally with gravel and earth and by 1828 they were cracked and badly out of plumb. Sir John Rennie then advised a complete reconstruction with internal longitudinal walls and voids and a clay seal under the road-metal. In 1960 these were removed and the arches strengthened on the extrados with reinforced concrete. Internal concrete walls were then built to carry a reinforced concrete road slab cantilevered over both facades to widen the bridge. This work was designed by Northumberland County Council and approved by the Royal Fine Art Commission. The area inside the ashlar rings on the spandrels has always been filled with black rubble, as it is now. Contrary to what has been written in many books, there were no tunnels through the spandrels and the rings on Smeaton's design were purely decorative.

As well as a plaque describing its construction the bridge bears another recording Robert Burns's first journey to England. By its position on the border it became a route for elopement from England and marriages took place in the toll-house. This had been built by Robert Reid for a contract sum of £27, but he cleverly made the underbuilding which was necessary to support it at road level into a two-storey house for himself. The trustees were annoyed, suspecting a waste of their funds, but Smeaton, who thought that Reid was underpaid, stepped in to commend the house as a useful support to the wingwall of the bridge. Reid, who was a local magistrate by 1770, remained supervisor of repairs to the bridge for at least another 20 years.

16. TWIZEL BRIDGE (NT 885434)

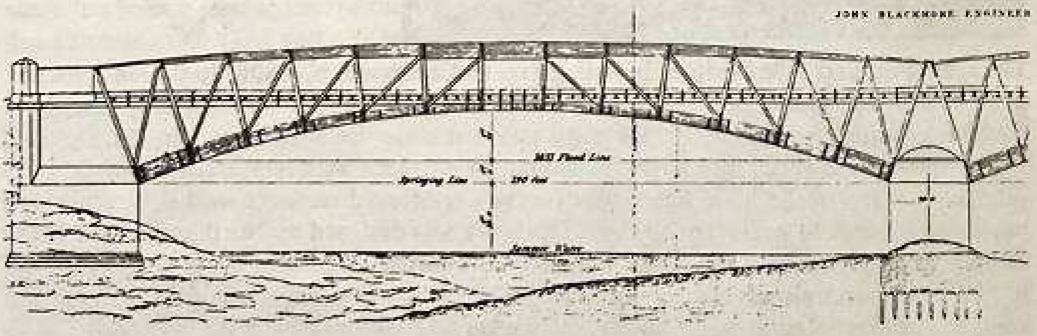
Twizel Bridge was crossed by the English army on the day of the battle of Flodden Field (1513). It was probably the bridge now standing, which has five narrow chamfered ribs spanning 90ft (27.5m) with 43ft (13.2m) rise–one of the longest spans in medieval Britain. The parapets and part of the spandrels appear recent and the original road was probably narrower than the present 13½ft (4.1m).

Ref: E. Jervoise, Ancient bridges of the north of England *(1931).*

17 & 18 NORHAM BRIDGE (NT 891474)

A bridge of four long segmental arches and rather stilted masonry details, but only 14ft (4.3m) wide between the parapets. It was built in 1885-7 by Messrs. Meakin and Dean to the design of Thomas Codrington, MICE (engineer of the Local Government Board in Whitehall) and Cuthbert Brereton, MICE. It replaced a much more daring structure, a timber bridge[18] of two arches each 190ft (58m) span built in 1838 to the design of John Blackmore of Newcastle-upon-Tyne (see fig.).

Ref: J. Weale, Architecture of bridges *(1843), vol. III, pl. V).*



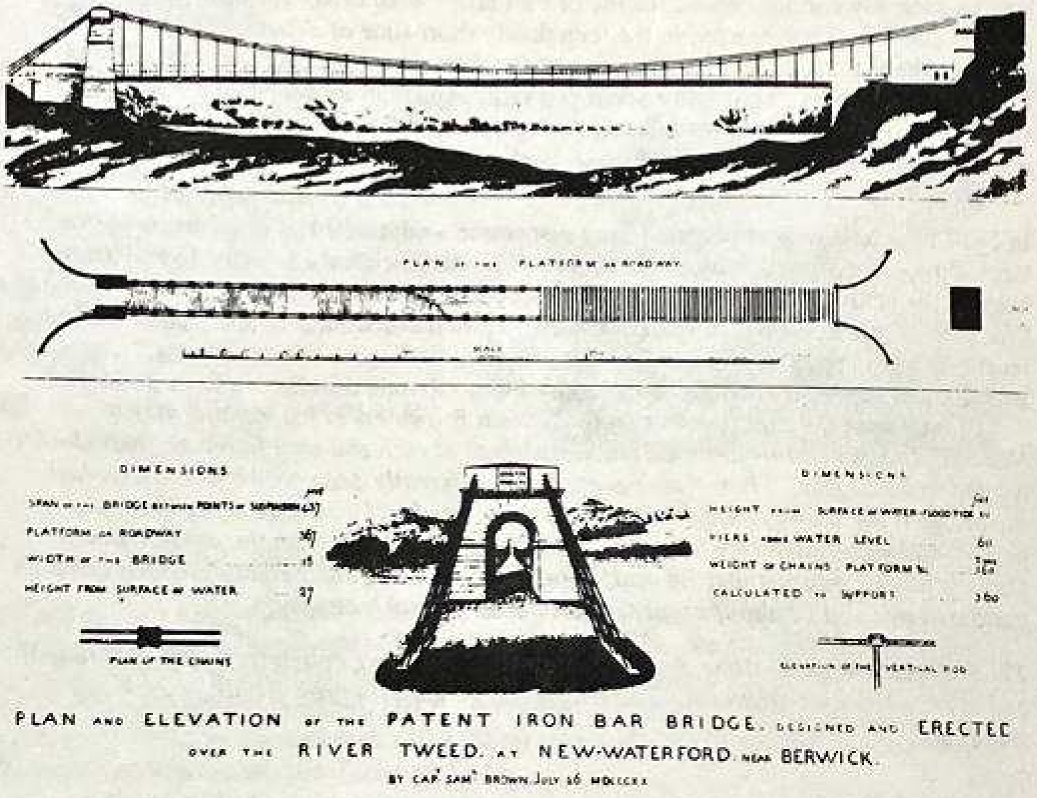
19. UNION CHAIN BRIDGE (NT 934510)

The Union Bridge, erected over the River Tweed in 1819-20, is the oldest surviving British suspension bridge still carrying vehicular traffic. Although started after Telford's Menai Bridge, which was on a much larger scale, Union Bridge was completed first and for five years, was the largest span wrought iron suspension bridge in the western world carrying carriage traffic. It was a triumph of the newly-emerging bridge technology of its day, utilising wrought iron to achieve a span between points of suspension of 437ft (133.2m), several times the largest masonry span previously constructed and greater than that of any timber or cast iron bridge. Its success encouraged the building of suspension bridges generally and influenced the use of bars rather than cables for main suspension cables. The bridge was erected in the remarkably short time of about one year and cost approximately £7,700, which was compared at the time with a sum of at least £20,000 for a masonry bridge. The highly developed skills applied in its design and construction were provided by the chain manufacturer, Capt. Samuel Brown, and the eminent civil engineer and bridge builder, John Rennie, both of whom have already been mentioned.

In 1817 two designs were prepared for a suspension bridge of 245ft (74.7m) span, one by Capt. Brown and the other by Robert Flinn of North Shields. In January 1818 Rennie became the consulting engineer for the project when he was requested by William Molle, Chairman of the Berwick Turnpike Trustees, to give his opinion on the designs they had received. Rennie preferred Capt. Brown's proposal, finding his bar link chains "very superior" to the common links proposed by Flinn. Rennie concludes a letter to Molle:- *". . . I have seen the experimental bridge Captain Brown has at his manufactory at Millwall. It is about 110 feet span and is sustained at each end by a framing of wood which is fixed in a soft clay. These framings are but indifferently done notwithstanding which the bridge is sufficiently supported to sustain the weight of a carriage along the bridge in perfect safety and with very little shake. So that I do not entertain the smallest doubt that a bridge of this sort may be made capable of sustaining the weight of loaded carriages passing over it and be also if properly attended to a durable structure.*

The architecture of the stone abutments in Captain Brown's design is clumsy, ill arranged and overloaded with ornament. This part might be much improved both in look and stability . . ."[1]

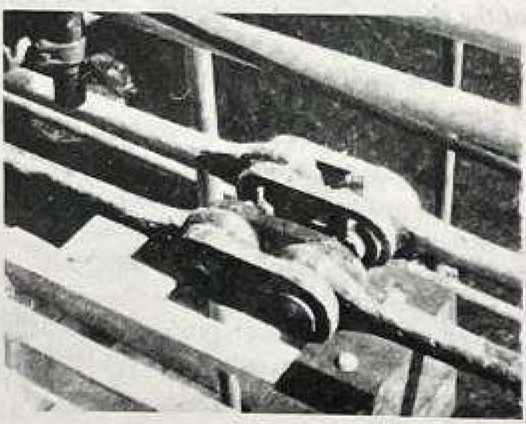
Capt. Brown and Rennie had a meeting late in 1818 to discuss details of the project. Rennie suggested a number of alterations to Capt. Brown's design which included, strengthening the abutments and towers by increasing their size and introducing tapering faces, reducing the span by 22ft (6.7m), providing rollers for the chains to pass over near the tower tops,[2] and raising the deck at mid-span about 3ft above the roadway level at each tower. In a letter to Molle written in November 1818 Rennie mentions that Capt. Brown had approved of these changes and that the latter had made out a new set of plans. Rennie commented: *". . . With respect to the suspending chains and other iron work, they are entirely in Capt. Brown's own line, and of course I have not ventured to make any material alterations in them, and moreover as I am not locally acquainted with the spot where the bridge is to be erected, I can give no opinion as to the nature of the foundation or the manner of fixing the ends of the chains–all I can say is, that if all these matters are properly attended to, my opinion is that the bridge will be a durable and useful structure, and as he takes the responsibility on himself I see no reason why the Trustees should not enter into a contract with him–all the extra expense incurred by the alterations I propose are on the abutments, and if these are approved of by the Trustees, it will be for them to consider what extra allowances should be made for this increase–this extra in my opinion should be liberal as I think he undertakes the work more for the sake of introducing bridges of this sort into general use, than from any profit he can derive from the undertaking . . ."*[3] The Trustees seem to have taken Rennie's advice as, after completion of the bridge, they presented Capt. Brown with 1000 guineas over and above his estimated price. Even so, it seems unlikely that Capt. Brown profited financially from the venture although its success undoubtedly established him nationally as a chain bridge builder.



An Act of Parliament was obtained for the bridge in 1819 and the foundation stone was laid on 2 August 1819 by William Molle. A detailed contemporary account of the bridge is provided by the Edinburgh civil engineer, Robert Stevenson[4], who was present at the opening ceremony on 26 July 1820. Perhaps he was one of the crowd of about 700 spectators who surged through the toll gates on to the bridge after Capt. Brown had tested its strength by crossing first in a curricle followed by twelve loaded carts.

The bridge attracted great public interest, one of the manifestations of which was the publication of an aquatint[5] which included the principal engineering details (see figure).

Link with saddle removed



Saddle and hanger

Bridge features of particular interest include the 15ft x 2in (4572 x 508mm) diameter eye-bars of South Welsh manufacture, the manner in which they are carried over the towers and anchored, and the hanger connections. Capt. Brown used individual lines of chains in three pairs, one above the other, at each side of the bridge, that is about 18ft (5.5m) apart. The tops of the hangers are secured into capping clips each resting upon or "saddling" a pair of chains (see photographs)[6]. This arrangement differs at Kalemouth (11).

The chains, hangers and deck, and their arrangement can be readily inspected on site, but not the four cast iron ballast plates into which the chains are anchored and which presumably still exist. Stevenson informs us that these plates measure 6ft (1.83m) in length, 5ft (1.52m) in breadth and 5in (1270mm) in thickness in the central parts diminishing to 2½in (635mm) at the edge. On the Scottish side of the bridge the ballast plates are sunk to the depth of 24ft (7.3m) and *"loaded with mound-stones and earthy matters to the level of the roadway of the bridge."* On the English side, the ballast plates are *"rather above the foundation of the pillar, where they are set nearly perpendicular, but are placed so as to correspond with the direction of the strain . . . they are connected with a horizontal arch of masonry which is dovetailed into the rock . . ."* The chains are "stopped" into the ballast plate *"by a strong iron spear or bolt, of an oval form, measuring 3 inches by 3½ inches in thickness."*[4]

Over a period of many years a popular misconception has gathered momentum that the bridge was blown down six months after its completion. Although countered to some extent by Cowe[7], this quite untrue statement appears in at least four books on bridges[8] published between 1911 and 1968. The evidence to the contrary is found in a letter from Capt. Brown to Dr Brewster written about eighteen months after the opening of the bridge in which he states of the bridge, *". . .the fact which is paramount to all others–that ever since it has been opened, it has given entire satisfaction and has been in constant use without any restriction."*[9]

The principal details of maintenance on the bridge since 1884 are shown in the table[6]:-

Details extracted from memoranda and reports to Tweed Bridges Trust 1884-1974

1902	Renewal of timber deck	£850
1903	Addition of steel-wire cables and hangers to strengthen bridge	£1,531:16
1919	Repairs to timberwork	£240
1925	Replacing wooden sleepers	£372:11:5
1926	Repainting bridge	£130
1933	Renewal of cross beam	£763:2:0
1952	Ironwork cleaned and repainted; repairs to towers	£1,217
1953	Repair of gale damage	£154
1955	Toll cottage demolished and facade erected	£1,015
1957	Repainting bridge; repairs to deck	£800
1963	Repainting bridge; improvements to north anchorage chamber	£550
1964	Replace footpath timbers	£346
1969	Repainting bridge	£900
1974	Renew deck	£37,000

In 1974 the Tweed Bridges Trust embarked on an extensive programme of preservation work which is expected to have cost over £100,000 by the time it is completed in 1981. The work being carried out at present includes the removal and replacement of defective links with spheroidal graphite cast iron links.

Although the original design of this historic bridge would be unacceptable today, being formulated at a time when knowledge of "strength of materials" was less accurate and theoretical design techniques were virtually non-existent, the bridge was, nevertheless, a remarkable achievement of contemporary technology[10]. Its survival is not only a testimony to Capt. Brown and Rennie but also to others, particularly the Surveyors of the Tweed Bridges Trust, who have been responsible for its subsequent maintenance and tasteful reconditioning.

References and Notes

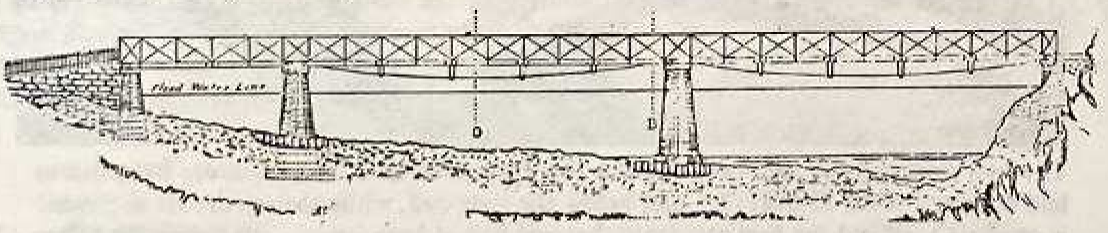
1. *Rennie, J. Ltr. to Molle 6 Jan. 1818. MS. I.C.E. library, IX, 245-8.*
2. *The Rollers only appear to have been adopted in the Scottish tower.*
3. *Rennie, J. Ltr. of Molle 11 Nov. 1818. MS. I.C.E. Library X, 21-3.*
4. *Stevenson, R. "Description of Bridges of Suspension", Edin. Phil. Jrnl. 1821, V.*
5. *Plan and Elevation of the Patent Iron Bar Bridge at New-Waterford near Berwick, London, J. Taylor 1822. Aquatint.*
6. *By courtesy Arthur, B. "Union Chain Bridge", The Consulting Engineer, Feb. 1976.*
7. *Cowe, F.M. "A pioneer suspension bridge of 1820". Country Life 6 July 1951.*
8. *By Tyrrell H.G. (1911); British Bridges, Pub. Wks. Cong. (1933); Smith H. Shirley (1953); and Pugsley Sir A. (1968).*
9. *Brown, Capt. S. "Description of the Trinity Pier", Edin. Phil. Jrnl., 1822. VI.*
10. *Ever since the bridge was opened the stresses in the main chains have been too high to allow what most engineers, even Telford and Rennie in 1819, would accept as a sufficiently generous safety margin. Apart from being somewhat underpowered, the bridge, unlike Kalemouth (11), also lacks any substantial provision against the effects of oscillation and it is fortunate that the site is a fairly sheltered location. For further information on early suspension bridges, the original strength of Union Bridge and the comparative practice of designers see Ref: Paxton R. A. ibid Kalemouth Bridge (11).*

20. HUTTON MILL BRIDGE (iron lattice-truss) (NT 921546)

A three-span wrought iron light lattice-truss bridge over the River Whiteadder. The spans are 55ft (16.7m) and two at 54ft (15.45m) and the width of the bridge is 12ft 4in (3.75m). The trusses which are on each side of the bridge are about 5ft (1.5m) deep and carry the deck on cross beams from their lower flanges. The piers are of ashlar masonry, about 50ft (15m) high and probably date from 1837 when they were spanned by an iron tension rod truss bridge, similar to Roxburgh Viaduct iron footbridge[12], except that the deck was probably level, to the design of the Edinburgh engineer James Jardine.

A cast iron plaque on the bridge reads: "Erected 1837, James Jardine, Engineer. Re-erected 1878. D. & T. Stevenson, Engineers. Oliver & Arrol, Contractors, Edinburgh."

D. & T. Stevenson were the sons of Robert Stevenson and it is interesting to note that this firm designed and erected a footbridge of 60ft (18.3m), 60ft (18.3m) and 24ft (7.3m) span in 1840-1 over the River Whiteadder at Abbey St Bathans (see fig.) which was similar to the original bridge at this site.



21. BERWICK-ON-TWEED OLD BRIDGE (NT 996527)

There are records of the destruction of several wooden bridges at Berwick, sometimes by men and sometimes by nature, from 1199 A.D. onwards. In 1608 ice carried by a strong current demolished ten of the timber 'piers' and petitions were made to the Privy Council for a grant to build a stone bridge. Grants were made and the stone bridge began to creep out from the east bank in 1611, the last arches at the west end being substantially finished about 1624.

The designer was James Burrell, surveyor and sometime major of Berwick, and he and Lancelot Branxton a master mason, undertook the main contracts. The cost to the Exchequer was almost £15,000 and the bridge was built to a higher standard than any contemporary bridge in Scotland, 17ft (5.2m) wide between the parapets, the largest arch spanning 74ft (22.6m) and with even a few flourishes of ornamental masonry on the facades. There are fifteen arches of near semi-circular shape. From the engineering point of view, the most interesting feature is the starlings which surround all the piers to a width of about 3-6ft (1.0-1.8m). The piles were of oak 6-23ft (2-7m) long and 12-18in (0.3-0.45m) square, using 823 trees felled in Chopwell forest and shipped from Newcastle.

The starlings are in excellent condition and can be studied at low tide; each is surrounded by a sloping apron of long narrow stones which is probably a fairly recent addition. Even more recent is some concrete work and a little steel sheet piling.

(The above is derived mainly from a full narrative of the construction to be published in vol. IV of *The history of the King's works* (H.M.S.O.). We are grateful to the author, Sir John Summerson, and editor, H. M. Colwin, for permission to include it here).

22. ROYAL TWEED BRIDGE AT BERWICK (NT 996528)

When it was opened in 1928 the Royal Tweed Bridge had the longest concrete arch in Britain (361ft 6in, or 110m). This was the arch at the north-east end, the other three arches reducing in span as the deck falls at a constant gradient of 1 in 51. There is a 30ft (9.15m) carriageway and two 8ft (2.44m) footways. It cost £160,000 including approaches, was designed by L. G. Mouchel and Partners and built between 1925 and 1928 by Holloway Bros. (London) Ltd.

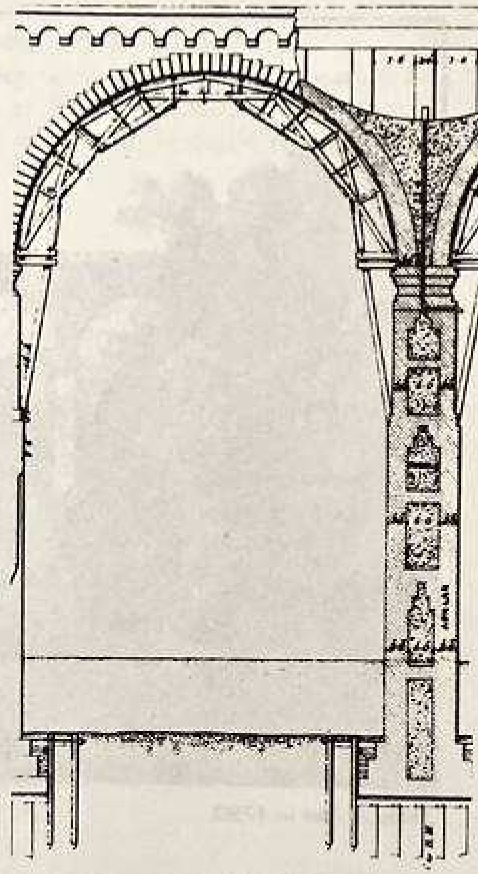
The two piers and the abutment towards the south-west have mass concrete foundations laid on gravel some 15-20ft (4.5-6m) below the river-bed, while the north-east abutment is on shale rock and the first pier from that end had to have precast concrete piles driven through a layer of running sand and peat. Staging and falsework were erected on driven timber piles and the whole structure cast in situ from mixing plants on both banks of the river. Each arch consists of four parallel ribs of rectangular cross-section, solid for one third of their length at the crowns but hollow towards the springings. A line of columns rise from each rib to support a main longitudinal beam and these beams carry secondary beams and the slab which forms the road. The concrete mixes were 1:1.25:2.5 for the ribs and 1:2:4 for the rest of the structure, 1,015 tons of reinforcing steel was used and the average labour force on the site was 170 men.

Ref. W. Hamley, 'Berwick's fifty-year-old Royal Tweed Bridge', Concrete, Jan. 1979, pp. 20-22.

23. ROYAL BORDER BRIDGE (NT 993434)

Three years after the opening of railways from Berwick to Edinburgh and Tweedmouth to Newcastle they were joined by the Royal Border Bridge in August 1850. It was designed by Robert Stephenson and T. E. Harrison for the York, Newcastle and Berwick Railway. It cost £120,000 and took three and a quarter years to build. The resident engineer was

George B. Bruce, a young man of only twenty-two, who later founded the firm of consulting engineers now known as Sir Bruce White, Wolfe Barry & Partners



The contractors were James McKay and J. Blackstock, who employed 2,738 men and 180 horses at the peak of the work. With the approaches included, their contract amounted to over £200,000.

There are 28 semi-circular arches of 61½ft (18.7m) span and the greatest height over the bed of the river is 126ft (38.4m). The Nasmyth steam hammer was used to drive the piles of the cofferdams and the pier foundations. American elm was used for all the piles. The bearing piles, driven 33-100ft (10-31m) into the river bed, carry a load of 70 tons each. The superstructure is all of ashlar with heartings of rubble masonry and brickwork.

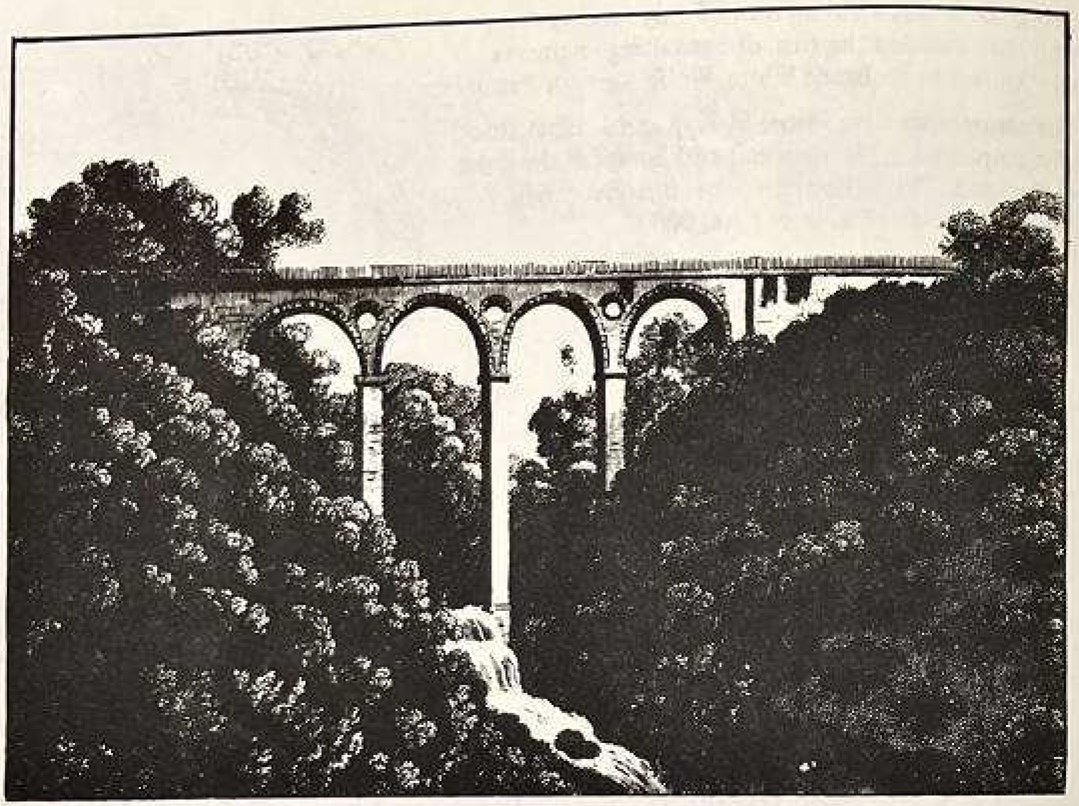
An 'abutment pier' was built on the south bank of the river so that traffic could use the viaduct to that point before the river spans were built. A single-track temporary viaduct of timber was used for access to work on the river spans.

Ref: G.B. Bruce, 'The Royal Border Bridge over the River Tweed', Minutes of proceedings of the Institution of Civil Engineers, X (1851), 219-244 (with further facts supplied by Sir Bruce White and Mr J. C. Banbery).

24. PEASE BRIDGE (NT 791699)

Before Pease Bridge was built in 1783 the road from Berwick to Edinburgh led steeply down to a ford across the Pease Burn near its mouth and mounted the other side of the gorge just as steeply. In 1762 the strongest arguments placed before parliament in favour of a grant for the building of Coldstream Bridge were by three military officers and all mentioned 'the hill called the Pees' as almost impassable for artillery. The grant was given and Coldstream Bridge built but twenty years later the steep sections of the coastal route were bypassed by bridging the Pease gorge at high level. The initial cost of Pease Bridge was £1,500, said to have been raised by voluntary subscriptions from local gentlemen, but within five years a further grant of £1,000 from the proceeds of resale of the Annexed Estates was spent either on the bridge or adjacent road. The designer was David Henderson of Edinburgh and he may have also been the contractor.

The bridge is 19ft (5.8m) wide overall and the carriageway 15ft 10in (4.8m). The top of the bridge is horizontal and the parapet 117ft (35.7m) above water-level in the burn. The middle pier rises from the bottom of the gorge and two others from points higher on the rocky sides. The four arches are approximately semicircular, the spans varying from 41ft 8in to 55ft 6in (12.7m to 16.9m). The masonry is red sandstone, roughly squared but not ashlar. The engraving indicates the very considerable height of the bridge.



Pease Bridge in 1790.

The bridge's interest lies in its great height and the fact that each of the spandrels is pierced by an arched cylindrical void 9ft (2.7m) in diameter. The high viaduct form presages Telford's high viaducts at similar sites, such as Pathhead Bridge and Cartland Crags in Lanarkshire; while the cylindrical voids refer back to events in David Henderson's earlier experience. His early career was chequered; starting as a mason at Sauchie near Alloa, he built the four-arched bridge over the Earn at Forteviot in 1761, but one arch failed and extra work was necessary. He was accepted as contractor for Coldstream Bridge in 1763 but was discharged after a year of erratic attendance at the site and disagreements with both Smeaton and Robert Reid. He was aspiring to practice as an architect and in 1765 won the premium in a competition for design of the new North Bridge in Edinburgh, a high structure in its time, but not nearly so high as Pease Bridge. North Bridge was not built to his design but to that of William Mylne and it failed in 1769 through excessive height and weight. It was repaired by several weight-reducing stratagems, including the formation of cylindrical voids of 20ft (6.1m) diameter in the spandrels, a feature which Henderson is thought to have suggested in his original—but rejected—design. He surveyed the bridge in detail after the collapse in 1769 and twice more in 1783 and 1784, finding that only very small movements had occurred between these inspections. His decision to lighten Pease Bridge by voids is a natural consequence of this experience. He was by then a fairly successful architect and mason, having built Inverleith House and the shell of Register House in Edinburgh, made an early plan for the new university building and also some plans for the Borrowstoness Canal Company. He died in or before 1788.

25. DUNGLASS OLD BRIDGE I (NT 773724)

This carries a section of the road which was probably abandoned for public traffic in 1798. The chasm of the Dunglass Burn is deep and steep-sided, so the bridge appears as a wedge of masonry pierced by a single lofty but narrow arch. The earliest parts probably date from early in the seventeenth century but there is evidence of extensive reconstruction.

26. DUNGLASS RAILWAY VIADUCT (NT 771722)

This is part of the original North British Railway from Edinburgh to Berwick, authorised by Parliament in July 1844 and opened for traffic within two years. John Miller was engineer for the line. There are five spans of 30ft (9.1m) and one of 135ft (41.2m), crossing the Dunglass Burn at a height of 110ft (33.5m). The whole structure is of masonry and the small and large arches are 1ft 5in and 4ft (0.4 & 1.2m) thick respectively.

(Details provided by British Rail)

27. DUNGLASS OLD BRIDGE II (NT 770721)

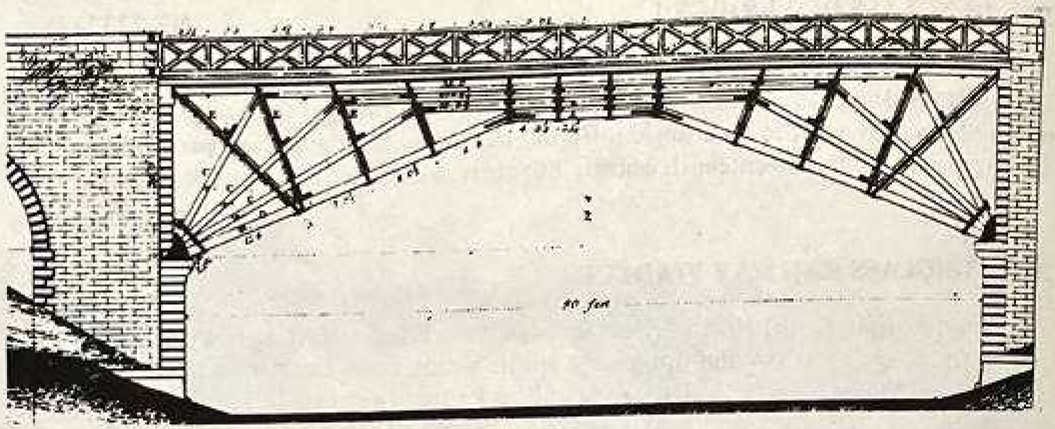
This bridge was opened in 1798, a single segmental arch of 83ft (25.3m) span rising to 76ft 6in (23.3m) above the bed of the burn. It is notable for its boldly rustic masonry and castellated parapets, possibly a style chosen to please the owner of Dunglass Hall. Bilsdean Bridge (NT 763725) is in the same style.

28. EAST LINTON BRIDGE (NT 593772)

A good example of a bridge with ribbed arches, easily inspected from the rock outcrop on the downstream side. A very likely date for the original structure is about 1550. There are two arches of about 43ft (13m) span, each of four ribs very closely spaced. '1762' and '1763' on keystones record the dates when it was widened. Other repairs took place in 1884, 1895 and 1934.

29. EAST LINTON RAILWAY BRIDGE (former timber) (NT 592771)

The two river arches of the original freestone bridge carrying the North British Railway over the River Tyne were carried away by a flood in September 1846. These arches were quickly replaced by an iron-strapped timber structure of 90ft (27.4m) span (see Figure)

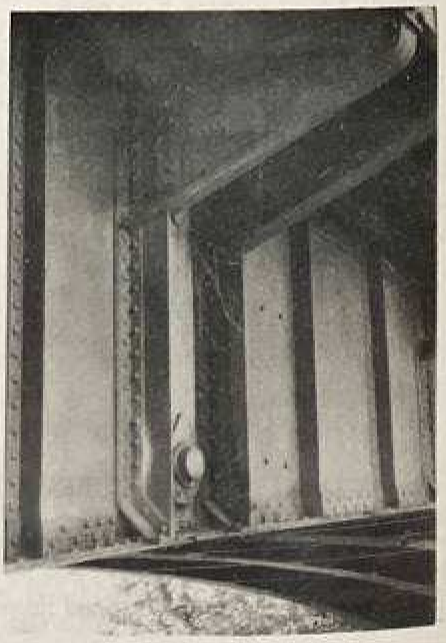


to the design of the Company's consulting engineer John Miller. The bridge still existed c.1860 but was replaced sometime within the next three decades by the present wrought iron girder structure of similar span.

30. TYNE BRIDGE, EAST LINTON (steel cantilever) (NT 592769)

A steel plate girder bridge of the cantilever and suspended span type carrying the A1 trunk road over the River Tyne. It was designed and built by Sir William Arrol & Co. and opened in 1927.

The bridge consists of three spans, abutments towards the top of steep side slopes and two slender masonry piers. The side spans measure 67ft 5in (20.5m)and the central span 102ft 8in (31.3m) of which the middle 62ft (18.9m) is hanging by pin-jointed suspender bars from each of the four plate girder cantilever ends (see photograph). The girders vary in depth from about 10ft (3m) at the piers to 5ft (1.5m) in the middle and at the abutments of the bridge.



The basic design concept of this bridge was not new, the Forth Bridge provides a much larger example, but it is an unusual example of the application of the concept to the economical achievement of smaller spans. In "British Bridges" published by the Public Works, Roads and Transport Congress in 1933, this bridge is illustrated as a good example of a plate girder bridge. With the arrangement adopted the stresses in the girders are less than if three simple spans of the same length had been employed.

The bridge is currently under investigation by Blyth & Blyth, Consultant Civil Engineers, Edinburgh on behalf of the Chief Road Engineer, Scottish Development Department.

31. ABBEY BRIDGE, NEAR HADDINGTON (NT 533745)

A bridge of three pointed arches, each with five ribs. It may date from the early sixteenth century, but an inscription on the east side records a repair in the early nineteenth century, while the west side has been rebuilt in a different style and probably at a later date.

32. NUNGATE BRIDGE, HADDINGTON (NT 519737)

Similar to the old bridge at Musselburgh in its three low segmental arches and in masonry details, but otherwise a misfit amongst Scotland's oldest bridges. The arches are equal, of about 44ft (13.5m) span, the width between parapets 10½ft (3.2m). A tentative date of construction is early seventeenth century.

33. VICTORIA BRIDGE, HADDINGTON (NT 517740)

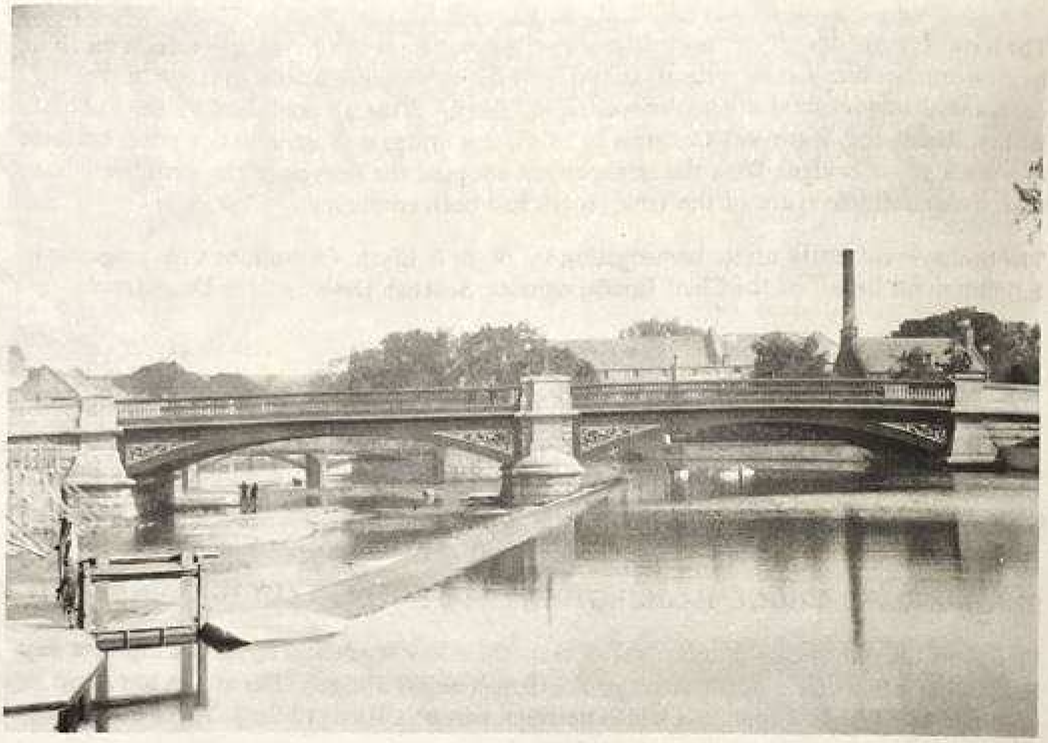
A two-span steel arch bridge constructed over the river Tyne in 1898-1900 at a cost of about £9000 and named after Queen Victoria. The slender curvature of the arches gives the bridge a pleasing appearance. It is a good example of the use of the steel arch on a much smaller scale than at North Bridge, Edinburgh.

The segmental arches each span 60ft (18.3m) with a rise of 6ft (1.8m) and the main girders are 3ft (0.9m) deep.

The designers of the bridge were Belfrage & Carfrae, C.E. of Edinburgh who also superintended the foundations and mason work. The steelwork and erection contractor was Somervail & Co. of Dalmuir.

Haddington Town Council had been considering building a new bridge from 1849. From this time onwards, innumerable plans and estimates had been prepared, including a scheme to utilise some of the girders from the ill-fated Tay Bridge destroyed in 1879. Eventually a Mr Montgomerie of Bernaline Mills who had offered to donate land and construct the approach roadway on the Nungate Bridge side of the bridge was asked to have plans prepared. Sir William Arrol prepared and submitted plans and an estimate for the bridge. Some Council Members objected to these plans and the Council decided to appoint a firm chosen by themselves to progress the matter. The Council selected Belfrage & Carfrae.

The bridge was reconditioned by Lothian Regional Council in 1975 at a cost approaching £20,000.



The works note-book of William Jackson (Resident Engineer?) enables an insight into the method of construction of the bridge to be obtained. A randomly selected entry in 1898 reads:

Thurs. night:	*18 men taking out sludge from top of concrete in E. Abut. 2 men on pumps.*
9th Frid:	*Men washing concrete under Mr Smith. 18 men, 5 masons. Weather fine.*
Frid. night:	*Concreting started at 7 p.m. Washing gravel. Foreman left at 11.30 & did not return–I kept men working all night till 6 a.m. 20 men. Weather fine.*
10th Sat:	*Concreting in E. Abut.–washing gravel–Cement brought over from west side–18 men 2 foremen 5 masons–Weather fine. Men worked till 4.30 p.m. Telegraphed to office about foreman being away on Frid. night–10½d.*
12th Mon:	*Concreting in E. Abut. 25 men 4 masons 2 foremen–Weather fine.*
13th Tues:	*Concreting in E. Abut. 25 men 3 masons 2 foremen. Weather fine. (Wrote Mr L.).*
14th Wed:	*Concreting in E. Abut. Looked over cement & instructed foreman to use cement which had come in second last–also to return cement which had come in last to makers. 28 men–4 masons–2 foremen–Weather fine–Wrote Mr L. to come and examine cement.*

Ref. The Carfrae & Morrison Papers
House of Lords' Judgment and Souvenir of Haddington. Glasgow: (1904).

34. WESTFIELD FOOTBRIDGE near HADDINGTON (NT 501716)

A steel reinforced concrete structure with a single span of 52ft 9in (16.1m) and a 3ft 3¼in (1.0m) footway crossing the River Tyne. The bridge consists of two straight side beams 10½in x 4ft (267 x 1219mm), which form the parapets, with an inter-connecting floor slab. The underside is about 8ft (2.4m) above water level and the deck is approached by a set of concrete steps at each side.

The parapet bears the date 1912 which places the structure, although of modest scale, amongst the earliest surviving examples of reinforced concrete bridges in Scotland. It is owned by the East Lothian District Council.

35. MUSSELBURGH OLD BRIDGE (NT 341725)

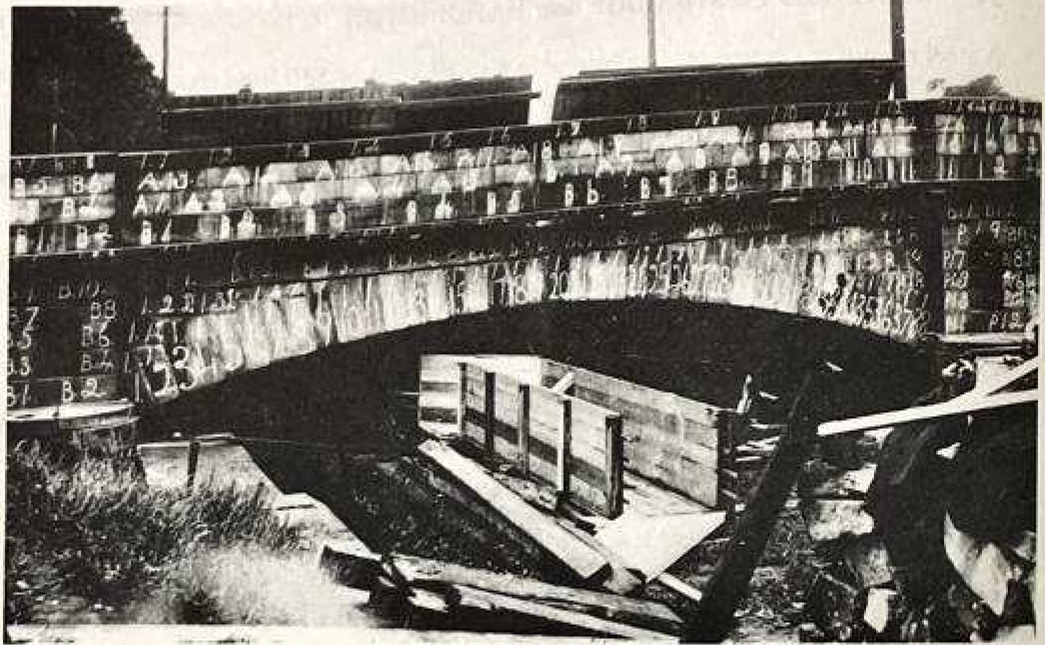
Like Nungate Bridge at Haddington this bridge has three rather low segmental arches, considerably distorted and each spanning about 51ft (15.4m). It is slightly angled in plan at the pier on the right (east) bank of the river. Both piers are protected by large 'whale-backs' of masonry and concrete and sagging courses in the spandrel masonry probably indicate that the arches have shortened over the centuries.

A plausible speculation is that an earlier stone bridge, which certainly existed, was damaged or destroyed when the English burned Musselburgh in 1548 and the present bridge was then erected at the expense of Jane, Lady Seton.

36. MUSSELBURGH "NEW" BRIDGE (NT 342727)

A metal plaque on the northern parapet informs the reader that, *"This bridge was built by John Rennie, Engineer, 1806.* Repaired and widened 1924-5 Alexander Mitchell, Provost, Blyth & Blyth, Engineers, John Angus & Sons, Contractors."*

The bridge, which is constructed of freestone, carries the A1 trunk road over the River Esk on five low rise arches of 37-42-46-42-37ft (11.3-12.8-14.0-12.8-11.3m) span and is



Stones of facade marked for re-location. (By courtesy Blyth & Blyth)

notable for the slender curvature of its longitudinal profile and low height (see photograph) being only about 14ft (4.2m) above water level and almost on the same level as the existing street approaches.

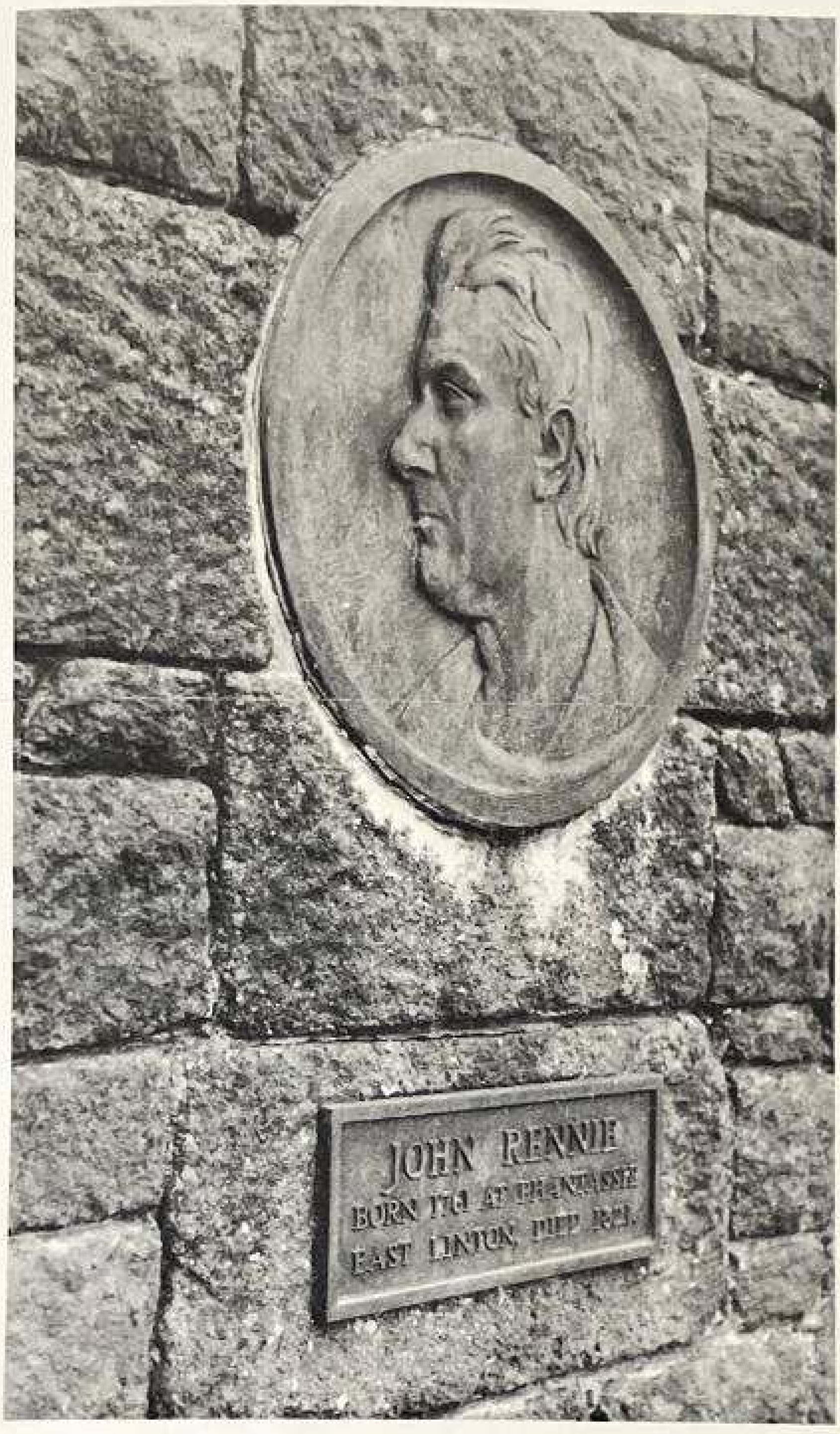
The original width of the bridge was 34ft 6in (10.5m) between parapets, but in 1923 Musselburgh Corporation, because "ever-increasing traffic, along with a frequent tram service from Edinburgh was causing considerable congestion", decided to increase this width to the present 53ft (16.2m), all the extension being on the sea-ward side. Although a reinforced concrete extension would have been more economical, the Corporation insisted on preserving Rennie's original design and the whole elevation on this side was carefully removed stone by stone (see photograph), apart from some blocks which were too firmly bedded, and rebuilt in its present position. The spandrels of the arch were strengthened with concrete.

This fine example of the work of John Rennie is at present maintained by the Chief Road Engineer, Scottish Development Department.

** The bridge was in fact completed in 1808.*

37. BERWICK FORTIFICATIONS–THE ELIZABETHAN WALLS
by Francis M. Cowe

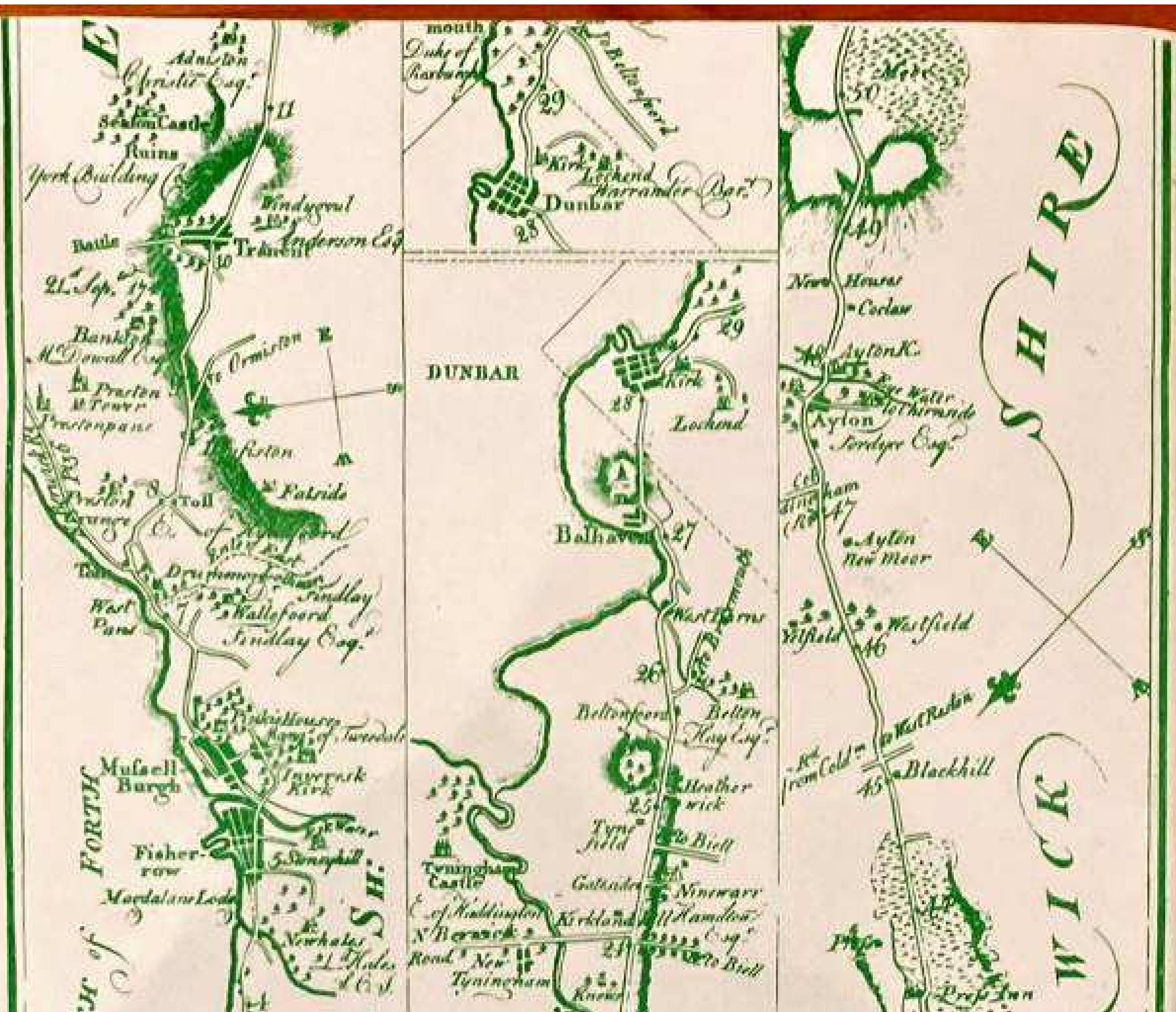
Under the Tudor kings and queens the obsolete medieval fortifications at Berwick were greatly altered. Artillery towers were added to the Castle in the reign of Henry VII and the Lord's Mount gun fortress was built at the north east corner of the defences at the same time. Under Edward VI a new fort, a square rampart with acute angled bastions at each corner, was constructed on the eastern side of the town astride the medieval walls. It was begun in 1550 and abandoned eight years later when Sir Richard Lee produced plans for an entirely different set of fortifications. By 1568 the new fort was known as the old fort.



38. RENNIE MEMORIAL, EAST LINTON **(NT 593 769)**

This memorial to Rennie in masonry and bronze, which includes seating and a baluster from his Waterloo Bridge, London, was erected in 1936 by local subscription. It is situated on the south side of the A1 trunk road overlooking his birthplace.

Produced by Dryden Printing Co., 6c Dryden Street, Edinburgh.



Published according to Act of Parliament the 6th of June 1775.

£1.50

Lee's plans were approved by Queen Elizabeth on 3 April 1560. An Italian military engineer, Giovanni Portinari, who was working in England, may have been involved in the original design, and he and his countryman, Iacopo a'Contio, later advised on some modifications to Lee's plans. The master mason in charge of the works, Rowland Johnson, a native of County Durham, who settled in Berwick, also had his own ideas as to the form the new ramparts should take, and some amendments had to be made because of difficulties experienced during construction.

The Elizabethan Walls were built on the landward side of the town, facing a possible attack from Scotland. On the north they were laid out well within the line of the medieval walls, cutting off about a third of the old town. On the east they were built just inside the older walls. The riverside fortifications were largely left alone, and it was not until the eighteenth century that they were renewed. The Elizabethan and the medieval walls were, however, joined to form a complete ring of defences about a mile and a quarter (2km) in circumference. The medieval circuit had measured about a mile and three quarters (2.8km).

The main purpose of the Elizabethan Walls was to provide protection against possible artillery attack, and in their design the most up-to-date ideas from Italy were adopted. A wall of ashlar, twenty-two feet (6.7m) high, slightly battered and supported internally by counterforts built at regular intervals, was backed with a thick bank of earth to form a rampart. From this rampart at intervals five massive bulwarks or bastions (three full and two demi-bastions) projected forwards into the ditch. They were built in the same way – a stone wall buttressed by counterforts–and their interiors were filled with earth and rubble to make gun platforms with a wide field of fire. The bastions also concealed flanking gun emplacements from which the ditch could be scoured.

The ditch or moat was 200 feet wide (61m). On the north front, and perhaps on the east, it was filled with water which was contained between cross walls known as batardeaux. The moat was shallow, but in the middle there was a smaller ditch which was twelve feet in width and eight feet deep.

The Elizabethan Walls were long in building. In 1560 two thousand men were employed on the works, and their wages, per day, were.as follows: hand hewers 12d;. carpenters, sawyers, wheelwrights, coopers, mason hewers of freestone, bricklayers and roughlayers 10d., quarriers, lime burners, labourers, carters and victuallers 8d., hod boys 5d., and clerks and overseers 12d. Sixty carriages were hired at 4s. each a day. The total charge for the work done in six months of this year was £12,000.

In May 1565 the great ditch from the walls to the sea, which is now known as the Covered Way, was dug by 300 men who worked from 4 a.m. to 8 p.m. By this year the new fortifications were in a condition to be defended, though they were not fully completed until the 1590s when the temporary wooden gates were replaced with stone structures.

In the seventeenth century the earthworks on the Walls were raised to their present levels, and the medieval town wall that survived along the riverside was rebuilt in the middle of the eighteenth century.