Conservation of the 1811 Railway Viaduct at Laigh Milton, Scotland*

by Roland Paxton**

Laigh Milton Viaduct over the River Irvine three miles west of Kilmarnock was the major structure on the first public railway in Scotland, the 'Kilmarnock & Troon', which was engineered for horse traction and operated from 1811-46. The four-span viaduct, designed under the direction of eminent engineer William Jessop (1745-1814) and believed to be the world's oldest surviving example of its type, is class A listed by Historic Scotland. From 1988, after nearly 150 years of neglect, the structure was twice reported by structural engineers to be in imminent danger of collapse. In February 1992, with a view to obviating this unwelcome probability, a Conservation Project was initiated by the ICE Panel for Historical Engineering Works with essential support from others and subsequently raised the necessary £1.06m for the viaduct's refurbishment. Work started last June and is due for completion by November 1996.

The paper commences with an introduction on the historical significance and use of the railway and viaduct, illustrated by a newly-composed operational view depicting steam locomotion in 1816, an account of the development of the iron plate rails used from 1809-46, and identification of August/September 1816 as the probable time that the first use of steam locomotion was underway on a Scottish railway. A reasoned account of the Conservation Project and its objectives, strategy and *modus operandi* from the Secretary's standpoint then follows, with particular reference to administrative, ownership, contractual, funding, accessibility and planning matters. The paper concludes with the author's findings and comment arising from past and present work at the viaduct, including innovative investigation by radar scanning.

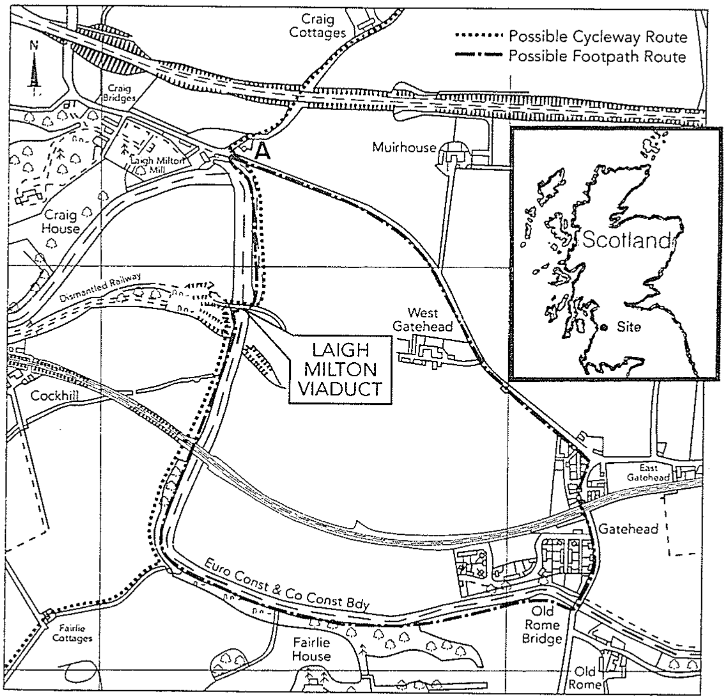

Fig. 1 Location plan - public access from road at A.

*Keywords : conservation, preservation, Laigh Milton, Scotland, viaducts, civil engineering, railway, history, radar scanning, iron rails, ICE-PHEW.

**MBE, MSc, CEng, FICE, FRSE, AMCST; Hon Professor, Civil & Offshore Eng., Heriot-Watt Univ., Edinburgh; Chairman, ICE Panel for Historical Engineering Works; Member of Royal Commission on the Ancient and Historic Monuments of Scotland; Secretary and Director, Laigh Milton Viaduct Project.

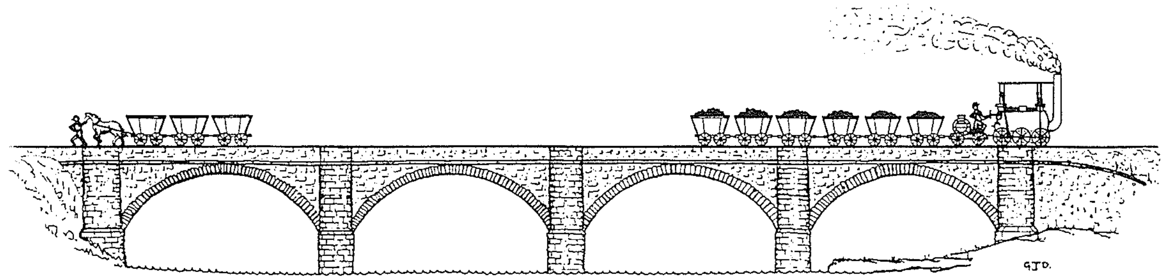

Fig.2 Conjectural view of Milton Bridge in 1816[9] looking south.

1. INTRODUCTION

(1) General

The Edinburgh civil engineer Robert Stevenson wrote in 1824 that 'the only public railway of extent in Scotland is that between the manufacturing town of Kilmarnock and the harbour of Troon; which, agreeably to act of parliament, is open to all on payment of a certain toll[1] (Fig. 1). This approximately 10-mile (16km) long, horse-hauled, double-track, iron plate-way completed in 1812 and the 'magnificent'[2] harbour at Troon with which it connected, were the work of one of Britain's most eminent early engineers William Jessop (1745-1814). These improvements, which played a fundamental part in the development and prosperity of the locality, led to a doubling of the population of Kilmarnock and the creation of the town of Troon from where before had been only some saltpans and an old smuggling inn. They were constructed from 1808-12, almost entirely at the expense of Kilmarnock's patron the Marquis of Titchfield (who became the 4th Duke of Portland on the death of his father in October 1809) and eventually cost over £150,000[3]-[5]. The improvements were created mainly to transport the Duke's coal from the Kilmarnock area[6]. In addition to its usefulness in carrying freight, the Kilmarnock and Troon Railway, or Troon Railway as it was sometimes called, had the unexpected distinction of becoming Scotland's first, and one of the world's earliest, public passenger-carrying railways. By 1826, according to 'Duncan's Itinerary of Scotland' the railway was serving the 'fashionable sea-bathing town' of Troon and its bridge over the Irvine was dubbed as 'handsome'. The railway is also of considerable historical interest in that it operated with a travelling steam engine hauling coal as early as 1816, although not with sufficient success to enable steam locomotion to replace the use of horse-traction on the line (Fig. 2)[7][8][9].

(2) Horse traction railways

The horse-traction railway or tram-road era in Britain reached its zenith in the third decade of the 19th century and thereafter declined to its demise c.1845 as steam locomotion led to the universal development of much more efficient railways following its proven success on the Liverpool and Manchester Railway from 1830. Nevertheless, for many years horse-powered railways, of which Jessop was in 1808 a leading national exponent, being from 1801 engineer for the world's first public railway in Surrey, made a significant contribution to the British economy and way of life. Their advantage over other modes of transport operating before 1830 can be readily appreciated by considering the traction achievable by a horse moving at 2½ mph (4kph) on the level. Exclusive of the unladen weight of the conveyance, a good horse could pull about 1¼ tons on a broken stone road, 10 tons (10.2 tonnes) on a railway or 30-45 tons on a canal[8] (30.5-45.7 tonnes).

If capital funding of some £3000-£5000 per mile (£1875 - £3125 per km) was available to finance the construction of a double-track railway, as was the case with the Marquis of Titchfield and the 'Kilmarnock & Troon', the cost of transporting coal from pit to harbour by rail could be reduced to about one-third that of a tedious 7-mile (11.2km) cartage by road to Irvine. The cost of coal cartage by road was then of the order of 8¾d - 1s 5d (3.6p - 7.1p) per ton-mile[10][11], which can be compared with 3½d (1.4p) per ton-mile for using the railway to Troon harbour, made up of traction costs and dues at 1½d (0.6p) and 2d (0.8p) per ton-mile respectively. It is recorded that 'His Grace wanted neither the public spirit nor the means of carrying (these improvements) into effect'[6].

(3) The Kilmarnock and Troon Railway - General

The railway was being actively promoted in 1806[12][13] and was constructed more or less concurrently with Troon Harbour under two acts of parliament passed on 27 May 1808 [14]. By 1814 construction costs of the railway had escalated to nearly £60,000, or about £6,000 per mile (£3750 per km) against Jessop's estimate of about £38,000[11]. Its engineering works are believed to have cost about £42,000[15]. The Marquis of Titchfield purchased 74 of the 77 shares originally issued by the company[16]. This proved to be a good investment for him as the venture was commercially successful for most of its 91-year existence[11]. Although completed in 1812, some accounts give its date of opening as 6 July 1812[17], the railway began to operate in 1811. It is known that passengers were carried from as early as 24 August 1811 from the record of an accident on that date to a conveyance from Troon which had passed over the viaduct to a point about 2 miles (3.2km) from Kilmarnock when, because of a harness giving way, it tumbled down

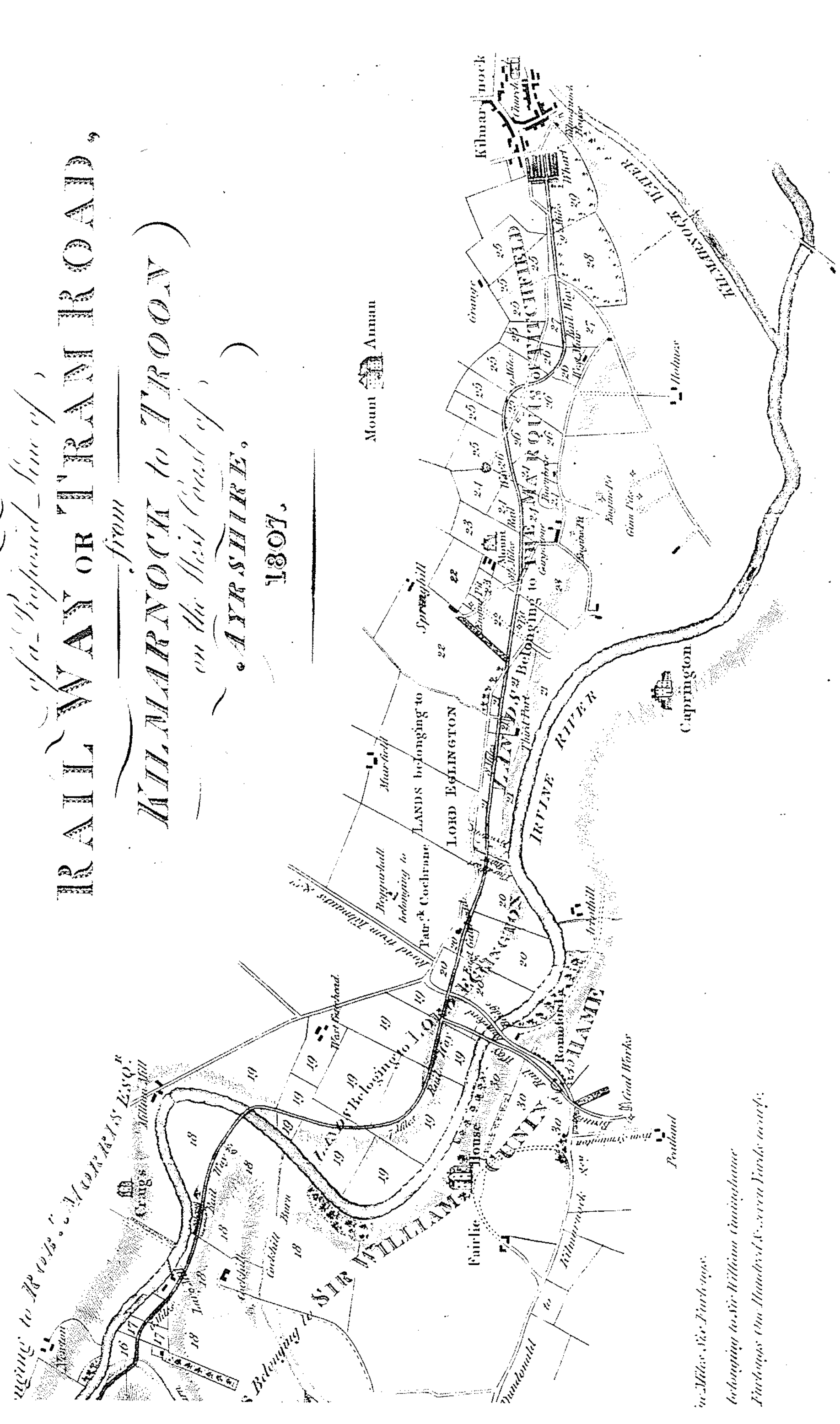

Fig. 3 Part of plan of Kilmarnock & Troon Railway, 1807.[20]

'seven or eight feet perpendicular'[18]. One man was killed and several persons were severely injured.

(4) Overall design of railway

The railway consisted of two, 4ft (1.2m) gauge, cast iron plate-ways throughout its 9¾-mile (15.7km) length and was horse operated originally under by-laws of 4 November 1811, 'at no faster than a walk'[19]. A 4ft (1.2m) path was provided between the plate-ways and the overall width was 19ft (5.8m) (at the viaduct). The line of the railway and the location of the proposed harbour and dry docks at Troon were surveyed in 1807[20] (Fig. 3) presumably under Jessop's direction, by John Wilson, who later managed the railway. The vertical profile adopted by Jessop for the railway was a continuous inclined plane falling uniformly at a gradient of about 1 in 660 from Kilmarnock to Troon Harbour, thus enabling a horse to draw at least three wagons, each of 13 cwt (0.66 tonnes) and containing about 33 cwt (1.67 tonnes) of coal, easily down to the harbour at 3 mph (4.8km) and to return without difficulty against the gradient with the empty wagons[1]. Excavation and embankment costs to achieve this profile were of the order of 6d - 1s (2.5p - 5p) per cubic yard[21]. A substantial drain was provided at each side of the railway.

(5) Passenger transport

Passengers were carried in privately-owned single wagons or omnibuses drawn by one horse and known as 'caledonias' from the opening. This term may have eventually included the 'Fair Trader'[22] (Fig. 4) and 'The Boat'[17], said to have been open-topped, which are also known to have operated, but probably later. Their owners paid dues to the company, presumably based on an agreed weight at 2d (0.8p) per ton per mile[4], the same rate as for goods, wares and merchandise[16]. On his fact-finding tour of Britain in 1817 Baron Charles Dupin described seeing 'diligences on the railway which conveyed the idea of an enormous wandering vehicle drawn without difficulty by a single horse'[23]. Another version reads 'the stage-coach has four iron wheels; it is like a caravan and,...drawn full of passengers with only one horse' [24]. An indication of the amount of passenger usage in 1837-38 can be gleaned from the £88.14s.5d (£88.72) paid in annual dues which equates to approximately 200,000 passenger miles travelled in 12 months, probably representing two or three return trips per day between Kilmarnock and Troon and increasing to four or five trips daily during the summer[4]. This usage was very modest by comparison with freight. The coal dues alone for the same period amounted to £7196.11s.1d[27] (£7196.55).

(6) Track operation

On payment of the appropriate dues, any common wagons and carts used on ordinary roads, with flat-soled wheels not less than 3" (76mm) wide and meeting the track gauge and a weight restriction, were allowed access to and from the railway by means of frequent 'turnouts'[7] (Fig. 5a). This convenient facility, which obviated double-handling of freight, encouraged a 'great deal' of use, thus exploiting an advantage not available with the upstanding, but otherwise much more efficient, wrought-iron edge rails universally adopted later. A significant drawback to the use of plate-rails was that their running surfaces tended to collect dirt and loose stones which impeded traction and required their regular cleaning by surfacemen. In order to facilitate operation, the space between rails, known as the 'horse path' was filled with 'road metal' (small, hard, angular-broken stone) to near the top of the upstands and the spaces outwith the tracks to the sole of the rails[6]. Each horse was led by an attendant walking on the central path between the tracks. For flexibility of operation during maintenance this path, which was of 4ft (1.2m) clear width between rail upstands was also used by railway traffic as necessary.

(7) Rails

Each of the original cast iron rails was 3ft (0.9m) long with a longitudinally curved upstand increasing from about 2in (51mm) at the ends to 3in (76mm) in the middle, on its inside edge (Figs. 5b & 5c). The earliest known specification for them was set out in a printed tender invitation of 1809[25] (Fig. 6). Most of the original rails were made by the Glenbuck Iron Company under a contract of July 1809. By 1813 the company had been paid £13,345.8s.8d (£13,345.43) at £10$^3/_8$ (£10.37) per ton for about 72,000 rails[26]. Each rail therefore cost about 3s.8½d (18p). In March 1819 replacements from the Kilmarnock Foundry, some improved by Wilson with two feathers on their underside and weighing 38-40lbs[21] (17.2-18.1kg) were costing about 3s.2d[27] (16p). On 3 October 1809 the Railway Company's Clerk, James Gregg, who also seems to have been Town Clerk of Kilmarnock, wrote to the resident engineer Thomas Hollis that the newly-made rails were accumulating so fast at Kilmarnock as to encumber the Weight House and instructed him to have them removed so as to avoid very considerable storage costs[28]. During laying, the rails were secured in place at each end by means of a wrought iron spike with a square chamfered head which was hammered, through a pre-formed chamfered notch in adjoining castings, into an oak plug located beneath within a 2in (51mm) diameter hole in the centre of a stone block. Each block measured about a foot (0.3m) square and 9in (0.23m) deep[7] (Fig. 5b top). In 1818 a block, including boring, cost 5d (2p). From the early 1820s at some locations Wilson incorporated a cast iron shoe between the top of the stone block supports and the rails[1] (Fig. 5b, bottom). This practice facilitated track laying and improved its alignment. In the late 1830's 6ft (1.8m) cast iron replacement rails were being used on some sections of track and although making a better road than the 3ft (0.9m) rails their breakage was still considerable[29]. From 1836-40 the average annual cost of rail replacement had increased to £1000 compared with £225 for 1816-20. By 1840 15ft (4.6m) lengths of malleable iron of plate rail form with 1½ in (38mm) uniform height upstand and weighing 32lb/yd (16kg/m) were being used with cast iron chairs for

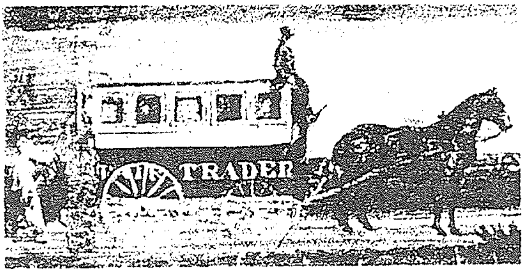

Fig. 4 Passenger carriage by 'Fair Trader.'[22]

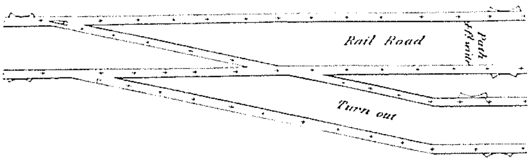

Fig. 5a Rail-road turnout 1811.

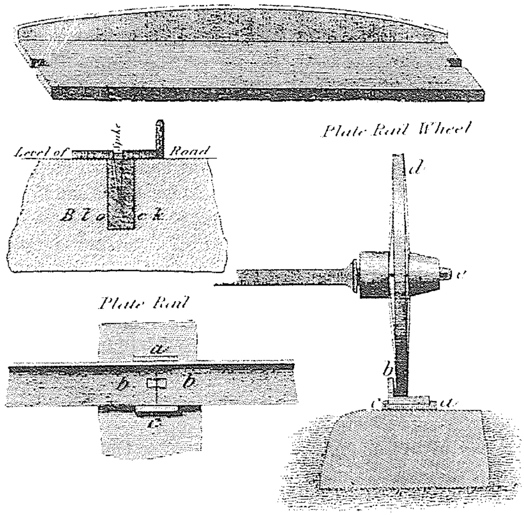

Fig. 5b Iron rail details

P R O P O S A L S

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 Natches 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.

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 One and one-half Inch wide, by One Inch at the top, and 7-8ths by One-half Inch at the bottom of the Head; to be not more than 5 Inches, nor less than 4 & 3-4*ths 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.

Fig. 6 Tender invitation for furnishing rails 1809.[25]

some track replacement[30] (Fig. 5d). In 1842 the track immediately east of the viaduct was still in its original state and in part 'not very good, but as there is only the trade of two collieries on this portion it may last for several years with repairs without being lifted and relaid'[29]. From the viaduct westwards a section of track was lifted and relaid with 6ft (1.8m) cast rails in the summer of 1839. A single line of 170yds (155m) of malleable iron plateway was laid at the viaduct in 1845[29]. A plate rail with plain underside and thought to date from 1809 was found at the viaduct in 1995 (Fig. 5c) and is now in the ICE Museum at Heriot-Watt University. The Dick Institute, Kilmarnock has an early rail with 'Kilmar(nock)' on its underside. Of four surviving rails known, each is broken having lost variously from 5-12in (127-305mm) of its length from one end.

(8) Steam locomotive trial 1816

In 1816 an attempt was made by the Duke of Portland to introduce steam locomotion on the railway from his collieries near Kilmarnock (Fig. 3). A trial was conducted using a George Stephenson 'Killingworth' locomotive engine adapted for operation on the plate-rails by means of six, rather than four, flat-soled wheels, each with steam piston springing, in order to spread its weight[31)-33] (Fig. 7). The locomotive was known appropriately as 'The Duke' and interestingly, according to an eye-witness John Kelso Hunter[34], the trial was conducted by Robert Stephenson, George Stephenson's brother[35] (not his son Robert who would then have been only 13 years old). The engine 'from its defective construction and ill adaption to the rails drew only ten tons (10.2 tonnes) at the rate of five miles an hour'[4] (8kph). 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. According to Edinburgh civil engineer 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'[36] (5.1 tonnes), or 7.5 tons[31] (7.6 tonnes). Present-day calculations, based on the dimensions of a surviving rail, indicate that a wheel load of 1.7 tons (1.72 tonnes), which would have been easily achievable at times with hammer-blow effect and rocking caused by the primitive locomotive's vertical to horizontal force transmission (Fig. 7), 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 (2.03 tonnes). For many years the date of this trial has been a matter of uncertainty to railway historians, 1816, 1817 and 1820 having been cited[17] [11], which the author has attempted to resolve by considering the incidence of rail breakage. A study of monthly railway company payments to the Kilmarnock Foundry for replacement rails and castings has revealed a sudden expenditure increase in September 1816 which can be considered indicative that by then the locomotive was in use [27] (Fig. 8).

Notwithstanding the locomotive's limited success on the Troon Railway, it is still of great historical interest as the first travelling engine ordered from George Stephenson outside Killingworth. The New Statistical Account records that on conclusion of this trial no further attempt was made to introduce steam power on the railway[4]. The engine is believed to have been sold in 1848 for only £13. Thomas[37] states that the locomotive remained in use from its introduction until 1848 but the author has been unable to confirm this.

(9) Upgrading the railway

In October 1836 George Stephenson, after examining the railway, strongly recommended that the Glasgow & Ayrshire Railway Company should try and influence the Duke of Portland to alter and improve it by regauging, increasing curve radii and providing edge-rails[38]. A plan of the same year exists indicating a deviation at each end of the viaduct[39]. Stephenson also suggested that the company should consider leasing the railway rather than trying to buy it at considerable cost. Following the passage of an act in 1846[40] the Ayrshire Railway Company did lease the railway from the Kilmarnock and Troon Company and began upgrading it with wrought iron edge-rails to 4ft 8½in (1.43m) gauge. The viaduct is believed to have been closed to passenger traffic on 20 July 1846, but its road still existed in September 1846 and a single track was almost certainly still being used by coal traffic in October[29] and November 1846[41]. The upgraded double track line over the new timber viaduct being constructed immediately south of it to an improved radius, and which was well advanced by September 1846[42], was opened in Spring 1847[43]*. The earthwork approaches to this viaduct can still be seen. About two decades later this structure was in turn superseded by the masonry viaduct 300m further south on the even more direct railway line which is still in use.

2. THE CONSERVATION PROJECT

(1) Origin

Forming a project for conserving this viaduct proved particularly challenging because of difficulties in determining and taking on ownership, inaccessibility of the viaduct to the public road network, its structurally dangerous condition and, because of

*although not for passenger traffic by June 1848 when a local user publicly bewailed the lack of a direct connection : 'No longer permitted to seat ourselves in our *Caledonias*, and be carried, without stirring from our seats, to our *Baiae liquidae*, with all our *impedimenta*, we are obliged to go circuitously first to Irvine - remove ourselves and baggage from the carriage into which we entered at the Kilmarnock Station, and get into another, and so be borne to another stage, which is not to Troon but within a mile of it, when we are entrusted to the mercy of an omnibus, into which if we are not fortunate enough to be one of the half dozen who can be accommodated inside, we must trudge on foot with every encumbrance we may have brought. Such is the very delectable rout(e) to Troon, which has superseded the old direct method of conveyance by the then despised but now much bemoaned and justly appreciated vehicles' [46].

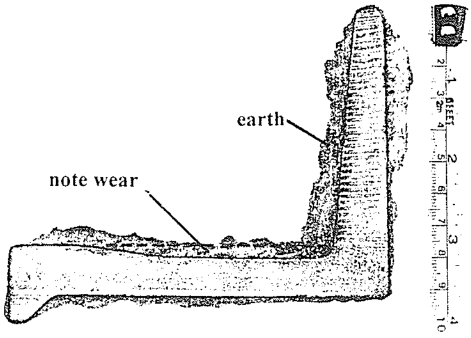

Fig. 5c Photo of iron rail section at mid-length.

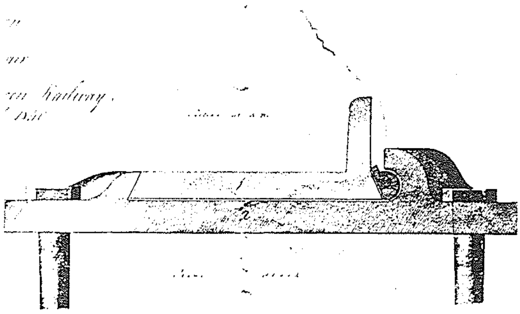

Fig. 5d Malleable iron rail 1840[30].

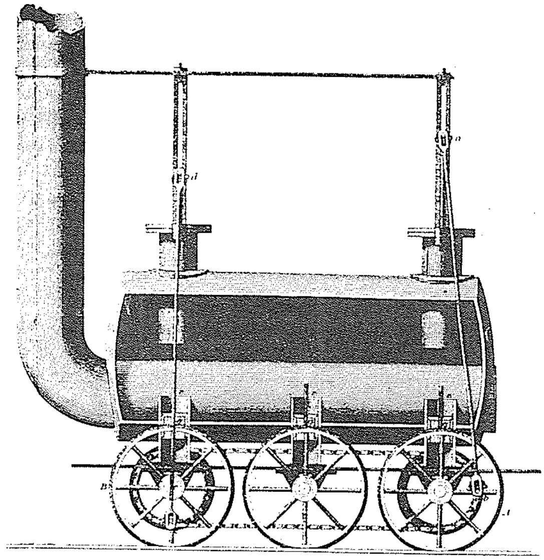

Fig. 7 Stephenson's 'Killingworth' locomotive engine 1816.[31]

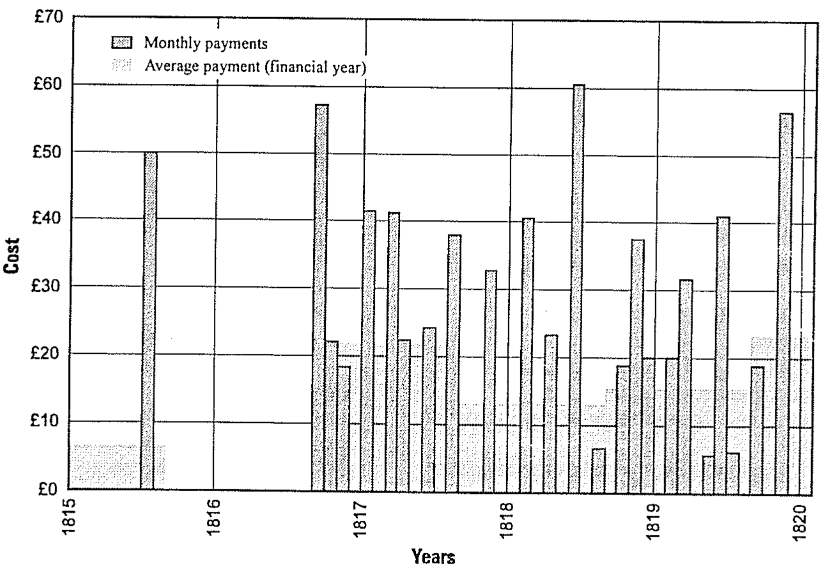

Fig. 8 Monthly payments to Kilmarnock Foundry for replacement rails and castings 1815-19.[27]

its overall poor state, a requirement for greater funding than was likely to be obtainable locally even with Strathclyde Regional Council's support. Efforts to save the viaduct during the 1980s, of which the author became aware through his membership of the Scottish Viaducts Committee, had come to nothing even though the structure had been pronounced 'in imminent danger of collapse'[43)-44)]. It was against this background in 1991 that the author, on behalf of the Institution of Civil Engineers Panel for Historical Engineering Works, wrote to the Historic Building and Monuments Department of the Scottish Office explaining the exceptional historical significance of the viaduct and requesting that it be taken into the nation's care. This request was declined, but Historic Buildings and Monuments (now Historic Scotland) indicated its willingness to consider financially supporting an appropriately constituted trust. Such a trust would be eligible for up to 50% grant-aid, double that for which a public authority would be eligible. In February 1992 the Project was formed, not as a trust, but as a limited liability company with charitable status, on the grounds that its activities were beneficial to the community, and with some degree of tax exemption. It was considered that a company would be more beneficial than a trust in limiting the liability of its members and would also give them greater flexibility in financial decision-making. Based on the author's earlier experience of trusts and conservation of historic Edinburgh & Dalkeith Railway structures on cycleway/footpaths for Lothian Regional Council, the professional constitution of the Project's directorate consisted of four civil engineers, including two leading contractors and an eminent engineering journalist and member of the House of Lords, an elected member representing each of the local authorities in whose area the viaduct stands, and a banker/lawyer with company and trust expertise. The directors are : Lord Howie of Troon (chairman), The Hon. Sir W. McAlpine Bt., W. J. Barr OBE, Provost D. Coffey Kilmarnock & Loudon District Council, P. A. Hearn Clydesdale Bank plc, Councillor A. C. Lambie Strathclyde Regional Council, Provost G. T. Macdonald Kyle & Carrick District Council and the author.

(2) Objectives

It was considered essential to commence the venture by agreeing objectives, which were:

To conserve the viaduct without necessarily taking on its ownership.

To promote future public use of the viaduct.

To promote knowledge of the viaduct.

To seek Central or Local Government to take on the future repair and maintenance of the viaduct.

To seek, receive and disburse funds in furtherance of these objectives.

In the event it did prove necessary for the directors to take on ownership of the viaduct, as this was a requirement of the major funders, but this was only done after :

(a) Strathclyde Regional Council (SRC) as part of its contribution had agreed that its Director of Roads would act on behalf of the Project in formulating, letting, and overseeing a contract for the main work. Also, that the Council would ultimately take on ownership and the future repair and maintenance of the viaduct on completion of conservation work to the satisfaction of its Director of Roads. This arrangement had the added benefit that the work would be exempt from Value Added Tax at 17.5% as the contract would be with the Council. Agreed in April 1994.

(b) The cost of the main work had been determined from tender submissions and the necessary funding had been promised. Achieved by February 1995.

(c) Acceptable terms for future ownership of the viaduct and access had been agreed with SRC, the funders, and the landowners. Agreed in principle February 1995.

(3) Ownership

In the absence, after a diligent search by the Project's solicitors, of anyone admitting to own the viaduct, ownership was deemed to rest with the riparian owners, the farmer on each bank of the river at the viaduct. Fortunately they were basically supportive of the enterprise and after negotiations, agreement was reached for the directors of the Project to purchase the viaduct for £1.00, on condition that, if for any reason it was not taken over by SRC, its ownership would revert to the farmers. The farmers accepted this condition because they would be relieved of the consequences of any collapse in the meantime and, in the unlikely eventuality of them having to take back the viaduct, it would then be in a much safer state than at the outset. The project undertook to meet the farmers' reasonable legal costs. From a study of records, the author believed that a good case could have been made for at least part of the viaduct being owned by the British Rail Property Board, an opinion which was reinforced when it was discovered that they had offered to sell one of the farmers some land which included part of the viaduct in 1977. In response the farmer maintained the land was his and the Board decided against pursuing their sale. They subsequently declined any further interest in the ownership of this land. Unfortunately, from the Project's funding standpoint this decision precluded any financial contribution either from the Board or the Railway Heritage Trust, both of whom had previously supported similar conservation projects. To have pursued the matter would have been a protracted and uncertain business which, as matters transpired, proved unnecessary as sufficient funding to complete the work was raised elsewhere.

(4) Input to specification

In April 1994, a decision was taken to proceed with the main work by contract and the Project notified SRC Roads of its interests to be taken into account when preparing the specification. These were, in addition to meeting its objectives where applicable, that :

(a) the contract should result in the viaduct being brought up to such a standard as would enable Strathclyde Regional Council to take over the ownership and maintenance responsibility from the Project in terms of the Council's Minutes.

(b) the viaduct should be preserved as far as practicable as it now exists, retaining its original character, and brought to a secure, waterproof, good state of repair, to allow its safe use by pedestrians. The work to involve, as required, securing the foundations, stabilising the piers and arches, cleaning off vegetation, replacing masonry where missing or defective with matching stone of similar colour and quality up to deck level and pointing the whole viaduct with appropriate strength mortar of similar colour. The deck and side railings or parapet walls required for pedestrian safety to be of a design to be approved by the Project and which is compatible with the historical engineering character of the structure. All work should comply with the stated requirements of Historic Scotland as this was a condition of their grant.

(c) in order to keep within the Project's funding, work should only progress from one stage to the next on completion within budget of the preceding stage. Provision should be made to safeguard the Project against any cost commitment which could exceed its financial resources in the event of major unexpected difficulties being encountered.

(d) the methodology for the safe conduct of each stage of the work, and the security of the whole structure at all times, should be clearly stated and demonstrated at the tender stage. The safety of the structure should be monitored throughout the progress of the work.

(e) a photographic record should be taken both before and during work for monitoring and record purposes.

(f) the Project should be safeguarded against possible claims from the farmers and river authority in respect of damage to their property and interests.

As far as possible these interests were covered in the specification and by insurance and, so far, no problems have arisen. The state of the viaduct before work started was recorded by a photographic survey contributed by the Royal Commission on the Ancient and Historic Monuments of Scotland.

(5) **Main contract formulation and award**

It was recognised that the 'design and build' lump sum contract procedure decided upon would involve the contractor in taking greater risk, than with the more usual practice of the design being undertaken by the client or a consultant, but considered that the possibility of claims later on would be reduced. In the event, this greater risk was reflected in the tender price received for phase 1 (at the time of tendering the work was envisaged as being carried out in two phases if necessary), the lowest coming in at about £200k greater than the Project's promised funding at that time. This setback was overcome by an urgent and only just successful approach to existing and prospective funders. Invitations to tender based on a carefully compiled specification were extended to selected firms on SRC's list of approved contractors. Design submissions were presented in Ayr on 5 July 1995 by Barr Limited, Henry Boot, Edmund Nuttall and Raynesway and their consultants. By the end of August tenders had been received ranging from £520k to £870k for phase 1 and from £981k to £1552k for the whole refurbishment in a continuous operation. The lowest, Barr Limited's, for the whole of the work to be carried out in a continuous operation was formally accepted in February 1995. At the design submission Barr Limited's outline proposal was based on not relying on any support from the existing structure. They proposed to found and position in the river, a pair of reinforced concrete beams under each arch at right angles to the length of the viaduct extending to an adjacent working area, immediately upstream of which a temporary dam would be formed across the river. Steel centering frameworks for all the arches were then to be fabricated and slid into place to support the extrados of the arches. Remedial work to stabilise the piers would then follow after which the spandrels would be strengthened as necessary and the new deck formed. Defective masonry would be replaced and the structure would be pointed with lime mortar. Two other tenderers independently proposed the same basic approach which tended to confirm that this was a reasonably economic solution commensurate with the risk to all parties.

(6) **Funding**

To obviate the possibility of having to return numerous small sums of money if the Project did not proceed, funding was sought for substantial sums only from selected sources from 1992. By February 1995 a package totalling £1.065m had been assembled. The National Heritage Memorial Fund agreed to contribute up to £400k, Historic Scotland £277k, the European Union £200k through the good offices of SRC Planning, SRC £63k plus the valuable services of its Roads and Planning Departments, Kyle and Carrick District Council £65k, Kilmarnock & Loudon District Council £45k and Enterprise Ayrshire £15k. The two largest funders required the Project to enter into formal agreements in order to safeguard their interests. Their contributions and that of the European Union were only payable to the Project after the work had been executed. This situation is managed as follows. SRC Roads check and certify the contractor's monthly accounts for payment. A copy of their certificate is then forwarded to the Project's Secretary who claims payment from the funders and the proceeds therefrom, less a small retention, are transferred into the Project's bank account, and then into an SRC suspense account as required. Because of this retrospective payment condition it was essential for the success of the venture that the other funding was not subject to such a restriction in order to meet essential preliminary and other non-grant earning work. About half of the grant-aid had been claimed by January 1996.

(7) **Access**

The Project entered into access agreements with both farmer landowners for use during the conservation work of existing farm roads and provision of new lengths of road. On the east side the farmer stipulated that the new road and contractor's hard standing must be removed on completion of work so that the ground could be returned to agricultural use. On the west side the situation was different as the new roadworks were substantial, involving provision of a 500m length of 4m wide carriageway along the original tram road line (Fig. 1) and the permanent strengthening with an r.c. saddle and parapet protection of the operational railway bridge at Cockhill. On 16 December 1993 the Project was informed by SRC Planning that if a contract could be prepared, let and started before 31 December, they could obtain £140k of funding for the Project from the EEC. The author and tendering contractors rose to this challenge. A specification and tender document were prepared within 24 hours and sent to four firms. Three sealed tenders were received and opened on 24 December containing amounts ranging from £12k to £30k, exclusive of the bridgeworks which were priced separately and executed for £3.3k. The contract was awarded to the lowest tenderer, Barr Limited. It was carried out in August 1994 and virtually done at cost. The landowner donated blaes (burnt coal shale) to be used in the road at the contractor's discretion which, because of the limited quantity, only marginally reduced its cost. The farmer subsequently claimed, with some justification, that heavy plant had damaged his existing road and insisted that it be resurfaced as a condition of his sale of the viaduct. The Project agreed but limited its commitment to £4k. The farmer agreed not to require the removal of the new road on completion of the works and thus it would be available as a permanent access for occasional future maintenance. Public access agreements with the farmers have also been agreed, but the paths, at least in the first instance, will be for pedestrian use only as, despite a considerable effort of persuasion, it was not possible to obtain agreement for cycle use from one of the farmers. The layout and construction of the finished deck of the viaduct will be capable of accommodating cyclists should this be decided on later. Public access to the viaduct is across the field from the public road near Laigh Milton mill (Fig. 1). It was considered important in maximising public accessibility to the viaduct that it should form a path link in a wider network and agreement has been reached with the farmer for the route to continue from the viaduct southwards along the west side of the river to the limit of his land. Eventually it is hoped that this route will continue to Gatehead with a connection to the minor road network at Fairlie Cottages (Fig. 1), but this will be a matter for the new South Ayrshire local authority. The project agreed to pay an annual rent to the farmers for access to the viaduct and to meet their legal expenses in connection with the agreement.

(8) Listed building consent

Planning consent for the work was not considered to be necessary as the structure was not being altered, but listed building consent under the Town and Country Planning (Scotland) Acts and General Development (Scotland) Orders was applied for and obtained conditionally by June 1994. Kilmarnock and Loudon District Council required to approve details of the deck surface and handrailing and Kyle and Carrick District Council required to approve details of the handrails. At a subsequent site meeting, at which the author produced photographs of early 19th century iron railings on similar structures, agreement was reached to having a 1m high light grey steel railing composed of vertical 30mm square section bars at 120mm centres with horizontal top and bottom rails. It was also agreed to add a segmented cap on the top rail, which would improve its appearance from below. The feet of the railings would be secured to new masonry copings at each side of the viaduct. The surface of the deck would be crushed stone similar to that used originally. The possibility of incorporating some replica cast iron rails was being investigated.

(9) Administration

The Project is administered by a Management Committee which, in addition to the directors, includes representatives from the planning departments of the three local authorities involved, SRC Roads and Historic Scotland. Twenty-six meetings have been held at various venues since February 1992. The Secretary writes the minutes which are submitted for approval to the following meeting.

(10) Insurance

The Project's directors are covered for 'all risks' as principals under the contractor's insurance with Sedgwick UK Limited. No additional premium was required. To minimise the directors, exposure to risk, the exchange of missives for ownership was timed to take place immediately before the contract was formally awarded and the insurance became effective. In the event of the viaduct collapsing, it was agreed that liability would be limited to any damage caused thereby and remedying the consequences thereof, but not to rebuilding the structure.

3. THE VIADUCT

(1) Description

The viaduct, which was built from 1809-11, carried the railway about 25ft (7.6m) above the River Irvine on four 40ft (12.2m) span segmental freestone arches each with a rise of one-third of its span. The arch stones are nominally 2ft (0.6m) deep and the overall width of the viaduct is 19ft (5.8m). No drawings or specification are known to have survived. It is probable that Jessop allowed Hollis considerable autonomy in the design as built, the materials used, and method of construction. The contractor was a Mr Simpson, possibly Telford's bridge-building 'treasure of talents' from Shropshire, John Simpson[47)], who about that time was also working on the construction of the Caledonian Canal for Telford and Jessop. Simpson was paid nearly £4000 for the viaduct, which was not expensive for a masonry river bridge of these dimensions. In 1809 Hollis was refused permission by Lord Eglinton's tenant at Milton Mill for part of the dam to be taken down to facilitate foundation of the piers

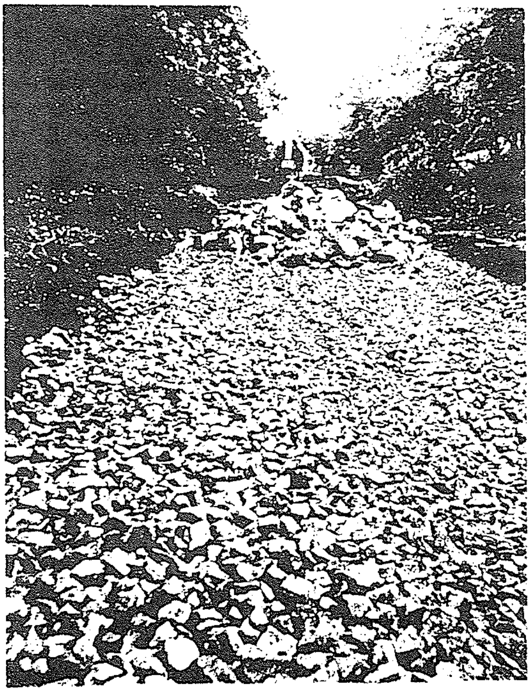

Fig. 9 Road-making on 1811 line in 1994.

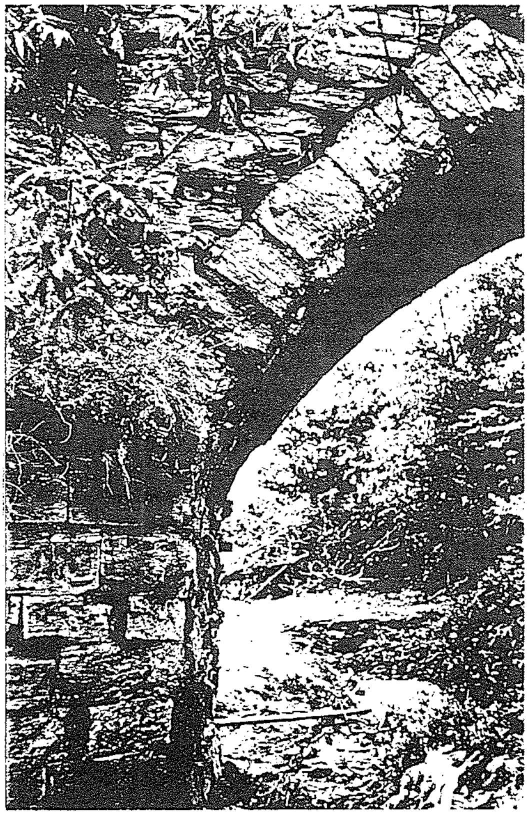

Fig. 10 Pier 1, north side in poor state.

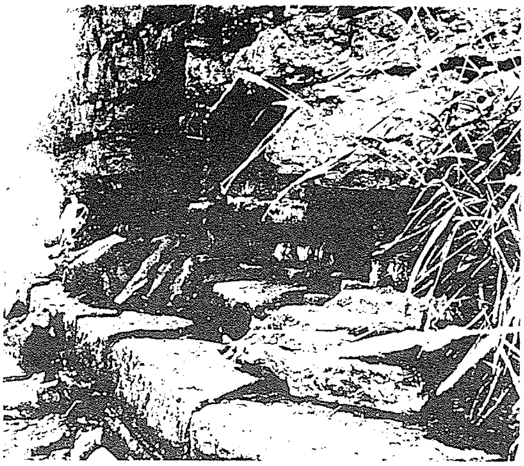

Fig. 11 Pier 3 undercut and firm foundation below.

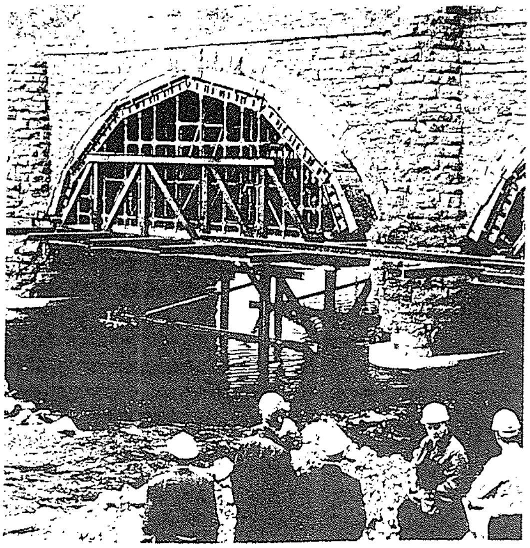

Fig. 12 Piers 2 & 3 with reinforced concrete collars.

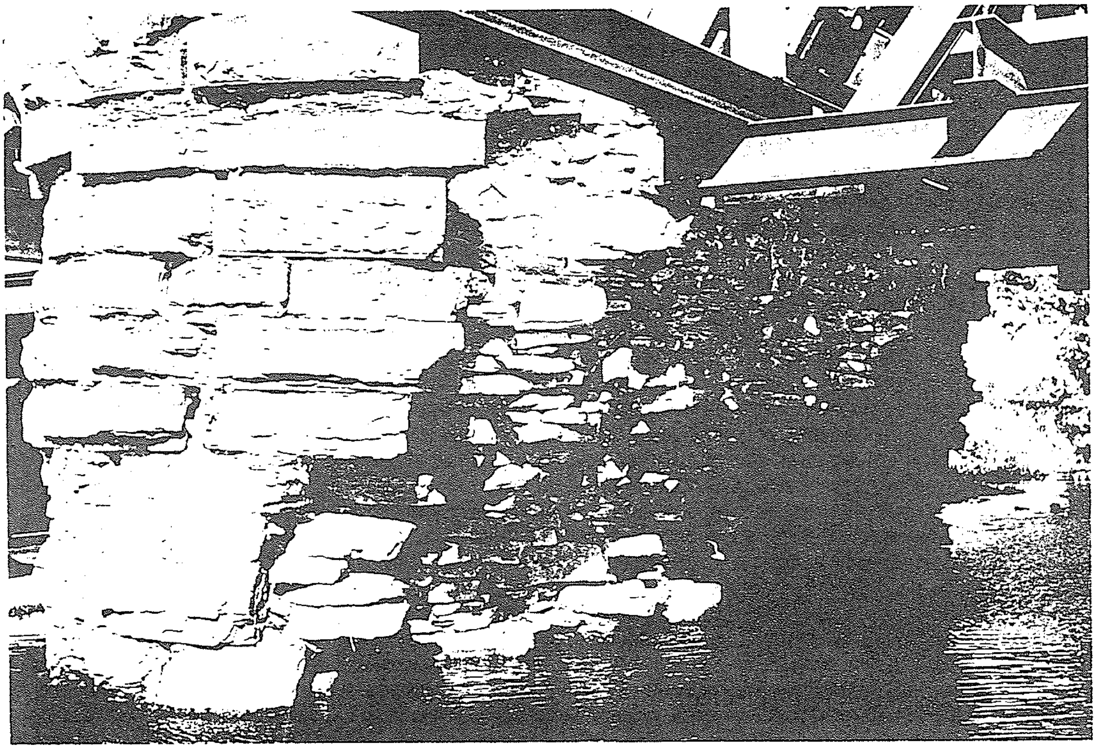

Fig. 13 Pier 1, east side - erosion into mortar-bedded hearting.

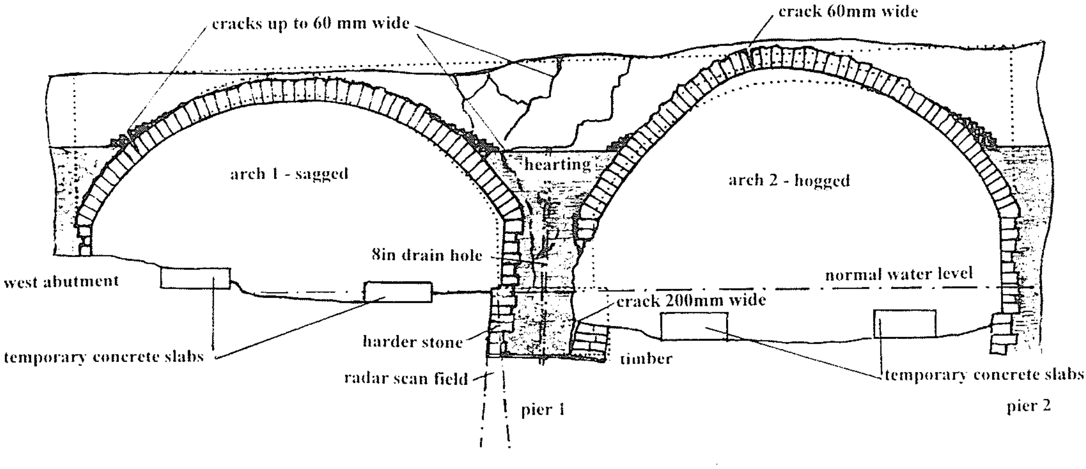

Fig. 14 Sketch section of pier 1 and adjoining arches with spandrel fill removed - looking north.

of the viaduct. On 7 July 1809 authorisation was given by the company for the work to be done by means of a cofferdam at 'very little more expense' than if part of the dam had been taken down, with the advantage 'that the stones for the bridge can be floated down on a punt'[26]. In March 1810 the company agreed that freestone from Third Part, about a mile (1.6km) west of the site (Fig. 3), was to be used for the bridge. Freestone from other sources including Gillburn Quarry, Laurieston, about a mile to the north of the mill and which was filled up c. 1817[23], was probably also used. By September 1810 the work was about half done as Simpson had been paid £1934.12.3d (£1934.61). It is probable that the viaduct was operational with at least one line of plate-way by July 1811.

(2) **Condition at start of refurbishment**
The viaduct has become fragile because of crumbling of its stone, much of which is of weak texture, being minutely fissured (Fig. 10) which, with lack of maintenance and weathering effects, has led to widespread stone loss of several inches and major loss from each pier at and near water level (Fig. 11). Pier 1 (the west pier) has lost about one-third of its original 9ft 6in (2.9m) thickness (Fig. 13) and is leaning at the top towards the river causing stretching of arch 1 (the west arch) and shortening of arch 2 (Fig. 14). Pier 1 and its adjoining spandrel walls above (Fig. 14) exhibit serious cracking extending across the bridge and down the pier to below the level of the missing masonry which is indicative of a foundation problem in or below the pier base masonry (Fig. 15). A 1988 report confirmed that the viaduct had not been undermined by past coal extraction[44]. Differences in thickness of vertical and horizontal joints still containing lime mortar and the considerable size variation and poor fit of stones in the spandrels are indicative that the west end of the viaduct was less well-built than the remainder, much of which can be preserved by pointing (compare Figs 10 & 12). Possibly some subsidence occurred at pier 1 during or soon after construction which was accepted by Hollis rather than incur the cost and delay of a major rebuild.

(3) **Radar scanning**
At the time of tendering it was essential to minimise uncertainty by providing as much information as possible on the depth, materials and form of the viaduct's foundations. In view of the lack of contemporary information and because it was not practicable for safety reasons to take boreholes at the structure, the author initiated and let a radar scanning site investigation contract to Geospace consultancy Services Ltd for £1.5k. Basically their findings were that the piers were founded above hard material at a depth of 2-3m and that there were fissuring problems in the base of pier 1. In order to furnish more detailed information for pier 1, before Barr Limited finalised their design, further radar scanning was carried out by Dr Colin Stove and the author as a research exercise (Fig 17). Part of this operation was to scan vertically downwards from water level through the stepped out base on the west side of pier 1 (Fig. 14). This scan was plotted out to a depth of 3.2m for a 3m length of pier, which included the centre line of the structure. (Fig. 18) Ten dielectric layers were identified on the basis of distinct velocity changes at horizon interfaces, some of which were probably mortar joints in the pier masonry. The upper dielectric constants (4.1 - 9.3) are typical of stone. This stone is resting on what is almost certainly a layer of saturated wood (19.0) at a depth of 2m resting on material indicative of a firm foundation with dielectric constants consistent with sand and gravel and fractured weathered rock above bedrock, sloping at about 30°. The fractures normal to the bedding which pass both through the bedrock and the structure may have resulted from seismic activity.

(4) **Progress on main contract**
Work on site started on 5 June with a ceremony performed by the Project's chairman, Lord Howie of Troon (Fig. 19). By 3 August operations were well in hand fabricating and positioning the arch support frameworks and by 14 November this work had been completed, scaffolding had been erected and the clay spandrel fill removed (Fig. 20). By then, the percentage completions of the various elements of work were: design 92%; preliminaries 59%; temporary works over 90%; west abutment repairs 10%; arch 1 53%, including grouting of cracks with 320 litres of cement mortar (Fig. 14); pier 1 40%; arch 2 50%; pier 2 70% including an r.c. collar; arch 3 60%; pier 3 70% including an r.c. collar (Fig.12); arch 4 60%; east abutment 30%. Structural mass concrete has now been poured at each pier head to form a base for the reinforced concrete arch strengthening[48]. Overall, excellent progress is being made and, to January 1996, Barr Limited have been paid about £500k.

(5) **Past practice findings**
Interesting features of the original structure revealed during the work were that :

(a) from the radar scan pier 1 appeared to be founded on a timber platform at a depth of about 2m below water level. In fact, timber was found at about that level in an excavation at the north end of the east side of the pier. The timber was saturated, but hard.

(b) the spandrels consisted of two, coursed rubble masonry, gravity acting walls, 19ft (5.8m) overall apart, running the full length of the viaduct and stepped out internally in thickness from 1ft (0.3m) at the top to 3ft 6in (1.1m) at their greatest depth of 9ft (2.7m) above the piers. The walls simply rest on the extrados of the undressed voussoirs and are not tied laterally (Fig. 18).

(c) internal pier masonry hearting, of smaller size flat stones than the facing, carried up to about 5ft (1.5m) above the arch springings and set in lime mortar had been used. This was an effective practice and typical for its period (Fig. 13).

(d) internal spandrel drainage provision consisted of a pair of 8in (0.2m) diameter drain holes down through

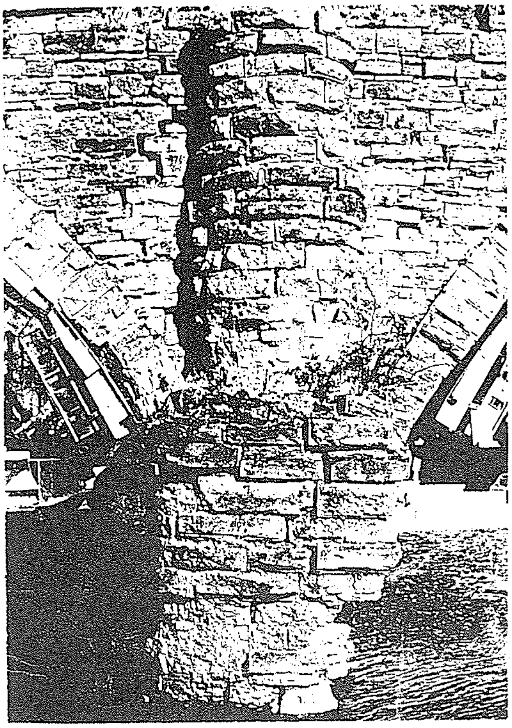

Fig. 15 Pier 1, south side - cracking and undercutting below arch springing.

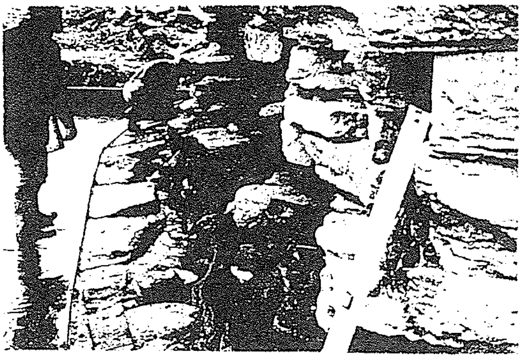

Fig. 16 Pier 1 - east side - 200mm crack in base masonry.

Fig. 17 Pier 1, - radar scanning, with oyo receiver.

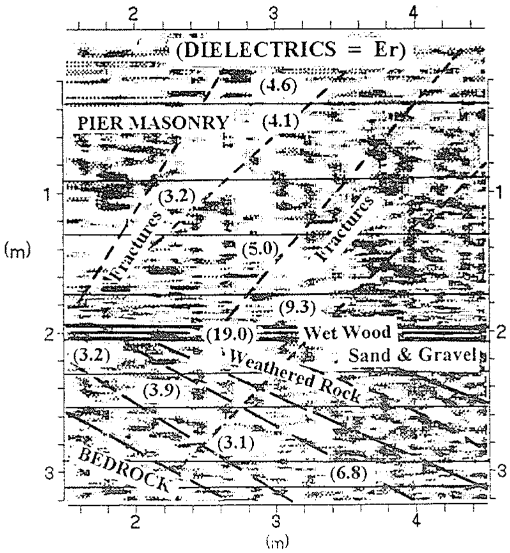

Fig. 18 Pier 1, west side - radar scan plot to depth of 3.2m (see Fig. 14).

Fig. 19 Lord Howie commencing operations on 5 June 1995.

the hearting of each pier, which were probably intended to operate only during construction (Fig. 14).

(e) the cavity between the spandrel walls, about 12ft (3.6m) wide at top of pier level and 17ft (5.18m) at track level, had been filled with stiff sticky clay resembling puddle-clay. When it was removed a layer of small broken stones was found at about former track level, presumably the horse attendants' path. Three broken plate rails were also found at this level.

(f) different elements of masonry work were ineffectively tied together e.g. spandrels to spandrels, spandrels to voussoirs; and pier bull-noses to spandrels.

(6) Main historical findings

(a) That the viaduct's outstanding historical significance rests mainly on its association with Scotland's first public railway engineered by the eminent Jessop and used by Stephenson's innovative locomotive engine as early as 1816 and in being the oldest known surviving example of a type of multi-span structure subsequently adopted universally.

(b) That the **design** of the viaduct, with its handsome functional elevations, based on sound traditional practice, was economical and suited to its purpose, but otherwise unremarkable. The structure when built was of medium scale for masonry construction and its design followed the normal late 18th rather than the best early 19th century practice, particularly in respect

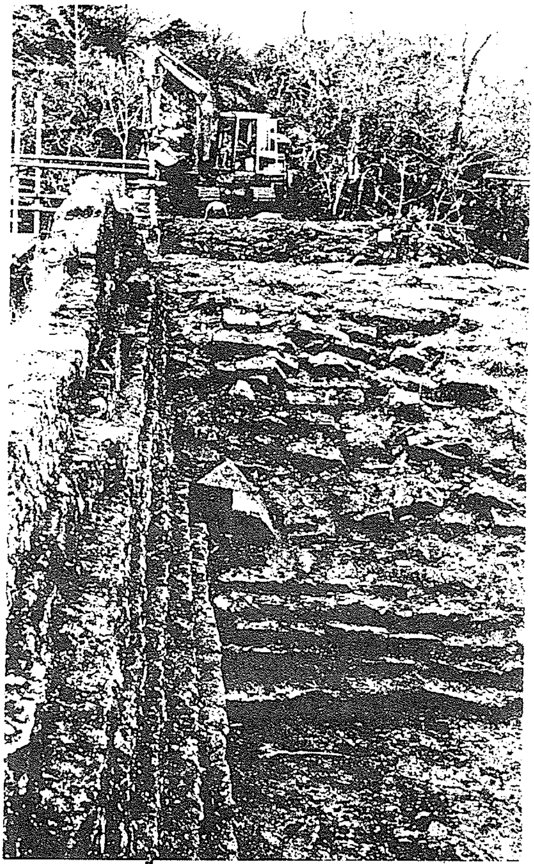

Fig. 20 (left) South spandrel wall and extrados of arch 2.

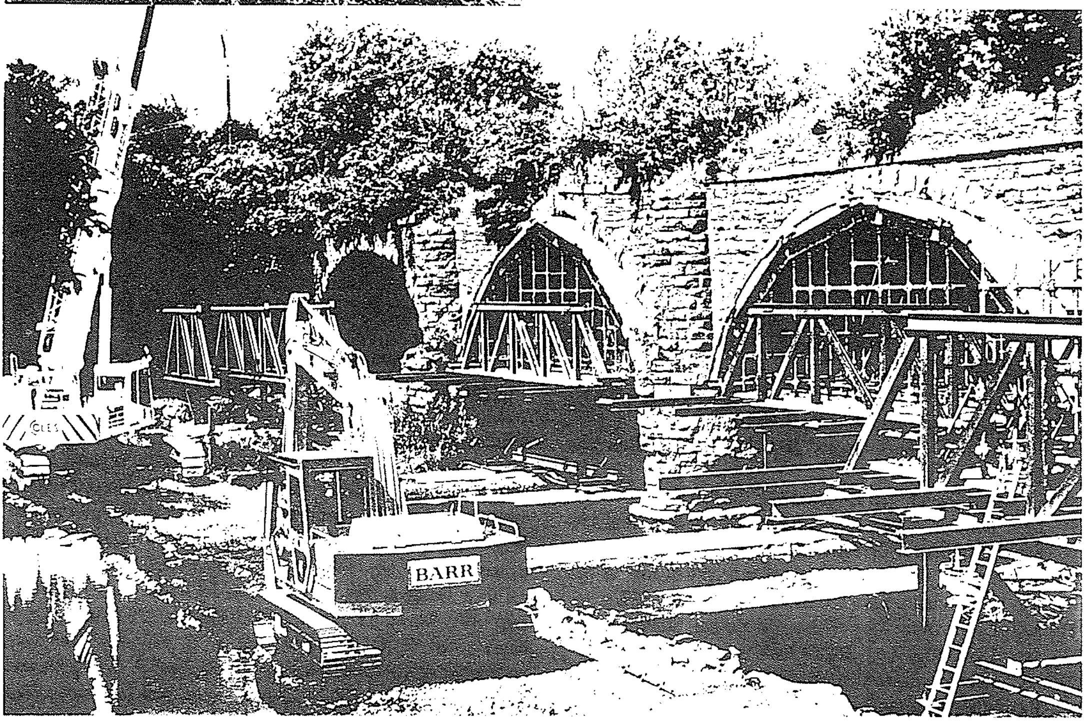

Fig. 21 Works on 3 August 1995 with water lowered.

of its clay-filled spandrels instead of the improved hollow form with longitudinal cross-tied walls which by 1809 were being adopted increasingly by Telford and others.

(c) That the viaduct's medium to low cost **construction**, because of a considerable use of readily available but not particularly good quality local stone, the indifferent tying together of its masonry elements, and poor quality work at the west side of the bridge, cannot be considered an example of best practice. Nevertheless, this construction work, which now constitutes a fascinating and important case study, was evidently considered adequate by its builders and in the event, it did pass the test of time, just!

References

1) Stevenson, R. : 'Railway' in Edinburgh Encyclopaedia, 1830. XV11, 303-310, pl.CCCCLXXVII. First published in 1824.
2) Stevenson, R. : Report relative to various lines of railway from the coalfields of Mid-Lothian to...Edinburgh, 1819.
3) - 'Description of the railway from Kilmarnock to the harbour of Troon' in Scots Magazine, Jan. 1812.
4) - New statistical account of Scotland, 1845. V, 554. Written 1839.
5) ibid. 683-4. Written 1841.
6) Aitken, W. : General view of the agriculture of the County of Ayr, 1811. 50-53, 554-61.
7) Buchanan, G. : 'Railway' in Supplement to the fourth, fifth and sixth editions of the Encyclopaedia Britannica, 1824. VI, 413-18, pl.CXV.
8) Tredgold, T. : A practical treatise on rail-roads and carriages, 1825. 169, pl.1.
9) - Composite view drawn up partly from refs 7 & 8 by Mr Graham Douglas to the author's specification.
10) Bald, R. : A general view of the coal trade of Scotland, 1808. 34.
11) Robertson, C. J. A. : The origins of the Scottish railway system 1722-1844, 1983. 22-24.
12) MS. Letter from Scott Titchfield (4th Duke of Portland from 1809) to the Earl of Eglinton, 22 April 1806. Nat. Lib. Scot. MS 9814 f.24.
13) Kirkpatrick, G. : 'The Kilmarnock and Troon Railway' in Backtrack, Jan/Feb 1992. 6, No.1.
14) Acts 48. Geo. III. c.46 (Railway) and c.47 (Harbour).
15) Hadfield, C. and Skempton, A. W. : William Jessop, Engineer, 1979. 181-2.
16) Priestley, J. : Historical account of the navigable rivers, canals, and railways, of Great Britain, 1831. 367.
17) Highet, C. : The Glasgow & South-Western Railway, 1965. 4-8.
18) - Glasgow Herald, 30 August 1811. 2e.
19) MS. Minute book, Kilmarnock and Troon Railway. Scottish Record Office. (SRO) BR/KTR/1/1.
20) Engraving. Wilson, J. : Plan of a proposed line of rail way or tram road, from Kilmarnock to Troon, 1807.
21) MS. Letter from John Wilson to Robert Stevenson, 10 Jan. 1818. NLS Acc. 10706, 76/5.
22) - Computer enhanced illustration from a photograph by the author of a contemporary unsigned and undated oil painting at the Dick Institute, Kilmarnock.
23) Dupin, Baron C. : Narrative of two excursions to the ports of England, Scotland and Ireland, in 1816, 1817, and 1818, (1819). 47.
24) Dupin, Baron C. : The commercial power of Great Britain. Translated from the French, 1825. II, 255.
25) - Taken from printed handbill at Nottingham County Record Office. Ref. DD4P 77/14. See ref. 13.
26) MS. SRO, BR/KTR/1/1, 18-54.
27) MS. SRO, BR/KTR/4/1.
28) MS. SRO, BR/KTR/4/3.
29) MS. SRO, BR/KTR/1/2.
30) MS. Plan and section of rail and chair used on the Kilmarnock & Troon Railway, March 1840, at the Dick Institute, Kilmarnock.
31) Wood, N. : A practical treatise on rail-roads, 1825. 124, pl.IV. 245.
32) Warren, J. G. H. : A century of locomotive building, 1923. 28.
33) Marshall, C.F. : Early British locomotives, 1939. 67.
34) Hunter, J. K. : Retrospect of an artist's life, 1868. 98-100.
35) Leigh, C. : 'Robert Stephenson the elder 1788-1837' in Trans. Lancs. & Cheshire Antiq. Soc., 1967.
36) Buchanan, G. : An account of the Lanarkshire railways, 1832.4.
37) Thomas, J. : A regional history of the railways of Great Britain : vol. VI. Scotland : the Lowlands and Borders, 1971. 19-20.
38) Stephenson, G. : 'Mr Stephenson's report...16 October 1836' in Proceedings of the first general meeting...Glasgow, Paisley, Kilmarnock & Ayr Railway, Glasgow, 1836.
39) Engraving. Laughlen, A. A Plan of...Kilmarnock & Troon Railway and proposed alterations...Dundonald & Kilmaurs, 1836. SRC Archives (Ayr Office). ATD 13/14/1.
40) Act 9 & 10 Vict. c.211, passed 16 July 1846.
41) SRC Archives (Ayr Office). ATD 13/14/3. Letter 18 Nov. 46.
42) - Kilmarnock Standard, 24 Sep. 1846.
43) - The Railway Times, 28/8/1847. X, 1119.
44) MS. Laigh Milton Viaduct. Stability assessment... August 1988. SRC Physical Planning Department. 3.
45) MS. Crouch Hogg Waterman. Laigh Milton Viaduct. Study Report CHW 11177. Jan. 1992.
46) - Kilmarnock Standard, 29 June 1848.
47) Letter from Telford to Andrew Little, 8 Decr. 1798 in Gibb, Sir A., The story of Telford, 1935. 39.
48) MS. McFarlane, W. Report - Contract progress at 12 December, 1995. SRC Roads, (Ayr).

Acknowledgements

The author acknowledges with thanks valuable support in the preparation of this paper from : The Scottish Record Office; Strathclyde Regional Archives; The Dick Institute, Kilmarnock (Figs 4 & 5d); Mr W. McFarlane and Mr D. Marshall, SRC Roads; Mr J. Kelly, Site Agent, Barr Limited; Mr M. Bailey; Mr G. J. Douglas (Fig. 2); Mr W. T. Johnston; Mr F. M. Jones (Fig. 17); Mr R. G. Maund SRC Physical Planning (Fig. 1 base) ; Mr E. C. Ruddock; Mr J. S. Shipway (checking calculations); Dr G. C. Stove (Fig. 18); Prof P. W. Jowitt and the Dept of Civil and Offshore Engineering, Heriot-Watt University.