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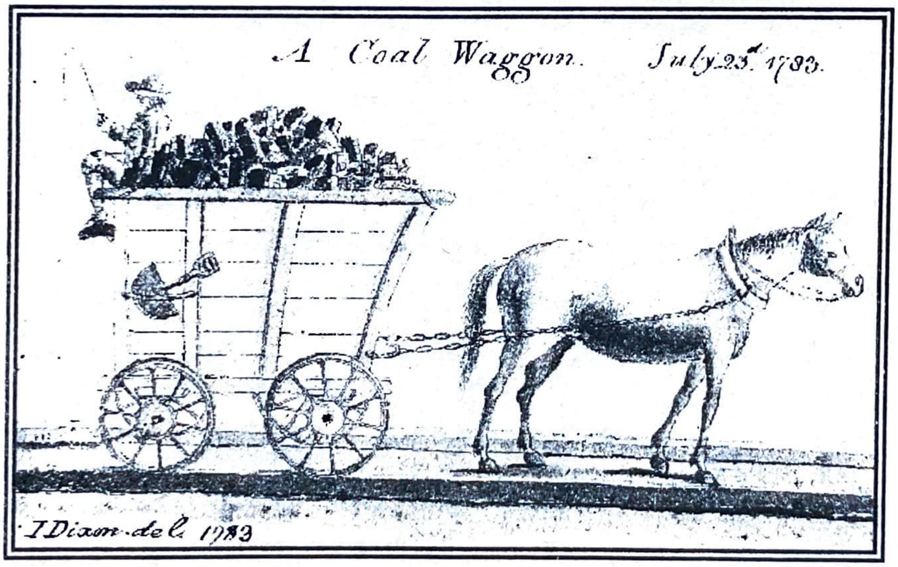

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AN ENGINEERING ASSESSMENT OF THE KILMARNOCK & TROON RAILWAY (1807-46)

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SYNOPSIS

In this paper the broad lines of the civil engineering practice employed in creating and maintaining Scotland's first public railway, the 'Kilmarnock & Troon' (K&TR), are identified and assessed. Particular reference is made to layout, profile, and plate-rail development, including the effect on the rails of steam locomotion in 1816 and the ingenious measures taken by the company's manager to counter the effect of the increasing incidence of breakages and improve in use of what was from *c*1820, an outdated type of rail. Attention is also given to the design and construction of the railway's major structure, the four-span Milton Bridge, now known as Laigh Milton Viaduct, thought to be the world's oldest surviving viaduct built under a public railway act. The findings are based on contemporary records and discoveries made during the recent £1.1m preservation of the viaduct by the Laigh Milton Viaduct Conservation Trust (LMVCT), including items of ironwork of outstanding interest and rarity.

INTRODUCTION

The K&TR which was operated by horse traction from 1811 to 1846, was described by Stevenson in 1824 as 'the only public railway of extent in Scotland. . . about ten miles in length, and laid with two sets of cast-iron tracks of the description technically described as plate-rails[1]'. The railway was created primarily to connect the Marquis of Titchfield's collieries near Kilmarnock with a 'magnificent[2]' new deep-water harbour at Troon part-constructed concurrently (**Fig 1,** page 83)[3] and by 1841 costing altogether over £150,000[4,5], now equivalent to about £40 million[6]. Both were commercially

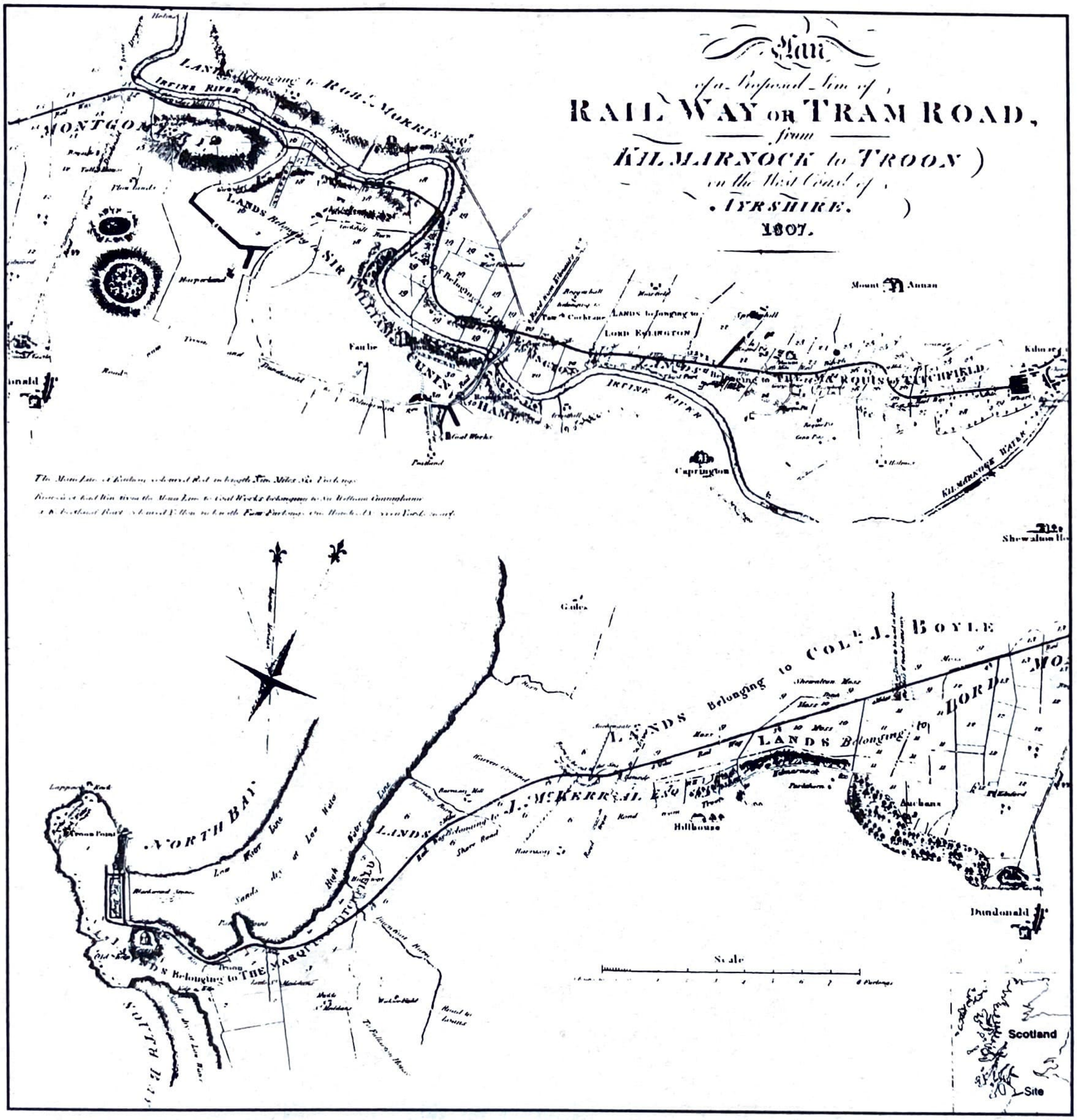


Fig 1. Location map and Wilson's plan, 1807. [J Wilson, *Plan of a proposed line of rail way or tram road, from Kilmarnock to Troon,* (1807) engraving. Also published with text in *Scots Magazine*, Jan 1812].

successful and the railway company continued in existence until 1902[7]. By 1841 they had contributed significantly to a doubling of the population of Kilmarnock[8] and the creation of the town of Troon. Both works were engineered by William Jessop (1745-1814), and after his death by John Wilson of Troon (*c*1775-1840), almost entirely at the expense of the marquis (who became the 4th Duke of Portland in October 1809).

The railway was promoted by the marquis in 1806, surveyed by Wilson in 1807[9] (**Fig 1**) and its Act of Parliament[10], together with that for the harbour, was obtained in 1808. From 1808 Wilson set out the railway and basic harbour and on their completion by 1812 managed both operations for the duke and also the extensive subsequent development of the harbour, including docks, until at least 1837, when he was listed in a directory as a 'civil engineer[11]'. He had acted in this capacity for at least two decades previously, before which he practised as a land surveyor. His earlier work for the marquis included the preparation of plans of Fullarton House and Skelmorlie estate in 1806. By 1837 the shipping trade of Troon had increased to 1,060 vessels employing 4,996 men and the port was exporting about 100,000 tons of coal annually[12].

The railway was almost certainly operational to Troon, with at least one track from the public road at Gargieston near Kilmarnock, by July 1811 and completed by July 1812[13]. In 1816, nine years before the opening of the Stockton and Darlington Railway with its locomotives and malleable iron edge rails, the K&TR had the distinction of carrying the earliest locomotive in Scotland, the first to be ordered from George Stephenson outside Killingworth[14], although not with sufficient success to replace horse traction.

Despite the drawbacks of plate-ways by comparison with edge railways, in that they required a greater tractive effort to pull the same load in the proportion of 10 to 7[15], the constant cleaning off of debris by 'surfacemen' and continual repair arising from breakages and subsidence, the K&TR still had an economic advantage of about three times over road carriage. The cost of coal cartage by road was then of the order of 8¾d to 1s 5d per ton-mile[16,17], compared with 3½d per ton-mile for the railway, of which 1½d was for dues and 2d for traction[18]. These figures accord broadly with the then generally accepted design parameters that a good horse could pull a load on the level, exclusive of the unladen weight of the conveyance, of about 1¼ tons on a broken stone road or 10 tons on a railway[19].

An advantage of the flat plate rails was that they enabled the company to accept any traffic, including carriages and carts from adjoining roads, complying with its regulations and meeting the dues. Under the company's by-laws, any traffic with flat-soled wheels not less than 3 inches wide and meeting the track gauge and weight restrictions, of not more than 2½ tons gross for waggons and 28 cwt net for carts, were allowed access to and from the railway by means of frequent 'turnouts[20]'. This convenient facility understandably encouraged a 'great deal[21]' of use, particularly by carts, but Strickland noted that they had 'a very injurious effect' on the rails 'arising from the roughness of the tire on their wheels and from the soil which adhered to them being deposited on the flat part of the rails[22].'

Unexpectedly, for what was intended as a mineral line, the K&TR turned out to be the first public railway in Scotland to carry fare-paying passengers. It is known that passengers were being carried by waggon, presumably on a tonnage basis, as early as 24 August 1811 because of a fatal accident on that date at about two miles from Kilmarnock (near Third Part Burn):

> 'The waggon was returning with a number of people from the Troon by the railway when harnessing gave way and, owing to the darkness of the night, the waggon tumbled down a precipice of seven or eight feet perpendicular. One man unfortunately was killed and some so severely hurt that their lives are despaired of[23].'

A regular passenger service by 'Caledonia' coach began on 1 May 1813[24]. By 1826 the railway, which was continuing to serve the 'fashionable sea-bathing town of Troon' over its 'handsome' Milton Bridge, had its own descriptive itinerary[25]. The amount of passenger usage in 1837-38 can be gleaned from the £88 14s 5d paid in tonnage dues which equates to approximately 200,000 passenger miles travelled in 12 months. This travel probably represented two or three return trips per day between termini, increasing to four or five trips daily in summer, a modest usage compared with freight (**Fig 2**)[26]. Coal dues alone for the same period were about 80 times greater at £7,196 11s 1d[27].

As more efficient locomotive operated railways spread nationwide in the

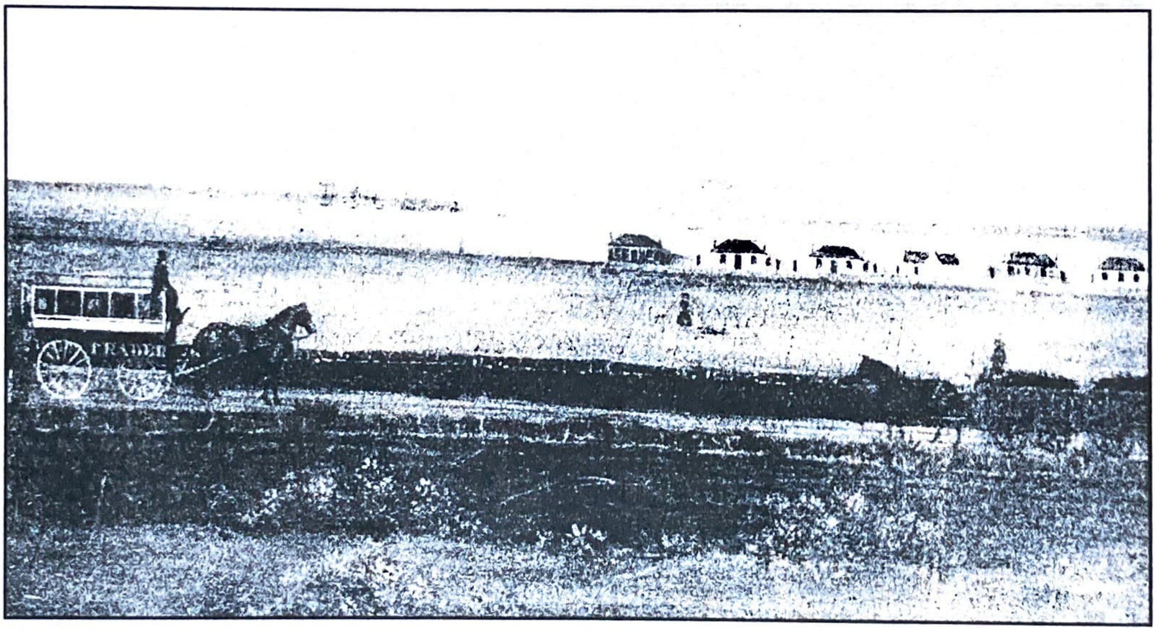


Fig 2. Passenger and coal carriage. East Ayrshire Council Museums and Arts Services. Oil painting at Dick Institute, Kilmarnock, not dated, unsigned. Courtesy EACM&AS, Kilmarnock.

late 1830s the K&TR with its slow travel and high maintenance costs, despite its continuing profitability and user-convenience, became increasingly outdated. In 1836 George Stephenson examined the line for a possible take-over by the Glasgow & Ayrshire Company and recommended that its directors should try to influence the Duke of Portland to alter and improve it by re-gauging and re-railing with malleable iron edge rails to larger curve radii[28]. A plan of this date shows a $2^1/_2$ mile length of the existing line, including the

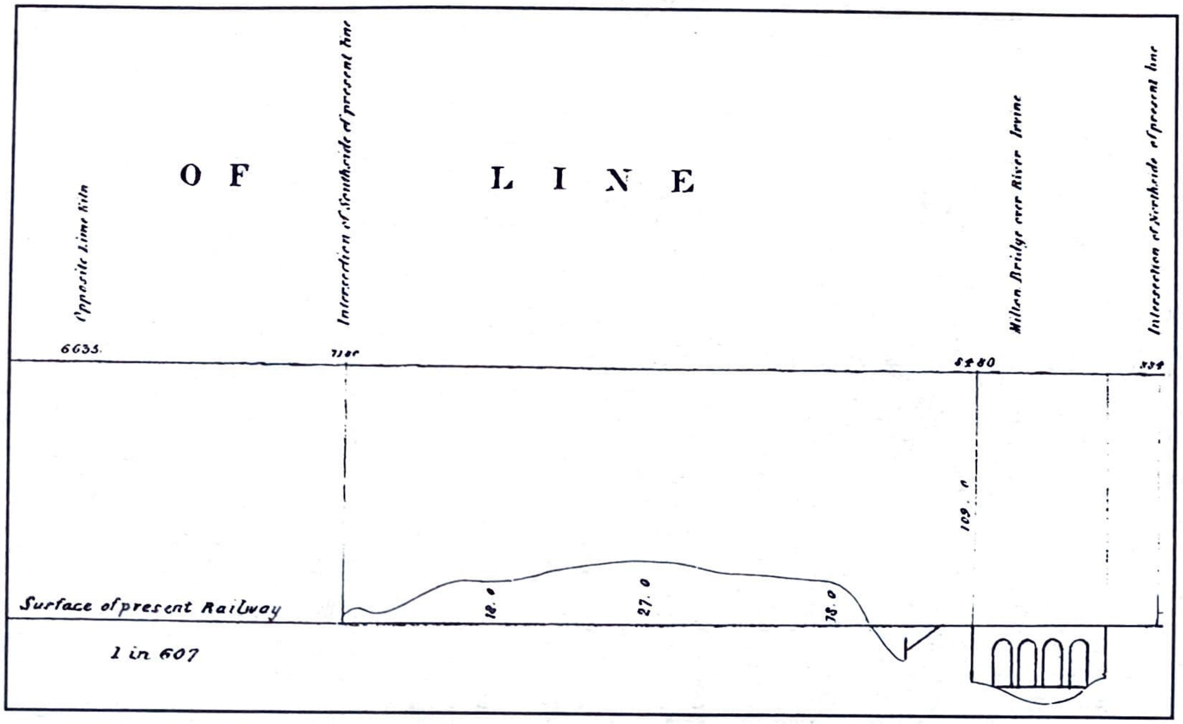


Fig 3. Laughlen's section, 1836, west approach to viaduct. Ayrshire Archives, ATD 13/14/1. And. Laughlen, Irvine. Plan of part of the present line of Kilmarnock & Troon Railway, and proposed alterations: in the parishes of Dundonald & Kilmaurs, 1836. Courtesy Ayrshire Archives.

earliest known drawn elevation of Milton Bridge **(Fig 3)**[29] and proposed curve improvements which were implemented about a decade later. This plan also shows part of the 1818 private Fairlie branch of 3 feet 4 inches gauge to Drybridge abandoned in *c*1849 with the opening of the new branch east of Gatehead. Eventually, following Stephenson's advice to avoid an expensive acquisition, the K&TR was leased by the Glasgow, Paisley, Kilmarnock & Ayrshire Railway and upgraded.

The original K&TR line was closed to most traffic on 20 July 1846[30], but Milton Bridge was almost certainly still being used by some coal traffic in November 1846[31]. By Spring 1847 the old viaduct had been abandoned, being by-passed by a timber viaduct on a curve immediately to the south, the construction of which was well advanced by September 1846[32] and which was, in turn, by-passed by the present line in 1865[33].

GENERAL DESIGN AND CONSTRUCTION

The railway, which was horse-operated, originally under by-laws of 4 November 1811 'at no faster than a walk', consisted of two, 4 feet gauge cast iron plate-ways termed 'horse paths' filled with hard angular broken stone to near the top of the rail upstands. A central 'attendants' path, said to have been

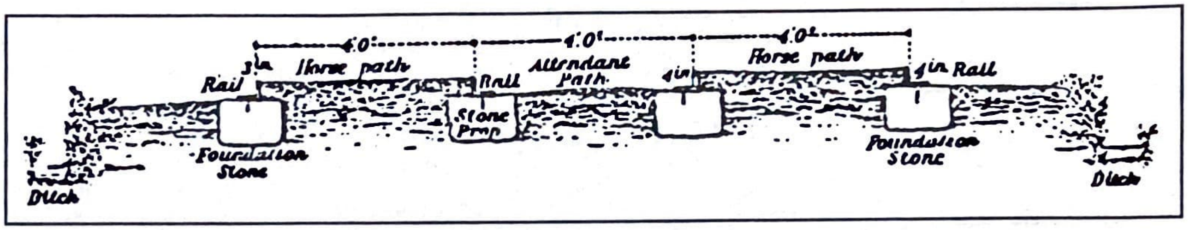


Fig 4. Cross-section c1826. W Strickland, *Reports on canals, railways*. . .(Philadelphia, 1826).

of 4 feet width was provided but, according to an informed observer William Aiton, for flexibility of operation during maintenance, 'a horse may travel in the middle space, with a wheel on the inner range of each of the roads[34]'. For this arrangement to have operated, the rails at each side of the central path must have been 4 feet apart between their lower edges or 4 feet 8 inches clear between upstands and this dimension on Strickland's cross-section is incorrect **(Fig 4)**[35].

Aiton also referred to 'frequent communications from one road to the other so as not only to admit of carriages going both ways; but to allow one carriage to pass another when both are travelling in one direction'. The railway:

> 'has been laid off, with all the skill and to every advantage which the situation of the ground would admit. The turns are not sudden or abrupt; but gentle and easy sweeps [for horse traction]. In some places the road is sunk and in others it is raised many feet above the general level of the ground . . . the whole is executed with the utmost skill and all the frugality which local circumstances would admit.'

The line passed:

> 'for about a mile through Shoalton-moss [Shewalton], which is between 30 and 40 feet deep in some places and extremely soft. Two deep drains have been cut laterally on each side of the railway and others are opened in a contrary direction; but from the extreme moist and soft quality of the moss and its tenacity in retaining water while it remains unbroken, these drains have not rendered it either dry or solid (**Fig 1** at 4 miles from Troon). Sand has been laid on the surface of the moss for several inches in depth under the blocks and rails. The greater part of the last two miles towards the harbour has been raised by embankments in some places 10 or 12 feet in height[36].'

In 1826 Strickland wrote of the railway through the moss being formed :

> 'without any other precaution than a low embankment made of sand and gravel mixed with loam. The top surface is coated over with fine coal brought from collieries in the neighbourhood and a good drain is formed on each side of the embankment, which is raised about two or three feet above the level of the moor[37]' (**Fig 4**).

Most of the engineering works of the railway, costing about £42,000[38], were constructed by direct labour under the direction of the resident engineer

Thomas Hollis, who seems to have been allowed considerable autonomy by Jessop in the work as built. Milton Bridge and the single span Dry Bridge over the Dundonald road were built under contract for £4,088 18s 1d[39], about 90 per cent of which was for the former, almost certainly by Telford's 'treasure of talents[40]' stonemason John Simpson (d 1816), who about that time was working at Ardrossan and on the Caledonian Canal. He had just completed Ballater Bridge, timber from the centering of which was probably re-used at Milton Bridge[41]. Dry Bridge bears the date 1811. Milton Bridge completed in the same year probably had a date stone which was lost by weathering.

ASSESSMENT

In terms of suitability for purpose the engineering practice adopted by Jessop and Hollis was competent at the time, economical but not particularly innovative. The rails and bridge-work will be referred to separately. An excellent feature was the adoption of a continuous inclined plane falling more or less uniformly at a gradient of about 1 in 66042 (Dupin states 1 in 56743, Stevenson 1 in 57644 and Laughlen 1 in 607 east of Drybridge — **fig 3**, page 86)[45] from Kilmarnock to Troon harbour, thus enabling a horse to draw at least three waggons, each of 13 cwt and containing about 33 cwt of coal easily down to the harbour at 3 mph and to return without difficulty against the gradient with the empty waggons. Manual excavation and embankment costs to achieve this profile were of the order of 6d to 1s per cubic yard. It is probable that this task which involved depths of in excess of 20 feet (**Fig 3**, page 86)[46] was facilitated in some sections by use of the railway. Other good design features were the double-track layout, frequent cross-overs and turn-outs resulting in a general high degree of flexibility for users, and the robust side drainage to keep the track dry and stable. The crossing of Shewalton Moss almost gave certainly a great deal of trouble and floating the railway on a raft of branches and brushwood, such as was successfully done later at Chat Moss, might have offered a better solution.

PLATE RAILS

The cast iron plate rails used were basically of the type previously used by Jessop on the Surrey Iron Railway *c*1803 and for moving earth and other materials during the construction of the Caledonian Canal. Each rail was 3 feet long with a longitudinally curved upstand increasing from about 2 inches deep above the running surface at its ends to 3 inches at mid-length and a deepening of its front edge $^1/_4$ inch below the base between the end-pads, features which added to its strength (**Figs 5 & 6**, page 89).

Conditions for rail manufacture were set out in a printed tender invitation of 1809:

'Proposals will be received by the Committee for the Management of the Kilmarnock Rail-way, for the whole, or part of 1000 tons of rails, to be delivered at the Troon, and at Kilmarnock; stating the price per ton at each place. The rails to be of the weight of 40 pounds each rail; to be cast from iron patterns furnished to the contractors by the rail-way company. Wood patterns, or any others than those provided by the company, on no account to be used.

The metal not to be run into the moulds at the ends where the rails are to be joined together; neither are air gates to be made at the ends.

The rails to be good clean castings, free from sand; the quality of the iron to be stout grey metal and open grained in its fracture.

The holes or notches at the ends to be clean and to the full size of the patterns; and so that when two rails are joined, the holes and flanges shall correspond exactly.

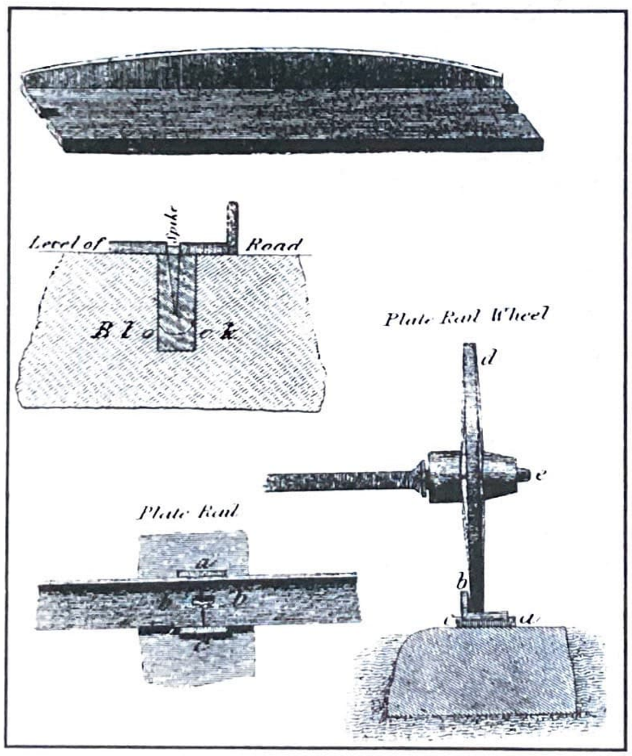
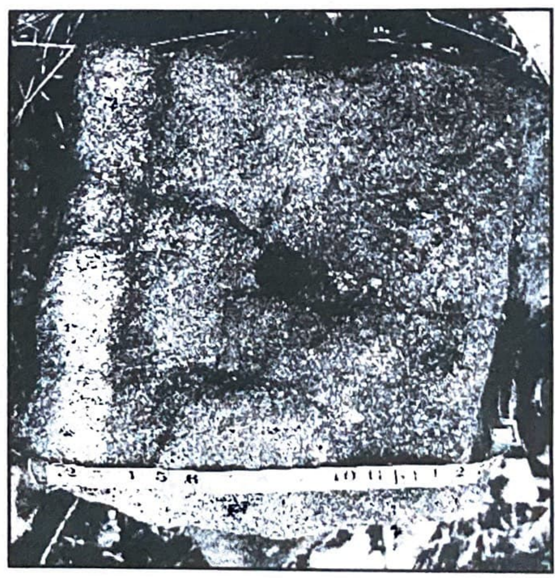


Fig 5. Plate rail details. Stevenson (bottom), R Stevenson, 'Railway,' *Edinburgh Encyclopaedia,* 17 (1830), pp 303-310, pl 477, first published 1824, **and Buchanan,** G Buchanan, 'Railway.' Supplement to the fourth, fifth and sixth editions of the *Encyclopaedia Britannica,* 6 (1824), pp 413-418, pl 115, **with minor changes.**



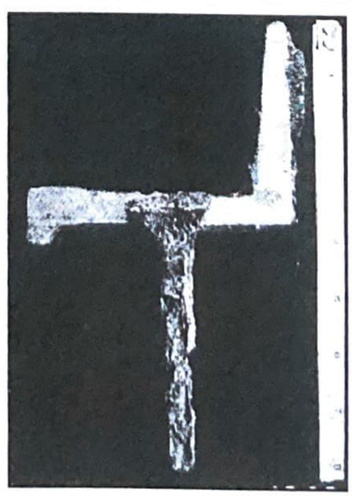


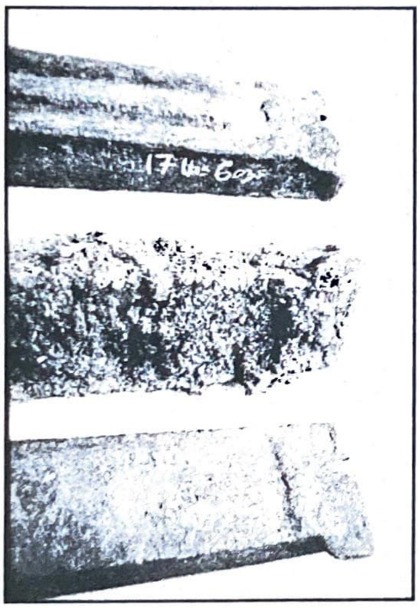
Fig 6. Whinstone block (above) and Glenbuck plate rail and spike *c*1810 found on site.

The whole of what may be contracted for, to be delivered on or before the day of . . . . in the year 1810.

The nails to be made in a bore corresponding with the two half-holes of the rails, or $1^{1}/_{2}$in wide by 1 in. at the top, and $^{7}/_{8}$ths by $^{1}/_{2}$in at the bottom of the head; to be not more than 5 in nor less than $4^{3}/_{4}$ths [*sic*] long.

The nails on no account to have a flash on the head, but made so that the nails will fill the hole without being above the surface of the rails[47].'

The Kilmarnock Foundry tendered for making and delivering the above rails at £12 per ton, the Clyde Iron Co at £11 per ton, David Smith, Airdrie at £11 per ton with discount 2s 6d per ton cash on delivery, and the Glenbuck Iron Co [near Muirkirk] at £10 7s 6d. The Glenbuck tender was accepted and by 1813 this company had been paid £13,345 8s 8d for about 72,000 rails[48] (**Fig 6,** page 89). Each rail therefore cost about 3s $8^{1}/_{2}$d. In addition, Jessop supplied cast iron costing £1,000 which may have been for rails. From 1815 almost identical rails with the word 'Kilmarnock' on the underside of the casting from



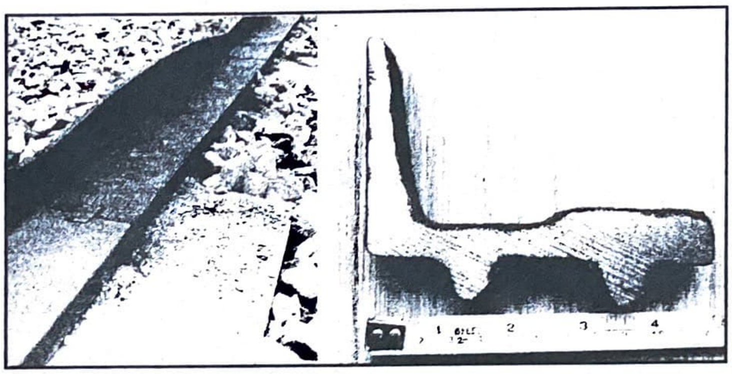
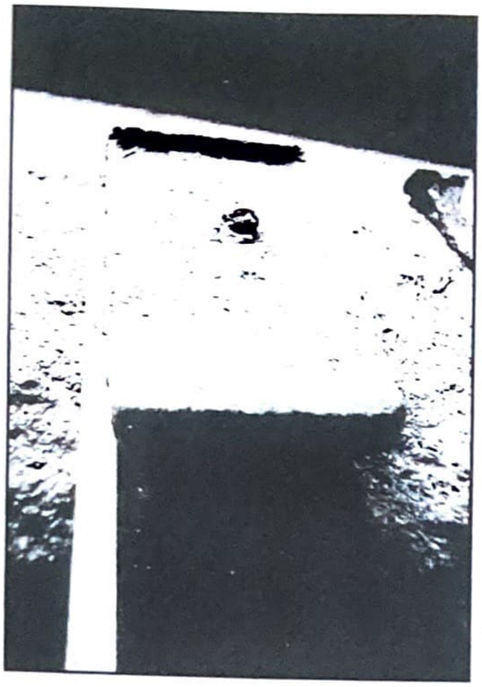


Fig 8. (above). Right, Kilmarnock Foundry rail c1818 with Wilson's underside 'feathers' (mid span); left, replica rails at viaduct made from original rail as a pattern

Fig 7 (left). Rails with 'feathers' as found (centre) and Caledonian Canal (bottom).

the Kilmarnock Foundry began to be used as replacement rails.

A study of the K&TR records indicates a considerable increase in the incidence of breakages for the year from September 1816, which seems to have induced Wilson to introduce a rail 'with a small improvement by myself . . . having two feathers on the under side . . . not so liable to break . . . adopted in all our renewal of rails[49]' (**Figs 7 & 8**). In **fig 7** a 'Jessop' type rail from the Caledonian Canal works *c*1810 is shown for comparison purposes. It is similar to the Glenbuck rails but without any deepening of the front edge. By March 1819 replacements from Kilmarnock Foundry and weighing 38-40 lbs were



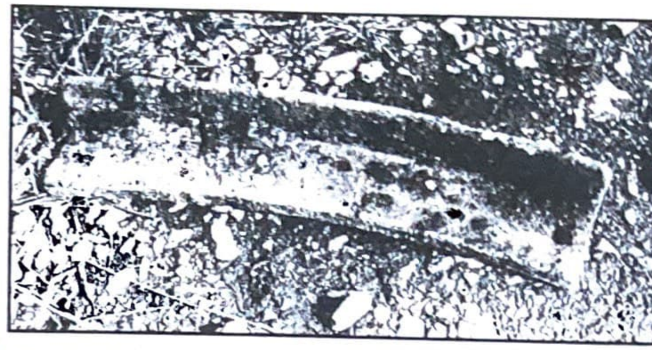
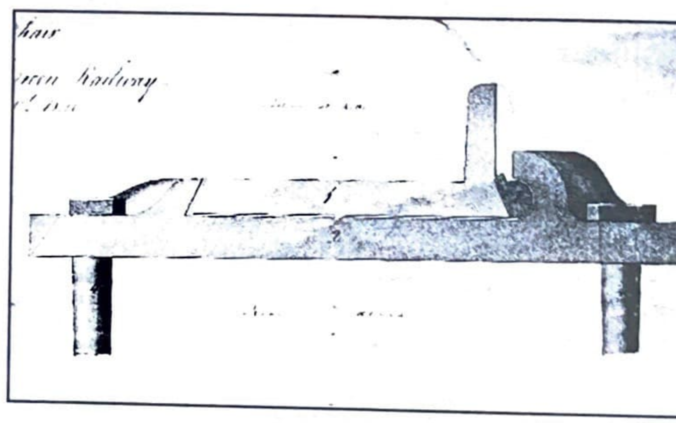


Fig 10 (above). Four feet diameter curved plate rail, found on site.
Fig 9 (left). Wilson's saddle, spike and block, all found on site.
Fig 11 (below). Malleable iron rail in use by 1840. EACM&AS, Dick Institute, Kilmarnock, 'Plan and section of rail and chair used on the Kilmarnock & Troon Railway, March 1840. Courtesy EACM&AS, Kilmarnock



costing about 3s 2d[50]. By 1824 Wilson had also introduced a 6¼ inches by 4¼ inches cast iron saddle ¾ inch deep with ½ inch wide by ¼ inch deep upstands along the narrower edges to retain the rail ends, between the top of the stone block and the foot of the rail, which 'kept the joints even and in their places[51]' (**Figs 5, bottom,** page 89, & **9**). The saddle was found with a 4 feet radius plate rail with 2 inches upstand and a hole near one end (**Fig 10**) and other items in the river bed just downstream of the viaduct.

Later developments were the use of cast iron rails in 6 feet lengths, which made 'a better road than the 3 feet rails still the breakage is considerable[52]' and, by 1839, the introduction of malleable iron plate rails, probably in 15 feet lengths and supported by stone blocks. Some malleable iron rails were laid on timber in 1840 which were 'still fresh and good' in 1842[53]. Rails of this type were laid on the viaduct in 1845. No surviving rails are known, but details are given on a drawing of 1840 (**Fig 11**)[54]. During laying, rails were secured in place at each end by means of the tapering head of the malleable iron nail described in the above tender document (**Figs 5 & 6,** page 89). The nail was driven into an oak plug within an 1½ inches diameter hole 5 inches deep in a stone block made of either whinstone or freestone. The block generally measured 12 inches to 14 inches square and from 8 inches to 10 inches deep (**Fig 5,** page 89). The ground beneath each block was 'beat solid and the stones are also beat down[55]'. Wilson provided some interesting rail-laying costs in 1818:

> 'we are at present getting [the rails] done and laid down at £10 per ton 38 to 40 lb. weight . . . stone blocks cost for boring and finding in the quarry 5 d each [excluding transport]. The laying of the rails and blocks was done by estimate at 5 d each double yard, that is [with the] pair of blocks [and] all materials being laid to hand. A cubic foot of oak wood for which we pay about 3 s per foot makes eleven or twelve plugs and they are made for $3^1/_2$ d per dozen as we have a machine for the purpose. The nails were made including iron at 6d per lb. Now I generally find the bar iron and I get them made for $1^1/_4$ d per lb[56].'

An estimate of *c*1839 for lifting and relaying 5 furlongs (1100 yards) of double track in malleable iron was £2,529 8s, almost equally divided between labour and materials. For the same length of line using 6 feet cast iron rails, and free-stone blocks (with two holes and larger than those used with 3 feet rails) costing 1s 3d each instead of granite at 2s, the estimate was £2,080 8s. Both estimates were after deduction of £250 scrap value for the broken rails, which was about 40% of the cost of new rails. In both cases the use of 80 tons of rails weighing 40 lbs/yard was envisaged and estimated to cost £800 and £600 respectively for malleable and cast iron[57].

ASSESSMENT

The use of 'Jessop' type plate rails, crude and inefficient as they may now seem, and a dead-end in terms of the progressive development of the modern railway rail, was standard practice although by no means innovative by 1809. However, the rails did make a fundamental contribution to the transport and economy of the locality, although at an ever increasing maintenance cost and an incompatibility with steam locomotion. The breakage of the cast iron rails was a worsening problem as indicated by annual replacement costs which had increased nearly ten-fold, from £163 in the financial year 1817/18 to £1,520 in 1839/40[58], although their prime cost was more or less the same. Apart from this and the constant removal of debris drawbacks, the short rails requiring support blocks every three feet which exerted a pressure under load of about $^3/_4$ ton/sq foot on the earth, must often have resulted in track undulation to the detriment of traction. An effective feature of the track was the method of joining the ends of adjoining rails by means of the tapering nails and notches. In mock-ups using the rails and nail discovered on site, and in the replica track on the viaduct (**Fig 8,** page 90), this arrangement resulted in a very firm and well aligned joint.

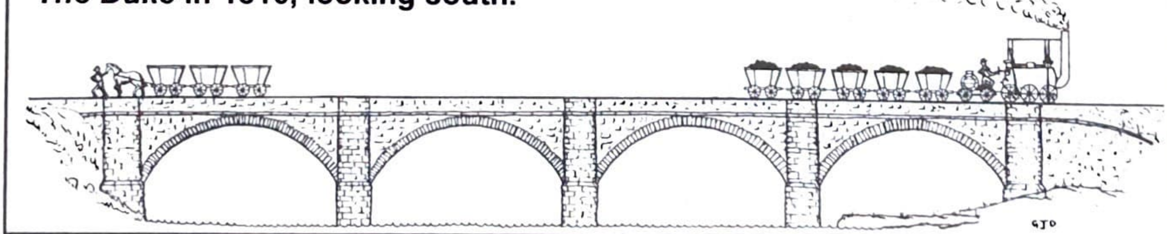
By 1821 Wilson would have been well aware of the improved traction, strength and consequently maintenance advantages of adopting the longer

Fig 12. Texture of Glenbuck plate-rail (X50). The dark area is a shallow cavity. High phosphide ore would have been used, hence the eutectic phosphides `and susceptibility to microporosity.
Courtesy Ballantine Boness Iron Co Ltd.

malleable iron edge rails capable of accommodating the primitive steam locomotion then available but, as the K&TR track had accounted for nearly half of its engineering cost, it would have been an impracticable economic proposition. As well as the high cost of track replacement, the rolling stock would have required modification and much of the common road traffic would have been lost, all for what would then have been a small advantage.

With the epoch-making development of locomotives and railways which occurred during the following decade this situation changed and the advantages of a complete overhaul of the line eventually became overwhelming. Wilson's efforts to make the most of the original concept, even to the introduction of malleable iron plate rails, although worthwhile, were only marginally effective when considered against the scale of the problem. The rail in **fig 8,** (page 90) provides an example of the usefulness of his 'feathers'. This rail, which is very worn by wheels $1^1/_2$ inches wide (so much for the regulations), would almost certainly have broken sooner without this improvement. In an attempt to obtain an indication of the composition and strength of an original rail from Glenbuck, a test was carried out by the author in conjunction with Ballantine Boness Iron Co Ltd. The sample tested consisted mainly of graphite iron with 3.9% carbon, 1.3% silicon, 0.8% magnesium, 0.7% phosphorus and 0.6% sulphur (**Fig 12**) and yielded a stronger than expected ultimate tensile strength result of 168 n/sq mm (10.7 tons/sq inch).

Fig 13. Conjectural view of Milton Bridge and *The Duke* in 1816, looking south.



STEAM LOCOMOTIVE TRIAL 1816

In late 1813 the Duke of Portland considered but did not proceed with the purchase of a Blenkinsop locomotive to haul coal from his collieries[59], but in 1816 he is understood to have bought a Stephenson Killingworth-type locomotive with six, flat-soled wheels, each with steam piston springing, in order to spread its weight[60] (**Fig 13,** page 93)[61]. The engine was appropriately named *The Duke* and, according to eye-witness John Kelso Hunter, its trial was conducted by Robert Stephenson[62], George Stephenson's brother — not, as mistakenly assumed by Highet[63], his son Robert who would then have been only 13 years old. It is recorded that the engine 'from its defective construction and ill adaption to the rails drew only ten tons at the rate of five miles an hour[64].' Its central chain-drive cog-wheel transmission occasionally caught on high sections of the horse path and caused bending of its axles and wheel connecting rods[65]. According to George Buchanan in 1831, the locomotive had 'succeeded well' but was given up on account of its destructive effect on the cast iron rails although its weight was only five tons[66] [or 7$^1/2$ tons[67]]. It is understood that on conclusion of this trial no further attempt was made to introduce steam power on the railway[68]. The engine is said to have been sold in 1848 for £13. Thomas[69] states that it remained in use from its introduction until 1848 but this is unconfirmed.

ASSESSMENT

The load hauled by the locomotive was little more than that pulled by a good horse, although at about twice the velocity, advantages more than outweighed by the considerable costs involved, not least for the replacement of broken rails. Horse traction continued. Modern calculations indicate that a wheel load of 1.7 tons, which would have been easily achievable at times with the primitive locomotive's hammer-blow effect and rocking, would have been sufficient to break a rail in shear near the edge of a block. The same rail without adequate support between blocks would probably have broken in bending with a 2 ton load. Of five broken rails found, all were broken from 5 inches to 12 inches from one end.

For many years the date of this trial has been a matter of uncertainty, 1816, 1817 and 1820 having been cited[70]. A study of railway company payments to the Kilmarnock Foundry for replacement rails and castings revealed a significant increase in expenditure from September 1816, indicating that the locomotive was probably in use by then (**Fig 14,** page 95)[71]. Its duration in use is not known although the histogram suggests less than a year. If the locomotive had been operational in the summer of 1817 it would almost certainly have been noted by Dupin on his technological fact finding tour of

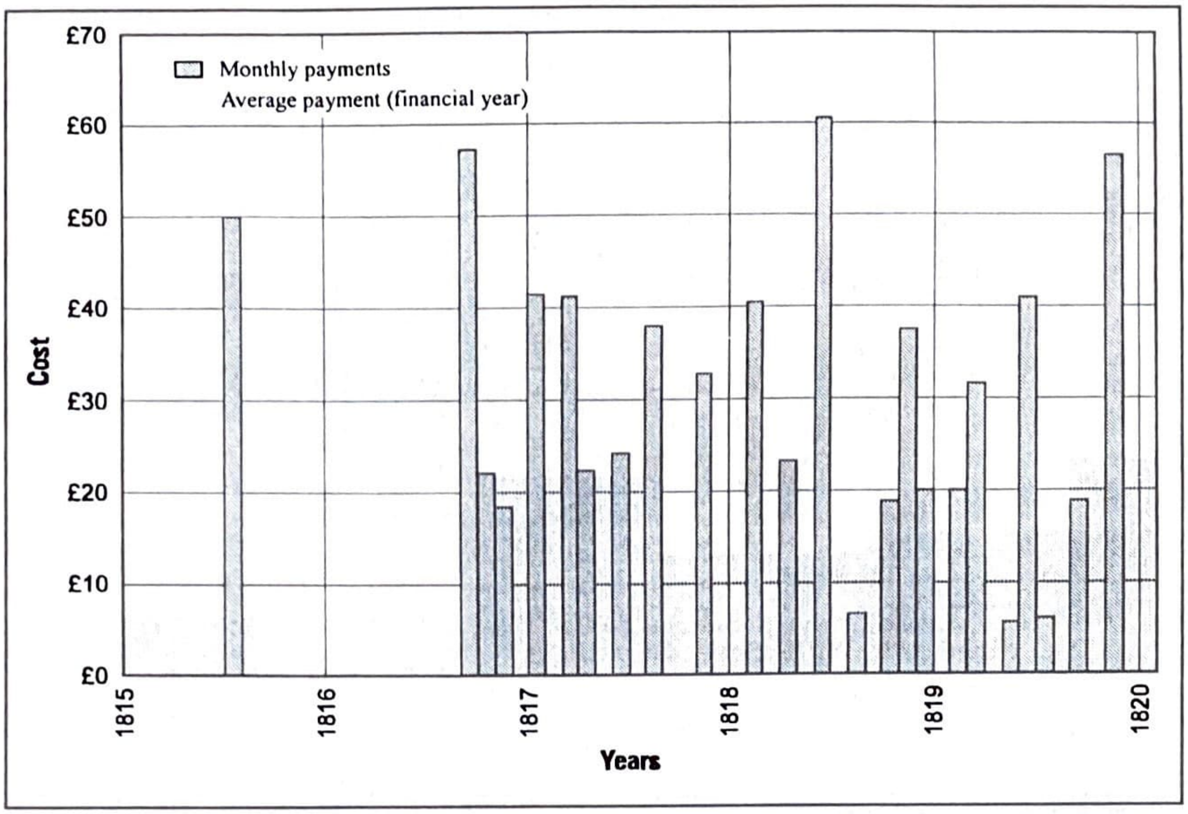


Fig 14. Payments to Kilmarnock Foundry for replacement rails and castings 1815-19.

Britain. He was impressed by the railway's passenger carrying role noting 'diligences on the railway which conveyed the idea of an enormous wandering vehicle drawn without difficulty by a single horse[72]'. Another version reads 'the stage coach has four iron wheels; it is like a caravan and drawn full of passengers with only one horse[73]'.

LAIGH MILTON VIADUCT DESIGN AND CONSTRUCTION

The viaduct, which is about 270 feet long and 19 feet wide overall, carried the railway about 25 feet above the river on four 40 feet span freestone arches with 9 feet wide piers. Each arch is of segmental elevation with a rise of one third span and with 2 feet deep arch rings (**Fig 13,** page 93). The approaches have curved wing walls. No evidence was found that parapets ever existed. In the absence of any drawings or specification the preservation work provided a valuable opportunity to study the viaduct's construction. The main findings were that:-

1. The piers were constructed in cofferdams because agreement could not be reached to dewatering the site by temporarily dismantling Milton mill dam.

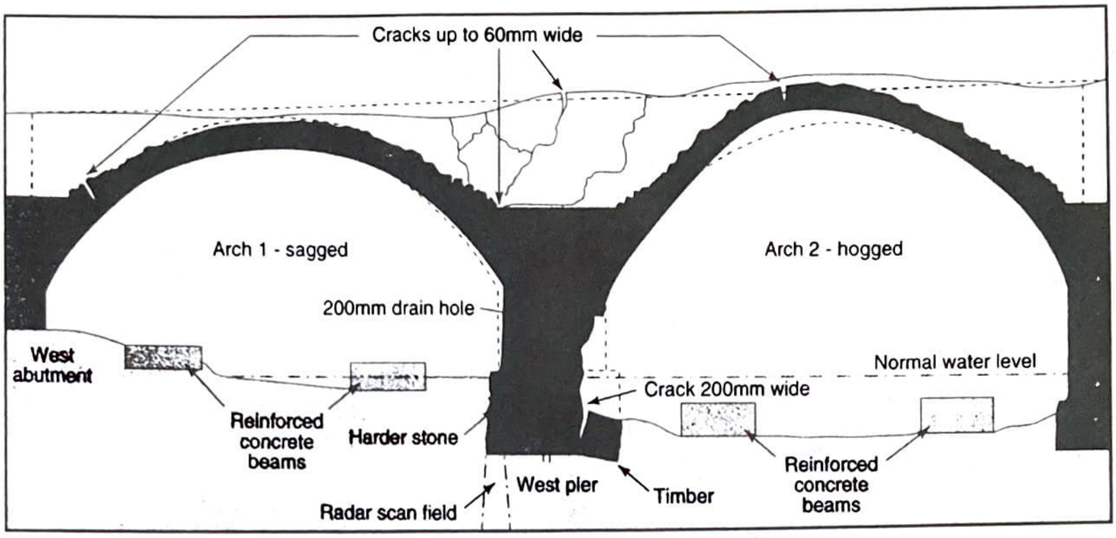


Fig 15. Section of west pier and adjoining arches without spandrel fill — looking north

It was thought that cofferdams would add 'very little more expense' with the advantage 'that the stones for the bridge [from nearby quarries — possibly Third Part, authorised in March 1810 and Gillburn] can be floated down [from near the mill] on a punt[74]'.

2. The west pier is founded on a 5 inch-thick timber platform of hard wood at a depth of about 6 feet below normal river level resting on sand, gravel and weathered bedrock (**Fig 15**). The timber is saturated but hard and continues in use (**Fig 16,** page 97). Probably the other piers are similarly founded. The poor quality local freestone had eroded more than a foot at and near water level at all piers, and more at the west pier, but the foundation courses proved to be of hard stone in generally good condition which greatly facilitated the viaduct's preservation (**Fig 17,** page 97).

3. The internal pier hearting consists of thinnish flat stones bedded and set in lime mortar and carried up to about 5 feet above the arch springings. This was an effective, traditional feature which had probably saved the structure from collapse (**Fig 18,** page 98).

4. The spandrels consist of coursed rubble masonry, gravity acting, retaining walls each running the full length of the viaduct and varying from 1 foot wide at the top by a series of steps internally to 3 feet 6 inches wide at a depth of 9 feet, above the piers where the distance between the wall faces is 12 feet (**Fig 19,** page 98). These steps were lined up by means of malleable iron pins one of which was found in the top of the west arch (**Fig 20,** page 99). The walls simply rest on the extrados of the undressed arch-stones without any lateral support except for any buttressing effect from the bullnoses.

5. That the internal spandrel drainage provision consisted of a pair of 8 inches diameter holes through the hearting of each pier down to or below water level.

6. That the cavity between the spandrel walls had been filled with a stiff clay containing some gravel and resembling boulder clay which had contributed to spandrel bulging. During the removal of vegetation a layer of small broken stone was found at about former track level, presumably the horse attendants' path. Three broken plate rails were also found at this level.

7. The different elements of masonry work were not very effectively tied together, for example, the pier bullnoses to the spandrels, and between the spandrel walls. Some bulging and loss had occurred particularly to the south spandrel wall (**Figs 19**, page 98 & **21**, page 99).

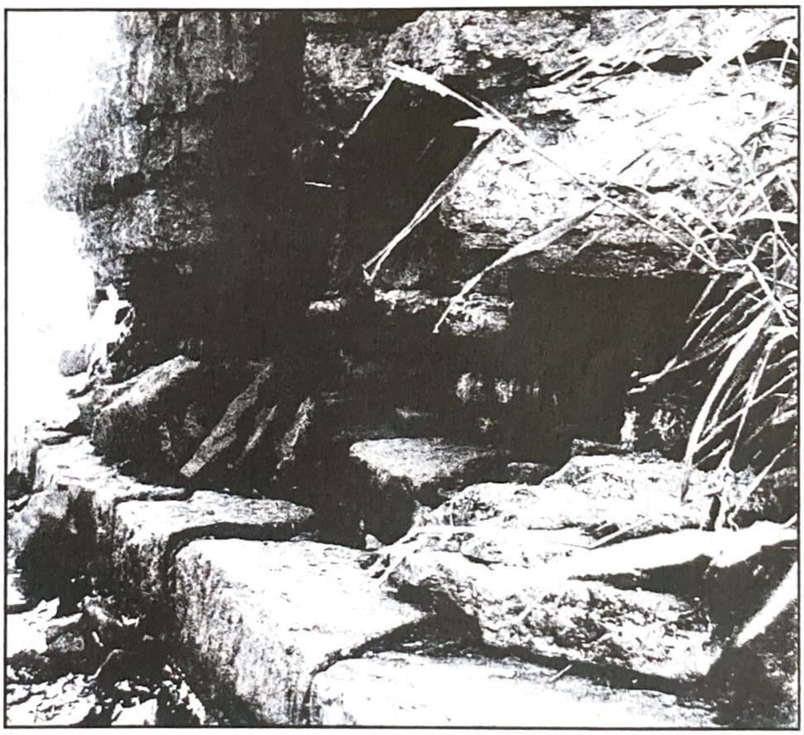


Fig 16 (top). West pier — edge of 5 inch thick timber foundation.

Fig 17 (bottom). East pier foundation — looking south showing base of harder stone

8. The loss of up to several inches of masonry from much of the external facing of the viaduct occurred because of the use of minutely fissured local freestone which had deteriorated through weathering.

Fig 18 (top). West pier, east side — erosion into lime-mortar-bedded hearting
Fig 19 (bottom). South 'stepped' spandrel wall and undressed extrados of arch

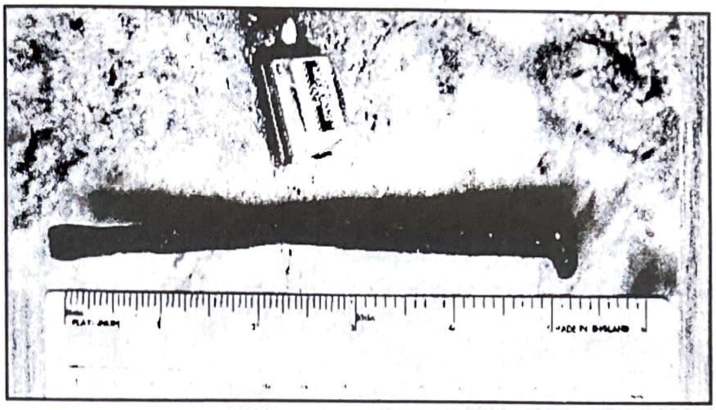
CONCLUSION

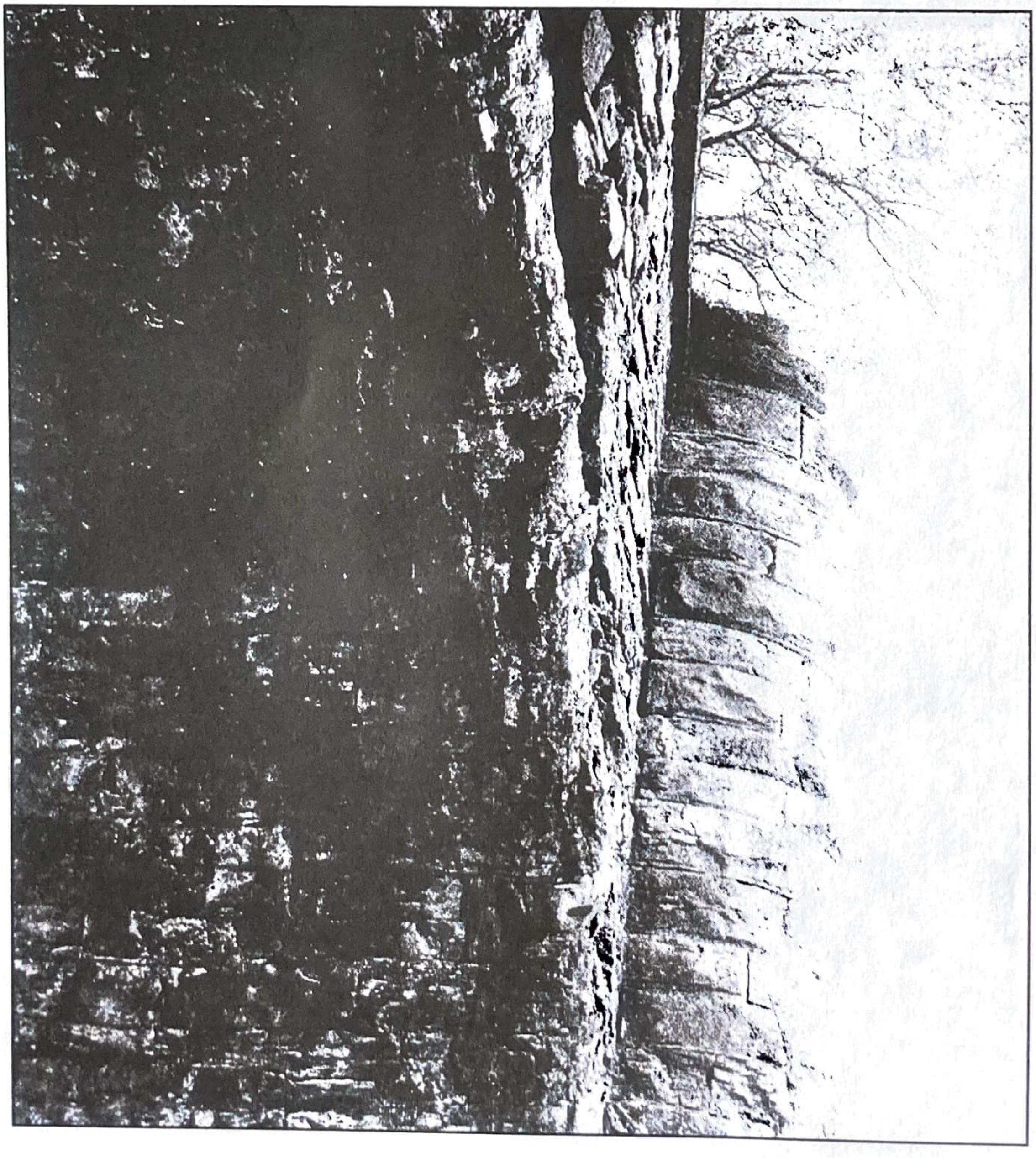
That much of the present railway follows the line and level determined by Jessop and Wilson is a useful and welcome legacy to posterity, but the most significant survivor of the original K&TR is the viaduct. Its outstanding historical significance rests on its association with Scotland's first public railway and its beneficial impact on society, the eminent Jessop, its use by Stephenson's locomotive in 1816 and in being the earliest surviving viaduct built under a public railway act. The structure was not on a particularly large scale for its date and its functional and economical design and construction followed normal late 18th rather than the most advanced early 19th Century practice.

In terms of its design and construction the via-

Fig 20 (right). Five inch wrought iron lining-up pin at top of west arch *in situ* and after removal.

Fig 21 (below). East arch, north side, showing crumbling masonry and bulging spandrels





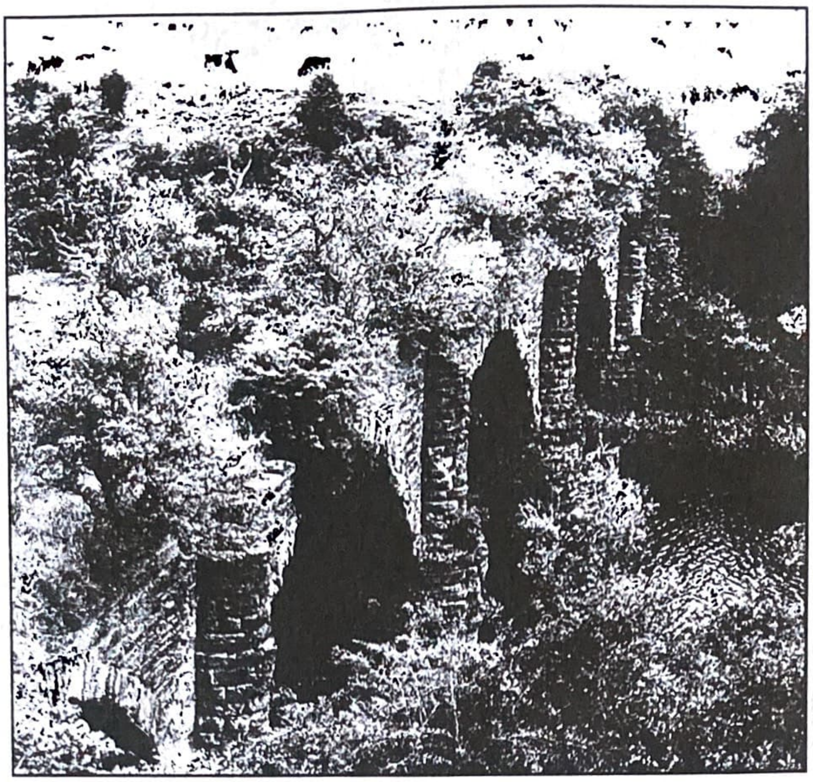


Fig 22. Viaduct in imminent danger of collapse, 1992

Fig 23. Conserved viaduct at re-opening on 29 October 1996

duct can be considered commensurate with Aiton's general assessment for the railway of a combination of frugality and skill, with just enough of the latter to barely survive one and a half centuries of neglect. The viaduct is now fittingly preserved as closely as practicable to its original 'handsome' state (**Figs 22 & 23**).

ACKNOWLEDGEMENTS

To Mr John Kelly site agent for Barr Construction and the firm's workmen for their diligence and interest in finding historic items and bringing them to the author's attention, including those shown in **figs 6,7,8,9,** and **20**. These artefacts are now preserved and displayed as part of the Institution of Civil Engineers museum in Scotland at the Civil & Offshore Engineering Dept, Heriot-Watt University, Edinburgh. To the organisations and persons mentioned in the notes and captions for generously making information available.

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