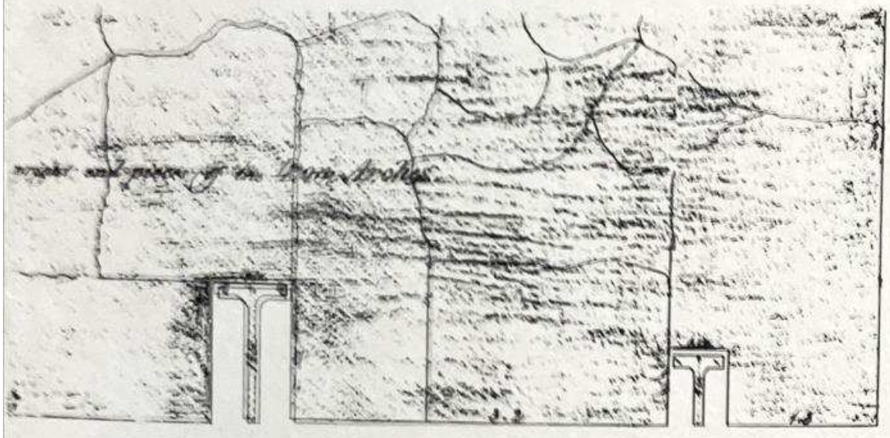
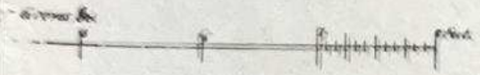
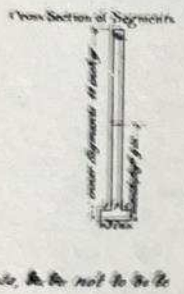




An appraisal of Dalhousie Viaduct 1830-46

Scotland's earliest known major iron and timber railway viaduct



by

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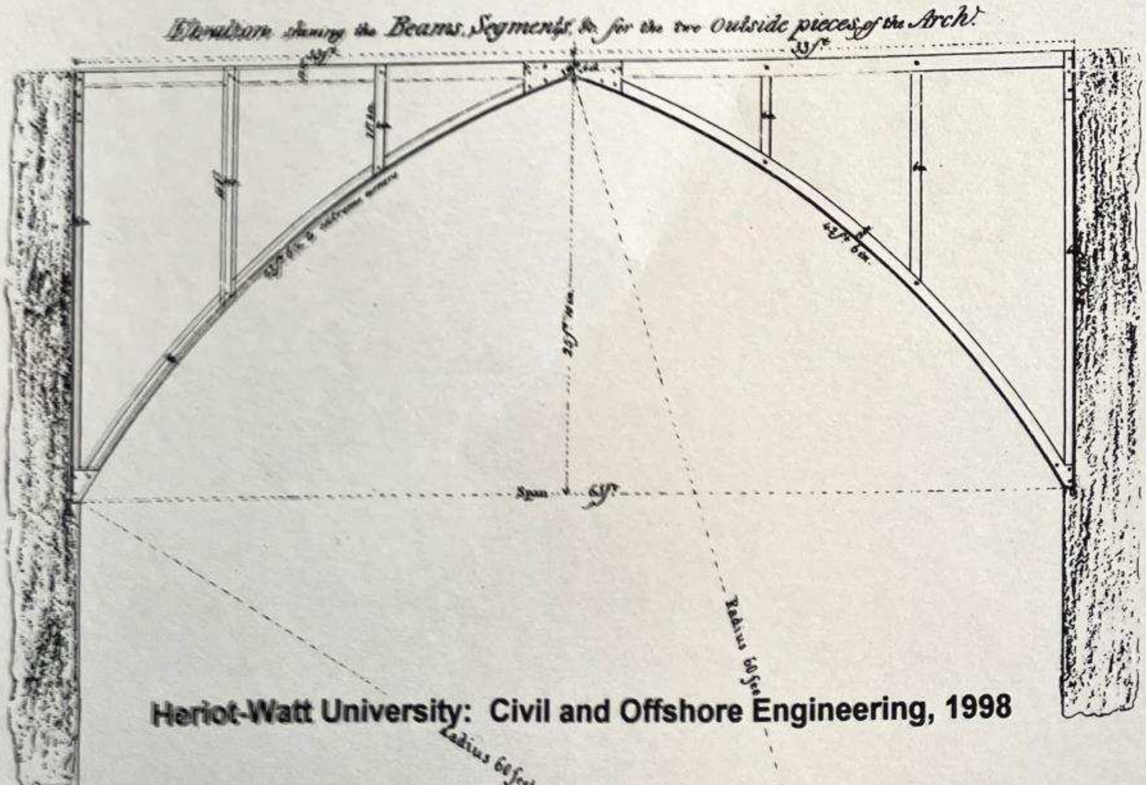

Heriot-Watt University: Civil and Offshore Engineering, 1998

Fig. 1. Part of Knox's map of the County of Edinburgh 1845

An appraisal of Dalhousie iron viaduct (1830-46) on the *Edinburgh & Dalkeith Railway* extension.

In this paper to be presented to a meeting of the Dalkeith History Society and members of the East of Scotland Association of the Institution of Civil Engineers on 9 March 1998, the long-sought elevation and design details of this fascinating cast iron viaduct are revealed from recently uncovered drawings.

Introduction

For more than 150 years the Galashiels road, now the A7, has twisted under a masonry and brick skew-arch of Dalhousie Viaduct. This impressive 23-arch masonry structure[1] built by the North British Railway in 1846-47 under the direction of leading Scottish railway engineer John Miller(1805-83), justly deserves its Historic Scotland category B listing. Its site possesses the added attraction of having previously hosted one of the most remarkable early cast iron viaducts ever built, stemming from an age when the use of wrought iron in girder and truss bridges had not developed to any extent and use of cast iron, despite its brittleness and weakness when stretched was *state of the art* practice for economical bridge building.

When built, the first Dalhousie Viaduct was almost certainly the largest and longest early cast iron viaduct on a public railway in Scotland. Since its demolition in c.1846 the viaduct's general description in the *New Statistical Account* has intreagued seekers of information about it but, in more than 30 years of research, the author has not, until recently, found any view of the viaduct or details of its ironwork. Fortuitously, when investigating Robert Stevenson's bridge-building practice, he found Stevenson's copies of plans of the viaduct by John Williamson dated 1830[2]. Fortunately these plans, the only known copies, had survived in the careful stewardship of the Stevenson family.

The *New Statistical Account* entry for Newbattle parish written in 1839 by its minister the Rev. John Thomson reads, *The Marquis of Lothian has at his own expense completed a railway from the mines* [Fig. 1][3], *one and a half miles in length, to Dalhousie Mains, where it forms a junction with the Edinburgh Company's Railway. . . In the progress of this operation, a valley of 1200 feet in breadth had to be overcome. This has been done by means of a bridge consisting of three main arches of cast iron in the Gothic style, each 65 feet span, and the one that crosses the river is 70 feet in height at the centre of the arch from its bed. The other two are not so high above the ground. The arches have stone piers, built from the quarries of the proprietor. Besides these there are eighteen stone pillars, ten of which are joined at the top by horizontal iron beams, and eight by beams of wood; the whole the design of Mr. John Williamson, Newton Grange, the manager of his Lordship's colliery*[4].

The Rev. Thomson also stated that use of the viaduct greatly reduced the cutting up of the parish roads by loaded coal carts. He considered the structure ***a great ornament to the neighbouring scenery, as it mixes the grand with the beautiful***[4]. It is believed that the Marquis of Lothian was so keen to have this rail connection to his pits, that work was started before the Act of Parliament was obtained on 4th June 1829. Nine months later Williamson had prepared his design for the viaduct and the

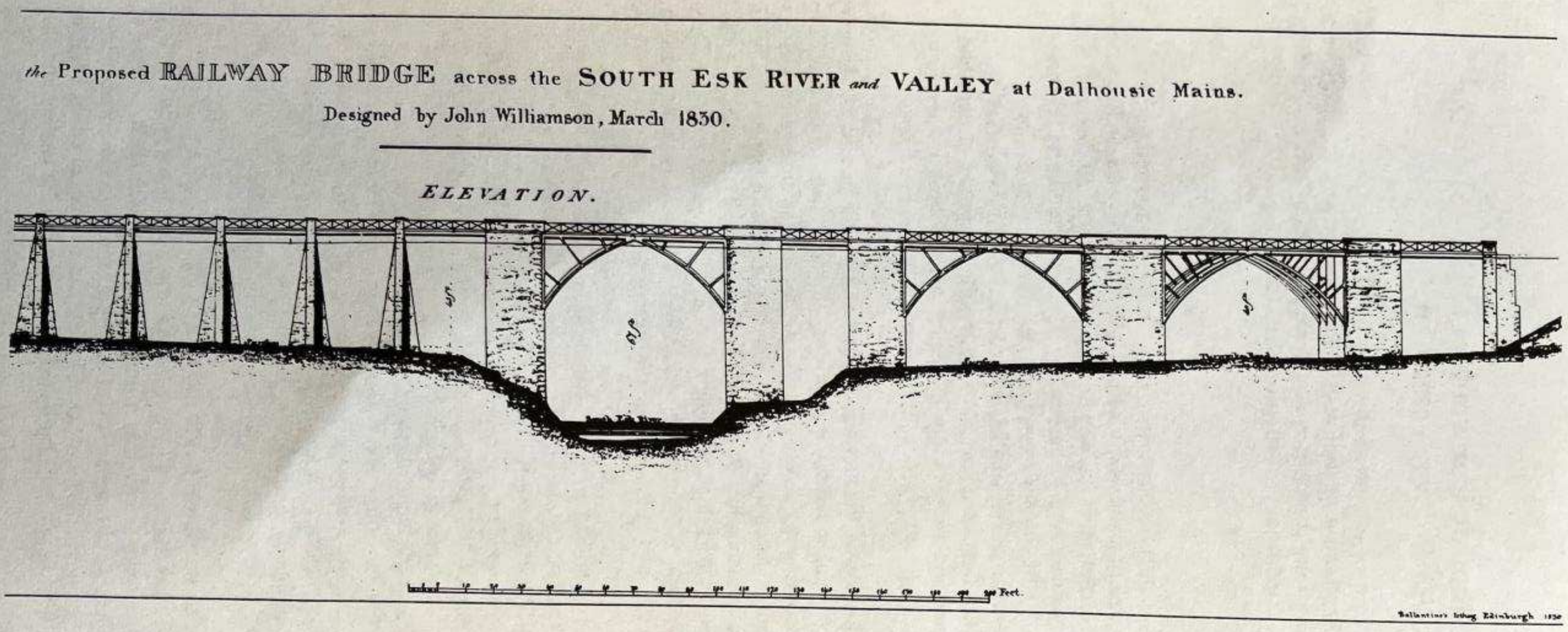

Fig. 2. Elevation of south end of viaduct 1830.

railway over it was opened on 21 January 1832[5]. The 24-span viaduct, which exceeded 1,000ft. in length overall, cannot have taken more than about 22 months to construct, a very creditable timescale for the achievement of such a large structure.

Although the horse-operated Edinburgh & Dalkeith Railway was constructed primarily for the purpose of transporting coal, unexpectedly, it soon developed an extensive passenger carrying role. In 1832 the total tonnage carried on the line and its extensions was 72,344 tons, including 91,814 passengers in privately operated coaches, increasing to 90,355 tons and 189,294 passengers for 1833. An *Edinburgh Railroad* directory of 1834[6] records 7 coaches a day operating on a two-hourly service to and from Edinburgh, over the viaduct, to what is now Gorebridge, 9 miles distant. The journey time from Dalhousie Mains at the north end of the viaduct to the south end of the line [Fig. 1] was 15 minutes, for which the fare from Edinburgh was *9d*. Recreational attractions for passengers travelling southwards over the viaduct included ***Roman Camp*** [which] *may be visited from the the south west, or by a two miles walk from viaduct bridge, by new Lingerwood, this wooded eminence is gained, where there is a splendid view of the whole country round.* ***Fushie Bridge****, lies two miles southwards of the termination of the railroad where there is a good Inn. Two miles south east lie the picturesque ruins of Borthwick and Crichton Castles*[6].

Williamson's design and its significance

Williamson had the daunting task of crossing this wide valley in the quickest and most economical manner. A masonry viaduct would have been very expensive, probably of the order of £20,000-£30,000, and he prepared the design [Fig. 2], for probably about two-thirds of this cost utilizing cast iron for 16 or 17 of the viaduct's 24 spans, the remainder being of timber. To have used timber throughout would probably have cost slightly less but the structure would certainly have had shorter life potential than one in cast iron. Most openings were to be spanned by 33ft. long straight beams, but for those that were too large for beams, he had recourse to pointed arches of 65ft. span with spandrel struts connected to a stringer beam at deck level.

For the design cross-sections of the main arch ribs Williamson adopted beams 1in. thick by 18in. deep with a 3in. bottom flange [Fig. 3 (cover)]. For the 30ft. spans with straight beams, he adopted flangeless beams 1in thick by 18-20in. deep under each rail position as shown in the author's composite section [Figs. 4 & 5]. An outer beam of 9in. or 12in. depth was provided at each side of the deck. All four beams are shown robustly cross-connected horizontally by cruxiform section cast iron bracing which, in the arches, seems barely adequate to perform the vital function of preventing side sway. The wider masonry piers at each side of the three large arches [Fig. 2] were adopted in order to accommodate endways thrust. Buttressing of the slender 3ft. wide piers carrying the straight beams was an unusual and prudent provision. In the spandrels Williamson seems to have opted for vertical struts [Fig. 3], rather than the less efficient radially orientation shown on Fig. 2. The extent to which the design may have been modified in the as-built structure is not known. The ironwork may have been made by the Shotts Iron Company who supplied Braidburn Bridge[7], the last surviving cast iron bridge on the Edinburgh & Dalkeith Railway engineered by James Jardine, which was conserved under the author's direction in 1982.

In general, the viaduct's ironwork details accorded with the traditional practice for cast iron construction which had developed over the previous half century based on experimentation and practical experience. Tredgold[7] and others introduced a degree of standardisation into the design process from 1822. Cast iron is very strong in compression and its adoption in arch form was appropriate in terms of strength and innovative in the pointed form. This concept was probably adopted in preference to low rise segmental arches in order to reduce horizontal thrust on the piers and, because of their greater depth, to add lateral stiffness. Also, the Gothic style arches, together with the timber deck railing and pier top detail with its coping and stringer course, added architectural interest to what was otherwise a very utilitarian structure.

The use of cast iron in tension in the beams and stringers, probably the weakest feature of the design, was less appropriate in strength terms than in the arch ribs, but was standard practice at the time. Modern-day calculations indicate that the viaduct would at times have been subjected to tensile stresses in excess of 4 tons/sq.in. or about twice what would now be considered acceptable. Today its design would be deemed unsafe, and yet good quality cast iron of this period is known to have resisted more than 2 to 3 times this stress before breaking and, as far as is known, the beams proved adequate. The viaduct was replaced after about 15 years not because of any known defects but because, unlike Glenesk Bridge[1], it was not practicable to adapt it for double-track locomotive operation on the Edinburgh to Hawick line in 1847.

Coming towards the close of the cast iron beam bridge era, which for beams as distinct from columns and arch ribs, can be considered generally to have ended about the mid-19th century, the viaduct cannot be considered to have exercised any significant influence on the progressive development of iron bridge-building. Nevertheless, it represents an outstanding example on a large scale of 1830 cast iron bridge technology, which was greatly beneficial to the Marquis of Lothian, road authorities and the local communities served by the *Edinburgh Railroad*.

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Acknowledgements

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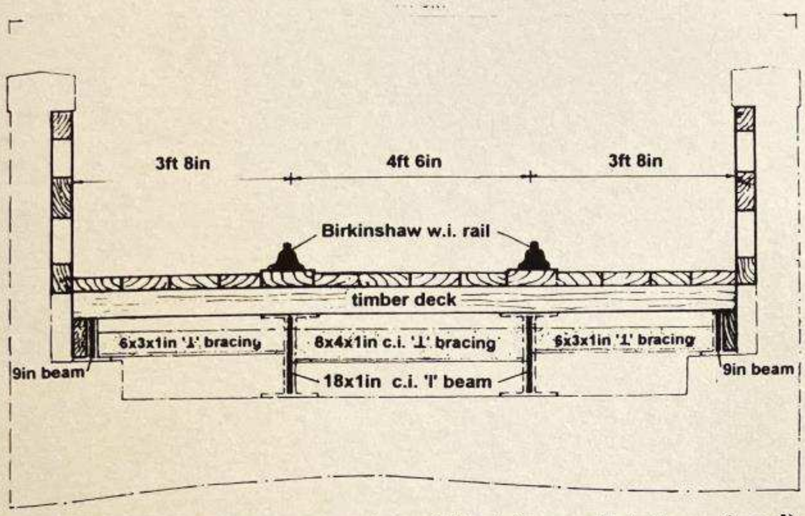

Fig. 4. Composite cross-section of deck (some details notional).

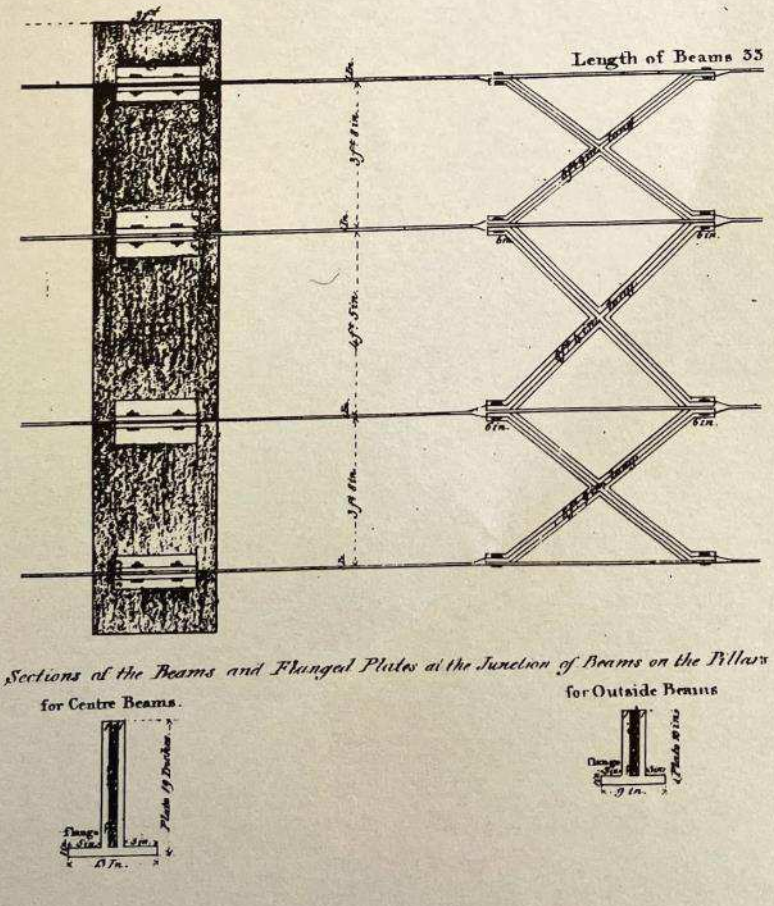

Fig. 5. Details of 30ft cast iron beam spans 1830.

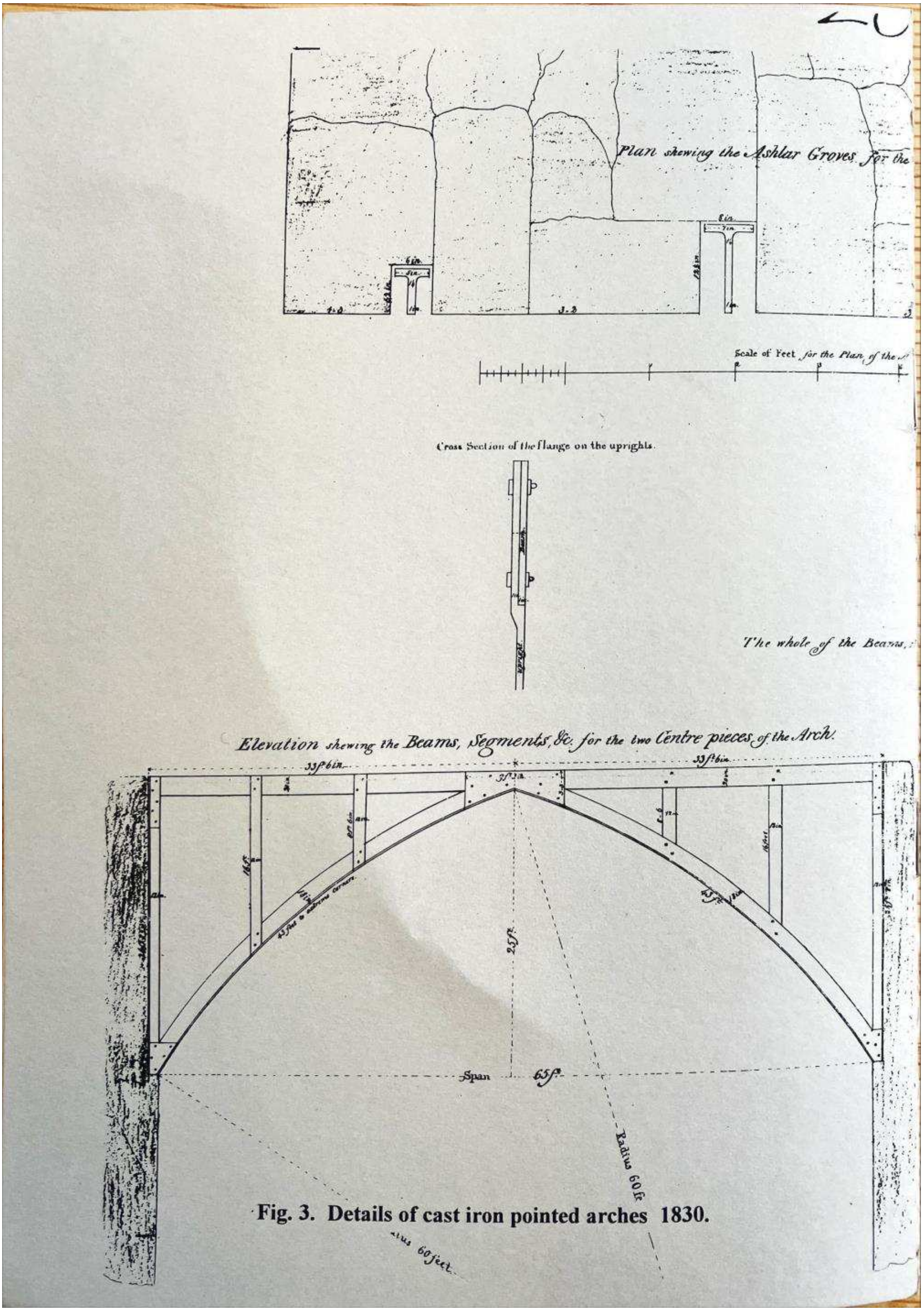

Fig. 3. Details of cast iron pointed arches 1830.