1. Argyll

Introduction

This chapter begins with Dunoon Pier (1-1), the main gateway to the county from the Clyde, another approach is via Rothesay Pier (1-2), Bute, to Rhubodach Ferry across the Kyles of Bute and on to the Glendaruel Road, of which more later. Away to the west, and unreachable by road, are the spectacular, world class, Stevenson lighthouses of Skerryvore (1844, 1-3), with its shore station at Tiree, and Dhu Heartach (1868, 1-4) with its shore station at Erraid, close to Iona. To these works perhaps should have been added, being rather more accessible, the fine lighthouse at the southern tip of the Mull of Kintyre, first erected in 1788 and rebuilt in its present form by Robert Stevenson in 1822.

The Mull of Kintyre is crossed near Lochgilphead by the strategic Crinan Canal accommodating small sea-going vessels and saving them a difficult 75-mile detour between Glasgow and Oban or the Caledonian Canal. The canal was designed by John Rennie and completed, far from perfectly, some 13 years late in 1809 after many difficulties. It was significantly improved under Telford's direction seven years later. Particular features noted are an ingenious water waster at Lochgilphead (5-5) and moveable bridges at Oakfield (5-6) and Dunardry (5-7), the latter horizontally retractable. Another maritime work noted, near Arrochar on Loch Long, is a reinforced concrete jetty constructed for the Admiralty Torpedo Testing Station during the First World War (1-23).

Masonry bridges include the architecturally inspired Garron (1748, 1-21) and Inveraray (1776, 1-17) examples. The latter may have influenced the appearance of a country-type precursor at Brenchoillie (1-18), and 'the bridge over the Atlantic' at Clachan Sound (1792, 1-8). Ballochindrain Bridge (1808) provides a good example of a Highland Road Commission bridge on the Glendaruel Road (1807–12, see pre 1-17), the longest road, at 19 miles, of about a dozen road projects amounting in all to some 100 miles in Argyll improved under Telford's general direction for the Commission.

The harnessing of steel to bridge construction from the end of the 19th century enabled the road and railway network to be improved by means

of larger spans, for example by the Caledonian Railway at Connel Ferry Bridge (1903, 1-9), which when it was opened comprised the largest steel cantilever bridge in Europe after the Forth Bridge, and at Ballachulish (1974, 1-26), where the A82 road is carried over Loch Etive on a bridge nearly 1000 ft long with a central span of 600 ft.

A notable later road improvement is the 30-mile 'New Glencoe Road', a government job creation project of 1928–32, which, by improved road width and alignment and reducing the rise and fall of the old road by nearly 1200 ft, significantly improved the travel time between central Scotland and the west coast (1-25).

Railway development is represented by the Callander & Oban line, completed in 1880 after having taken 15 years to construct its 71 miles. Impressive structures include the two Awe viaducts (1885, 1-16), and a viaduct (1-27) on the Killin branch line. The line was partly closed permanently in 1965 after a rock fall, but still operates between Crianlarich and Oban.

Hydro-electric power works are represented by Loch Sloy (1950, 1-24); Glen Shira (1956, 1-19); Cruachan Hydro-Electric Scheme (1-15), the first installation of its kind in Scotland; and the Allt-na-Lairige pre-stressed concrete dam (1957, 1-20), the only one of its kind in Britain.

An unusual sideline of Telford's work for the Highland Road Commission was his design of 'parliamentary' churches and manses. The fine example at Duror, Appin (1827, 1-11), still in use for worship, is one of 32 churches and 43 manses, scattered throughout the Highlands and Islands, built in gratitude to God for the victory of 1815 at Waterloo (1-11, map). Another unusual work, which called for what Smeaton would have regarded as civil engineering skills, was Bonawe iron furnace and pier (ca.1753, 1-13-14) at what was once one of the largest charcoal-fuelled ironworks in Scotland.

1. Dunoon Pier

HEW 2446
NS 1765 7648

This pier, probably of timber, was erected in 1835 as the steam boat revolution in communications, particularly with Glasgow, was gathering momentum. Its continuing growth led to extensions and other improvements in 1867 and by 1881 the jetty extended almost 400 ft from the shore. In 1896–98 the pier head was developed to its present form in a depth of about 24 ft of water with buildings by architects Clarke & Bell. It is the terminal for the ferry to Gourock connecting with the train to Glasgow.

The buildings are extensive, much more so than their rivals at Rothesay, and give an impression of Tudor-style architecture with red-tiled roofs and timber gables. A promenade balcony was added in 1937, but this fell into disuse and has since been removed. Even today this pier still provides the shortest and fastest route to Glasgow and is in constant use daily. [1]

2. Rothesay Pier, Bute

HEW 2447
NS 0889 6483

This is a masonry pier of traditional construction opposite the Watergate. It originated in 1752, by 1756 had reached about 100 ft in length, and was completed in 1781 at about double this length and a width of 30 ft. From 1785–90 the New Quay was built parallel to it on the west side with a turn to the east in an L-shape plan to provide a fishing boat harbour (see figure).

With the coming of the Clyde steamer and tourist boom, both quays were joined by a drawbridge at the end of the original pier in 1833. A wooden and iron slip, 330 ft long for boat repairs, was erected in 1839–40 by Caird & Co. (£848), with piling and mason work by J. Kinghorn (£233). Albert Pier, a smaller quay to the east mainly for coasting vessels, was built from 1860–65.

Of Rothesay Pier's buildings of 1903 only a cabbie's shelter and the public toilets remain, both memorable survivors in their own right, particularly the latter with its tiled walls, black marble, mosaic floors and burnished copper piping. The other buildings were demolished in 1967.

A new swing bridge, designed by consulting engineer J. B. Brodie, was built by G. Halliday Ltd in 1907–08 at a

Rothesay Pier looking west [postcard 1908]

contract price of £2180. In 1908–09, under Brodie's direction, the same firm built an extension to Albert Pier in greenheart timber (£3741) and the solid quay wall at Albert Place (£1744). The present terminal built in 1992 is reminiscent of the first pier with its pagoda roof and red tiles. [2]

3. Skerryvore Lighthouse

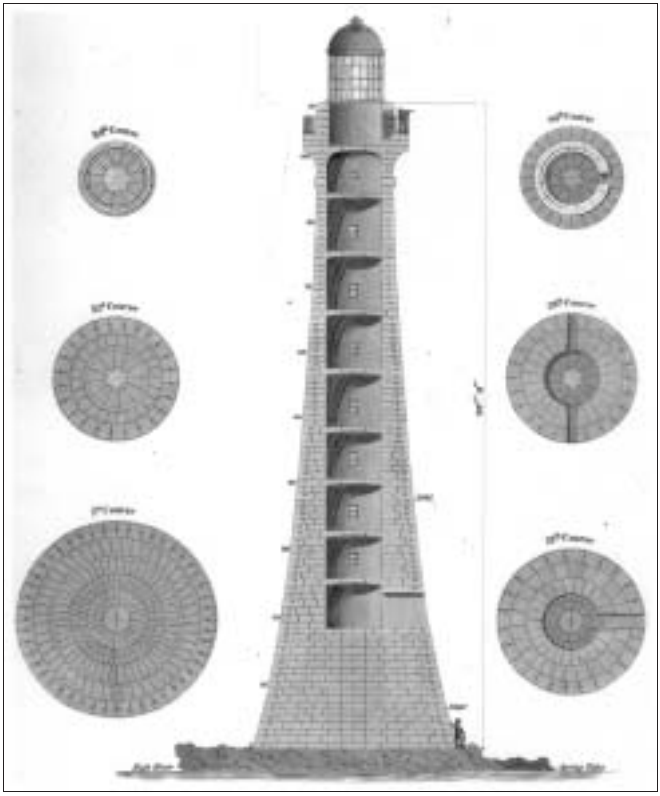
HEW 2456
NL 8405 2635

The creation of Skerryvore Lighthouse, on an occasionally 5-ton rock swept reef, exposed to the full fetch of the Atlantic 12 miles west-south-west of Tiree, was an extraordinary human achievement. Sadly, it took its toll on the health of its designer/resident engineer, Alan Stevenson, who also designed and directed the building of the Hynish shore station at Tiree with its pier, dock, stores, houses, reservoir and signal station.

The masonry tower supporting the lantern is $138\frac{1}{2}$ ft high with a diameter of 42 ft at the base, tapering to 16 ft at the top. It houses a flashing white light 150 ft above high water with a nominal range of 26 miles. Unlike the Bell Rock Lighthouse (2-10) its base is above high water level and its lower masonry courses were not dovetailed, resulting in a considerable cost saving in stone working. Apart from the first three courses, which were of Hynish gneiss which proved difficult to work, the lighthouse is built of granite from the Ross of Mull brought to Hynish shore station for dressing before shipment to the rock.

Skerryvore
Lighthouse

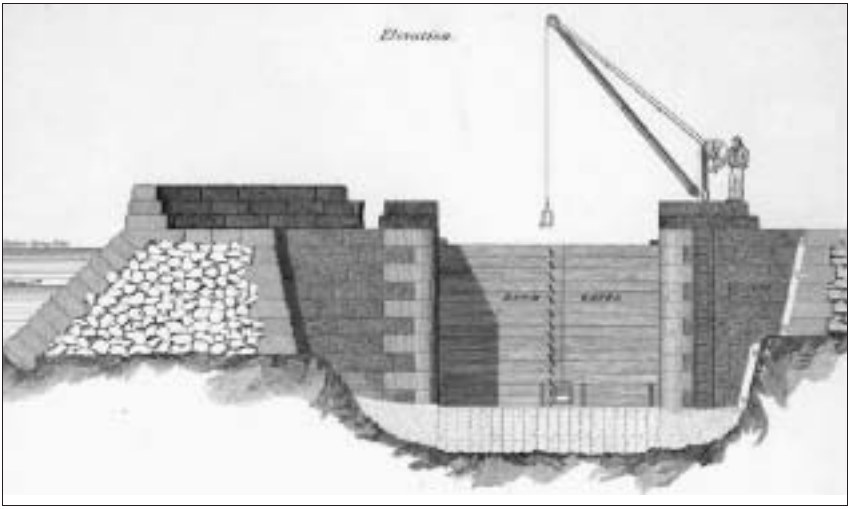
Skerryvore Lighthouse – sectional details [3]



The Hynish facilities included a dry dock 20 ft wide by 16 ft deep, the double entrance gate of which consisted of timber booms about 21 ft long which were lifted into position by the crane when required (see figure).

The method of conducting the work was basically similar to that used by his father at the Bell Rock Lighthouse, by first erecting a temporary barrack beacon on the reef from which to carry out the work. Construction of the beacon started in 1838, but it was destroyed by the sea before completion. A fresh start was made in 1839, the barrack was successfully erected, and the tower was built from 1840–43. The light was first exhibited on 1 February 1844. The cost was nearly £87 000.

This structure represented a landmark in scientific lighthouse design for mass combined with elegance of outline. Stevenson calculated the centre of gravity for towers of



Hynish Dock, Tiree [23, pl. XI]

five different curvatures, finding that of the rectangular hyperbola to be the best, resulting in a solid tower of 62 915 cu. ft with its centre of gravity 41.227 ft from the base. He took issue with Smeaton's analogy of an oak tree in lighthouse design, considering the action of the materials and forces to be quite different. But he acknowledged that, in general terms, Smeaton had implemented the correct design concept, which was for a tower with sides curved as 'a solid generated by the revolution' of the form of curve 'about its asymptote as a vertical axis', which had the lowest centre of gravity. The lighthouse's exemplary design was the model for Alguada Reef Lighthouse, Burma, erected from 1862–65.

The revolving dioptric light apparatus (operating by refraction through lenses instead of reflection from mirrors), was the most advanced in the world in 1844. Stevenson's innovation of prismatic rings below the Fresnel central lens belt further extended the dioptric effect. The prisms were made by M. Soliel at Paris under the direction of M. Léonor Fresnel. The light source was an intricate and finely executed oil lamp with four concentric wicks, now preserved at the Northern Lighthouse Board headquarters at 84 George St, in Edinburgh.

The lighthouse was severely damaged internally by fire in 1954 and refurbished in the following year. [3–5]

4. Dhu Heartach Lighthouse

HEW 1806
NM 1227 0305

From time immemorial the treacherous seas in the area bounded by the islands of Tiree, Iona, Colonsay and Islay claimed many victims. During the winter of 1865–66 no less than 24 vessels were wrecked or driven aground. In order to improve this situation D. & T. Stevenson, engineers to the Northern Lighthouse Board, recommended that a light be established on Dhu Heartach Rock some 14 miles south west of Mull. In 1867–68, under their direction, a shore station for the dressing and fitting of stone was established on the Island of Erraid, Mull, where an abundant supply of excellent granite was available. The construction method was similar to that used at Skerryvore, operating from a temporary barrack, except that, fortunately as it transpired, a wrought-iron instead of a timber framework was used to support the barrack room.

The barrack, which was erected in 1868, was soon put to the test when resident engineer Alan Brebner and 13 workmen found themselves unexpectedly occupying it during a five-day storm in August, when 'heavy broken water frequently rose far above the barrack, and falling on top, which was 77 feet above high water level, completely excluded all light for several seconds'.

Dhu Heartach Lighthouse

Northern Lighthouse Board

The 108 ft high tower, with the curvature of a parabolic frustrum, was built from 1869–72. It is 36 ft in diameter at the base and 16 ft at the top. The pre-cut stones were lifted from the lighter on to the landing place by a derrick crane. The stone was then placed in a truck running on rails which was pulled up to the top of the rock about 33 ft above high water by steam winch and was immediately laid because of lack of storage space.

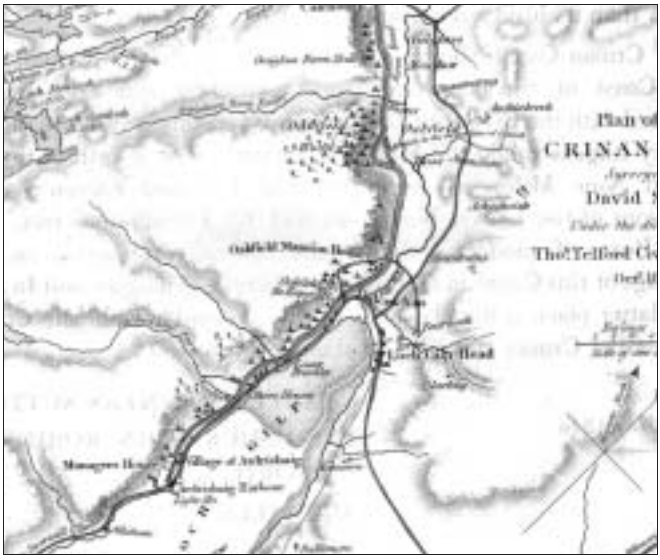
The flashing white light is at an elevation of 144 ft and has a nominal range of 20 miles. [6, 7]

Crinan Canal

HEW 0184

The first civil engineer to make proposals for this canal was James Watt in the early 1770s, but no action was taken then. In 1792 John Rennie, for the Duke of Argyll and other promoters, surveyed routes for this canal between Ardrishaig on Loch Gilp and Crinan to facilitate communication between Glasgow and Inverness and his proposals were adopted. The canal was to be 9 miles long and 15 ft

Crinan – aerial view



Crinan Canal map – Ardrishaig to Cairnbaan Locks [21st Report of Caledonian Canal Commissioners 1824]

deep, later amended to 12 ft, and the estimated cost was £108 000.

Work began in 1794 with completion planned for late 1796. But in the event, with labour shortages, construction difficulties and lack of funds, a depth of only 8 ft was achieved throughout by 1802. After further difficulties and water supply provision, the canal was pronounced finally complete in August 1809 at a depth of about 9 ft. The resident engineer was James Hollingsworth, who was succeeded by his son James in 1811.

The canal has 15 locks each 96 ft long × 24 ft wide. The summit at Dhaill reached a height of 64 ft above sea level. When constructed, the entrance locks at Ardrishaig and Crinan gave a depth of only 8 ft of water at low tide. These locks were replaced in 1933 by new locks in reinforced concrete giving normal accessibility at all states of the tide. The arrangements at Crinan are shown in the aerial photograph.

On the whole the canal was poorly built which made it vulnerable to storm and other damage. Good building stone was hard to obtain and the locks at the summit were built of rubble, which required more frequent repair, rather than ashlar masonry. In 1811 the dam at the feeder reservoir at Glen Clachaig collapsed and caused serious damage.

The canal was partly reopened in January 1812 and Telford consulted regarding its completion. In January 1813 he reported that the canal was in 'very imperfect condition'.

Hugh Baird was brought in, in 1814, to report on the reservoirs and by April 1815 the dams at Loch Clachaig and Camloch & Donloch had been raised (see map). But water was still in short supply at times and in 1835 Gibb heightened the dam at Loch-an-Add.

In 1816 the Exchequer made £19 400 available to the Caledonian Canal Commission for completion of the canal. It was then repaired and completed under Telford's direction by the contractor John Gibb with William Thomson as resident engineer, who served the canal well in this capacity until his retirement in 1847. Gibb replaced 15 lock gates, six bridges in cast-iron, widened several bends and repaired banks. This enabled the canal to be reopened in 1817 under the management of the Caledonian Canal Commissioners, with a water depth of 10–11 ft.

By 1835 the canal was deteriorating again and in the next five years various improvements were made under Thomson's direction, including the repair and sheathing in iron of the Crinan sea-lock gates and, in 1843, a new steamboat pier at Crinan.

In 1963, just 150 years after the first passage of Henry Bell's *Comet*, the canal was used by a hovercraft on its way from Dumbarton to the Thames. Today the canal is a major leisure attraction maintained by British Waterways and in regular use by fishing boats and pleasure craft. [8, 9]

5. Water Waster, Lochgilphead

HEW 0184/01
NR 8565 8795

A water waster was installed between Lock 4 and Oakfield Bridge in 1882 to remove surplus water from the east reach of the canal. It comprises two large iron buckets which are hung at each end of a beam pivoted at its midpoint, forming a see-saw. One arm of the see-saw and its bucket is housed in a concrete chamber which is connected to the canal and filled with water to the same level. The bucket is submerged (and full) and is designed to plug a horizontal orifice leading to a large conduit connecting to nearby Loch Gilp.

When the canal water rises to overflow level it is piped to fill the second larger bucket which, becoming heavier than the first, tips the see-saw. The plug is lifted and water

escapes to Loch Gilp. As the canal water level falls below the overflow pipe, water ceases to enter the second bucket, which empties via the small hole in its base. The see-saw then tips into its original position and closes the plug.

It is difficult to see the advantage of this ingenious device, which is reminiscent of Thom's water wasters at Greenock, over a simple side weir.

6. Oakfield Bridge, Lochgilphead

HEW 0184/02
NR 8561 8796

This bridge provided access to Oakfield House then belonging to Lochgilphead landowner John MacNeill. It is a swing bridge, pivoted on the west bank, and bears the inscription 'P. & W. MACLELLAN, Clutha Works, 1877'. It replaced an earlier bridge (see Crinan Canal map), possibly one of Gibb's iron bridges of 1817, and spans 35 ft from the pivot to the far bank and is 11 ft wide.

The timber deck is carried on hogbacked iron plate-girders with a maximum depth of 16 in. The manually operated swing mechanism is worked from the west bank, which allowed MacNeill to isolate his house if he so wished. [8]

7. Dunardry Bridge

HEW 0184/03
NR 8199 9120

At the west end of Dunardry locks is a horizontally retractable bridge which moves on rails and cantilevers out over the canal. Its deck is of timber 9 ft wide and a hinged timber ramp on the shoreward end spans between the access road and bridge deck.

Dunardry Bridge

Roland Paxton

When the bridge is to be opened, the ramp is first raised to a horizontal position allowing the bridge to run freely on the rails. The rails are 10 ft $8\frac{1}{2}$ in. apart and the bridge spans 23 ft 7 in. over the canal. The main beams are 14 in. × 7 in. timbers and two light iron towers 9 ft high carry tie rods 1 in. diameter which radiate to the main span and anchor arm.

The maker is unknown but the bridge was erected in 1900 replacing a turn bridge, possibly one of Gibb's iron bridges of 1817, which had developed foundation defects. [8, 9]

8. Clachan Bridge, Seil

HEW 0416
NM 7853 1969

Clachan Bridge is known as 'the bridge over the Atlantic' because it crosses a tiny arm of that ocean, namely the Clachan Sound, to join the Island of Seil to the mainland about 7 miles south-west of Oban.

The bridge is markedly humpbacked with an overall length of 300 ft and a single span masonry arch of 72 ft rising 27 ft above high water level and has a width between parapets of 15 ft. It was built in 1791–92 of roughly coursed rubble with long thin slabs forming the arch-rings. The central portion of the parapet is defined by small pyramidal blocks set above circular recesses 6 ft in diameter in the spandrels.

Before the bridge was built there was a suggestion in 1790 that the Sound be filled in, but this was rejected because of the passage required by fishing boats.

The bridge, commissioned by the Earl of Breadalbane and others, was to the design of John Stevenson of Oban, revised by Robert Mylne. Stevenson was also the contractor. Attribution of the bridge to Telford by some writers and on some postcards is incorrect. [10]

9. Connel Ferry Bridge

HEW 0200 B
NM 9111 3449

Connel Ferry Bridge, once the longest cantilever railway bridge in Europe after the Forth Bridge, is situated 5 miles north-east of Oban at the entrance to Loch Etive, where strong currents and the tide race ruled out the placing of the bridge piers in mid-channel. It was constructed between 1898–1903, on the Ballachulish branch of the

Connel Ferry Bridge [postcard 1903]

Caledonian Railway. The span of the bridge is 524 ft between the piers, but the inward-sloping support structure reduces the clear span to 500 ft.

The engineer was Sir John Wolfe Barry whose partners H. M. Brunel and E. Cruttwell were also involved. The contractor was Arrol's Bridge & Roofing Company of Glasgow, and the superstructure of the bridge contains about 2600 tons of steel mostly erected from 1900–03. The bridge originally carried a single line railway which ruled out the use of scarfed rail expansion joints as trains ran in each direction.

The bridge has a suspended span of 232 ft, large in comparison to the 524 ft total span, which in conjunction with the short anchor spans of 106 ft tends to give the bridge a rather awkward appearance. The struts are all rectangular box members (unlike the circular tubes of the Forth Bridge) with the stiffeners on the outside, somewhat like the welded seams of a Mini car.

In 1914 the bridge deck was modified to take both road and rail traffic and, subsequent to the closure of the railway in 1966, was adapted solely for road traffic. [11]

10. Isle of Eriska Bridge

NM 8982 4243

This bridge, carrying the approach road to the Isle of Eriska Hotel over an arm of the sea, consists of two double-triangular Warren truss spans of 74 ft. The girders are of riveted steel $4\frac{1}{2}$ ft deep overall with raking supports

Jim Shipway

Isle of Eriska Bridge

to their top flanges. The bridge has approach railings and ornamental iron gates for closing the bridge.

The bridge, which probably dates from ca.1900, has a timber deck 12 ft wide and a 20 ton weight restriction. The original country house, now the hotel, was built in 1884.

11. Telford Churches and Manses

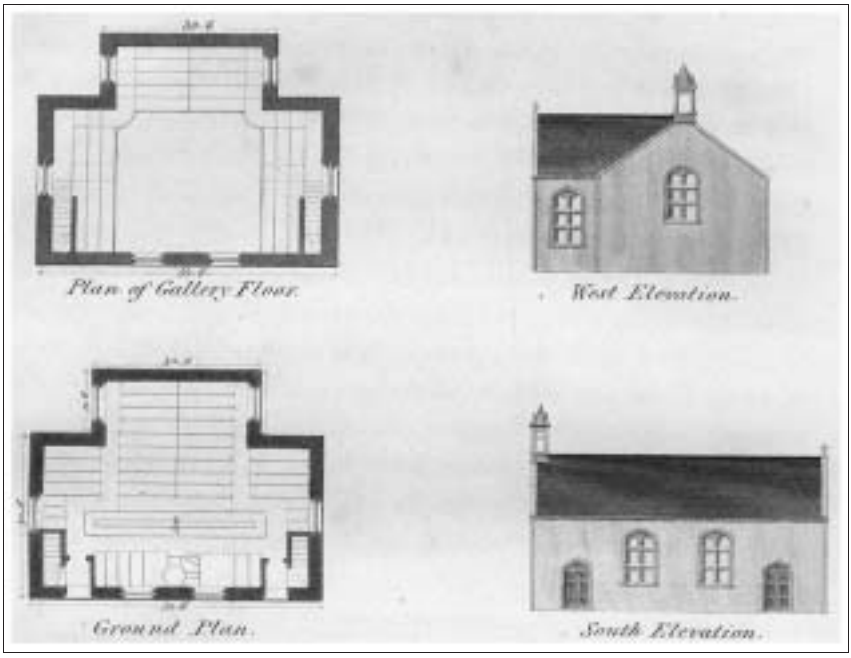
After the victory over Napoleon at Waterloo, Parliament responded to an appeal which said 'Let us show our thanks by immediately dedicating to God's honour a number of free churches and chapels…'. The Highlands and Islands, with their scattered communities, were seen to be in much need of churches and manses and in July 1823 an Act was passed which led to the building of 32 churches and 43 manses from 1825–30. The sites chosen were all north of a line from Aberdeen to Lochgilphead to the Oa, on Islay, and from there 300 miles northwards to Shetland (see map, which omits two sites in Orkney and two in Shetland).

Telford was given the task of approving designs, which were to cost not more than £1500, and organising the work. He asked three of his surveyors William Thomson, Crinan Canal resident engineer, James Smith, Inverness architect and Joseph Mitchell, to submit designs which he

Telford Churches and Manses map [6th Report of Highland Churches Commission 1831]

amended, eventually approving Thomson's. The Thomson/Telford church was a clever design, being easily adaptable from its basic plan to increase or decrease the seating; the standard design was to seat 312. The manses came in two styles, single-storey (Smith/Telford) and two-storey (Mitchell/Telford). Both churches and manses were to be durable and sufficiently robust to keep out the worst of the Highland weather.

The churches were constructed by various contractors and generally in keeping with the approved plans. Over the years, however, changes of use, modifications and alterations have taken place, and some of the churches are barely recognisable as 'Telford' or 'Parliamentary'. Two churches in this area that are little changed are at



Top: Telford Church – standard plan and elevation [6th Report of Highland Churches Commission 1831]

Jim Shipway

Duror Church

Duror (1827) built by Gibb & Minto for £1470 (HEW 2457/01 NM 9937 5528) and Iona (1828) built by William Thomson for £1503.

Duror Church is T-shaped in plan, 52 ft × 32 ft overall, with six wide Gothic windows, and a small spiky belfry on one gable. The windows, of metal framing, were all bought pre-made from James Abernethy, Aberdeen. These Highland churches, so nearly identical, were the forerunners of the 'kit' buildings of today. [12, 13]

12. Bridge of Awe, Taynuilt

NN 0306 2980

Although only the west arch and approaches of this bridge now remain, they are a substantial local reminder of the spirit of road improvement abroad in Scotland during the second half of the 18th century, partly financed by the proceeds of the Forfeited Estates after the Jacobite rebellions.

This bridge, carrying the Dalmally to Bonawe road across the Awe, was built in 1778–79 at a location subject to sudden intense floods. Whilst being built in 1778, a flood carried away the centring of the centre span, but the bridge was completed in 1779. It had three segmental rubble masonry arches of 45 ft, 59 ft and 47 ft span from east to west and the roadway is $13\frac{3}{4}$ ft wide. The names of the designer and builder have not been found.

The bridge, partly destroyed by a flood on 2 January 1990, was bypassed in 1938 by the present bridge about 100 yards downstream carrying the A85 road. [14]

13. Kelly's Pier, Bonawe, Loch Etive

NN 0070 3219

Kelly's Pier, of traditional drystone construction in granite, built in 1752–53, extends over 400 ft northwards into Loch Etive. It is 20 ft wide and enlarged at the head for the berthing of ships carrying iron ore from Cumbria and was built for, and possibly by, the Newland Company of Furness in Cumberland. A short extension in timber to reach deeper water was added later, probably when steamships were introduced, of which only the rotting timber piles now remain.

The lease of the nearby Bonawe Furnace was assumed by Alexander Kelly of Bonawe in 1863, from whom the pier

has taken its name. Repairs were made in 1960 and in 1994–95 a full scheme of repair by traditional drystone building methods was undertaken. The pier is now privately owned and still in use. [15]

14. Bonawe Iron Furnace

NN 0098 3187

Bonawe is said to be the most complete site of a charcoal-fuelled ironworks in Britain with extensive remains of an 18th/19th century ironworks employing at its peak 600 people. It was the second last and largest in the West Highlands, selected for its extensive forests of oak and birch which provided the charcoal for the smelting. Limestone obtained locally was used as a flux.

The furnace was built for Cumbrian ironmaster Richard Ford, who founded the Newland Company of Furness. The iron lintels over the tap holes are dated 1753 and 1757.

Ted Ruddock

Bonawe Iron Furnace

The iron ore was imported both from Lanarkshire and Cumbria and shipped to nearby piers on Loch Etive, including Kelly's Pier. The pig-iron produced was shipped back to forges in the south for making into finished products, and cannon balls produced at Bonawe were used in the Napoleonic Wars. The works were in almost continuous production for 120 years until they closed in 1876.

The blast for the furnace was obtained by large bellows, originally powered by a waterwheel fed by a lade, now dry, almost a mile long from the Awe to the wheel pit. The low breast-shot wheel existed up to the time of the second world war when it was removed for scrap. Materials were conveyed around the site by barrows along early tramways made from slate tracks.

The site, which included cottages for workers and Bonawe House, the furnace manager's residence, is now under the care of Historic Scotland. [15]

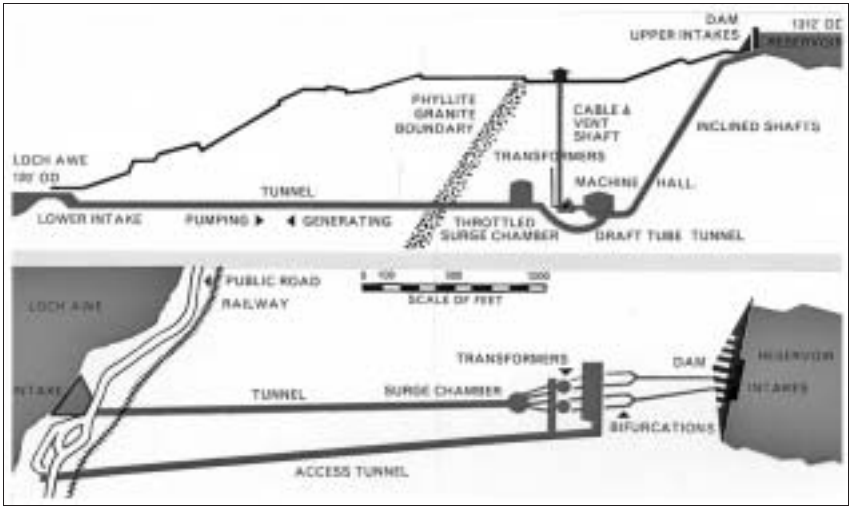
15. Cruachan Hydro-Electric Scheme

NN 0800 2775

Cruachan is part of the Awe scheme designed by James Williamson & Partners for the North of Scotland Hydro-Electric Board, and is a 440 MW reversible pumped storage development. It was built from 1959–65 and was the first large pumped storage installation in Scotland.

The operating head between the reservoir on Ben Cruachan and Loch Awe is 1200 ft, the highest in the world for this kind of plant. The power station and machine hall are entirely underground, located in a cavern 300 ft long and 120 ft high hewn out of the rock of the mountain.

The upper dam is of the massive buttress-type containing 115 900 cu. yards of concrete. It is 1037 ft long with a greatest height of 153 ft and crest 1315 ft above sea level. Generation of electricity is timed to occur during daytime peak loads on the supply system, using water flowing from the reservoir down to Loch Awe. Pumping is carried out mostly at night and at weekends, using surplus energy from steam generating stations elsewhere. The turbines are rotated in a reverse direction and lift the water from Loch Awe up to the reservoir on Loch Cruachan.



Awe Hydro-Electric Scheme layout scheme [NSHEB *Power from the Glens* 1963, 28]

The tail-race from the power station runs into Loch Awe not far from a visitor centre at the loch side with displays illustrating the scheme.

The A85 Tyndrum to Oban trunk road runs past the visitor centre. From 1967–74 the road was reconstructed and realigned on a reinforced concrete viaduct cantilevered out over, and with supporting columns in, Loch Awe. This work, of considerable technical difficulty, avoiding interference with the Callander & Oban Railway which ran

Cruachan Dam under construction [NSHEB *Power from the Glens* 1963, 30]

along the hillside some 50 ft above, is comparatively unknown. The engineers were W. A. Fairhurst and Partners and the contractors, Balfour Beatty. [16, 17]

16. Awe or Orchy Viaduct (Railway)

NN 1371 2807

An impressive double-triangular iron lattice truss viaduct built in 1878–79 on the Callander & Oban Railway crossing the Orchy at the head of Loch Awe 2 miles west of Dalmally. It is the longest viaduct on the line and has seven spans of 63 ft supported on short masonry piers and abutments. The line opened in June 1880.

Near Taynuilt, west of the Pass of Brander, is another Awe Viaduct (NN 0075 3120) of three spans built in 1879, with a double-triangular iron lattice truss of 103 ft 3 in., flanked on each side by a plate girder span of $51\frac{1}{2}$ ft, supported on tall masonry piers and abutments.

This final part of the railway to Oban was resurveyed by John Strain of Glasgow who became the engineer in place of Blyth & Cunningham. The contractor for both viaducts was W. & T. Adams. [18]

Awe Viaduct (Railway)

Highland Roads Commission (Argyll and Bute)

This Commission, for which Telford was the engineer and John Mitchell the inspector, improved about 100 miles of road in this area from 1804–21. Namely, on the Ardnoe (6.4 miles), Arran (6.9 miles), Ballenoch (1.82 miles), Crinan (0.32 miles), Glendaruel (18.97 miles), Riddan (1.82 miles), Islay (14.7 miles), Jura (16.09 miles), Keils (1.3 miles), Kilmelford (8.5 miles), Lockieside (12.31 miles) and Strachur (10.7 miles) Roads, and part of the Moydart Road, the surveys for most of which were done by Messrs Langlands.

The longest road, the Glendaruel, connected Rothesay with Inveraray, saving 97 miles on the post road route. The Glendaruel Road extended from South Hall, south of the Bute ferry, northwards through Glendaruel to Strachur on the Fyneside Road. It involved 19 miles of road making and a new twin 32 ft span bridge at Ballochindrain (NR 9953 8315) over 'the dangerous and rapid river in

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Highland Roads – bypassed section of Glendaruel Road

attempting to ford which lives are lost almost every season'. In 1805 leading 'memorialist' for improving the road, John Campbell of South Hall, and others estimated that a bridge could be built for not more than £300 sterling.

The Glendaruel Road was made from 1807–12 (January) by a contractor named Paterson at a contract price of £3480 plus £264 for the enlargement of small arches deemed to be of insufficient dimensions to carry off occasional floods from steep gullies on the vast flank of Cruach an Lochain. By 1815 the road was pronounced 'judiciously made' at a saving of £148 on the Commission's estimate. The contract repair cost was £8 12s per mile in 1815 dropping to £2 10s in 1816. The illustration shows a bypassed section of the original 10 ft wide road. (See Highland Roads Commission pre 4-1 for general details.) [19]

17. Aray Bridge, Inveraray

HEW 0675
NN 0981 0905

An architecturally-inspired twin-span segmental masonry arched bridge over the Aray with a conspicuous oculus (cylindrical opening) through the spandrel over the central pier. This feature enables the bridge to escape the unattractive appearance offered by two equal spans of 65 ft, referred to as an 'unresolved duality' in architecture.

The bridge was planned and erected from 1773–76. It was designed by Robert Mylne for the Board of Ordnance and the contractor, J. Brown. The Duke of Argyll, whose seat Inveraray Castle overlooks the bridge, is said to have influenced its design, particularly the parapets. The steep approaches must have been a trial to horses pulling heavy carts. The bridge is now operated as a single-lane carriageway controlled by traffic lights.

The elegant Garden Bridge (NN 0955 0950) just upstream, built for the Duke of Argyll from 1759–61, with an elliptical masonry arch and spandrel medallions was designed by John Adam and built by David Frew. [20, 21]

18. Brenchoillie Bridge, Furnace

NN 0233 0190

A small twin-arched masonry bridge with a pier in mid-stream on the access road to Brenchoillie Farm. In the spandrel over the cutwater on both elevations is an ornamental 3 ft diameter blind oculus recessed about 6 in.

Jim Shipway

into the random rubble masonry face. The arches are segmental and of 15 ft span between a 4 ft wide pier and the width between parapets at the crown is 12 ft 6 in.

Brenchoillie Bridge

The bridge, a good example of a late-18th century precursor of the Highland Roads Commission bridges, possibly influenced by Inveraray Bridge, is on what was formerly an old road linking Loch Aweside and Loch Fyneside, now off the A83 about 1 mile north of Furnace.

19. Glen Shira Dam

NN 1634 2020

The Glen Shira Hydro-Electric project was designed to harness the Shira and Fyne and adjacent streams between Loch Fyne and Loch Awe. The Shira Dam is the centrepiece of the scheme and is 133 ft high and 2250 ft long. It is a mass concrete round-head buttress-type dam, the heads of the buttresses being of angular shape rather than truly curved as at Sloy Dam. The project generates 45 MW.

The geography of the catchment area led to the construction of a smaller concrete and earth filled dam, 58 ft high, below the main dam to fully utilise the storage potential. This lower reservoir is also used for pumped storage to top up the upper reservoir as required. The high-pressure tunnel to the main dam's power station is unusual in that it is a partly sloping shaft. It was driven almost entirely from the bottom, because the slope allowed most of the spoil to be removed with very little mechanical assistance.

The original scheme was conceived by James Williamson. The consulting engineers for the works as built were Babtie, Shaw & Morton and the main contractor was A. M. Carmichael of Edinburgh. The scheme was completed in 1956. [22]

20. Allt-na-Lairige Dam

HEW 1419
NN 2524 1744

The Allt-na-Lairige Dam has the unique distinction being the first (and so far the only) large pre-stressed concrete dam constructed in Britain. Others, pioneered by the French engineer Andre Coyne, exist on the Continent and elsewhere.

The dam is part of the Glen Shira Hydro-Electric Scheme and is situated in a valley in the hills some 8 miles north-east of the head of Loch Fyne. The structure was designed by J. A. Banks of Babtie, Shaw & Morton, Glasgow, and built by Marples, Ridgway & Partners. It was completed in 1957.

It is 73 ft high at its maximum and some 1360 ft long. The slender section was achieved by groups of pre-stressing anchors each consisting of 28 high-tensile steel bars, each $1\frac{1}{8}$ in. in diameter, located at 21 ft centres and extending downward from the crest of the dam to a depth of 27 ft into the rock below its base. The associated power station is about 2 miles downstream on the east bank of the River Fyne. [23]

21. Garron Bridge

NN 1139 1009

A handsome single-span segmental arch bridge of about 40 ft span over the Garron about 2 miles north-east of Inveraray. It was designed for the Board of Ordnance by Roger Morris, overseer John Adam, and built in 1748. It is strongly ornamented, with masonry baluster parapets leading to solid work at the crown, pronounced shaped abutments on the elevations surmounted by masonry globes and a denticulate string course. The bridge has been bypassed on its north side by a modern road bridge which affords a good view of its predecessor.

Another attractive architecturally designed example, about 600 yards north, is Dhu Loch Bridge (NN 1140 1060) which has a segmental arch of 60 ft span over the

Garron with an arch-ring increasing in depth from the keystone to springing from 39–44 in. but with a cosmetically pronounced taper in each façade. This bridge was designed by Robert Mylne and erected in 1785 by J. Tavish. [21, 24]

22. Strachur Estate Bridge (Private)

NN 0908 0157

A good local example of a small late-18th century estate bridge over a stream in the grounds of Strachur mansion completed in ca.1783. The masonry arch, presumably contemporary, is segmental of 26 ft span and 14 ft wide between parapets. It has two blind oculi of 3 ft diameter set in the abutment pilasters flanking the arch. The masonry is coursed rubble stone set in lime mortar. The architect and builder have not been traced.

23. Arrochar MoD Jetty (Private)

HEW 1877
NN 2883 0387

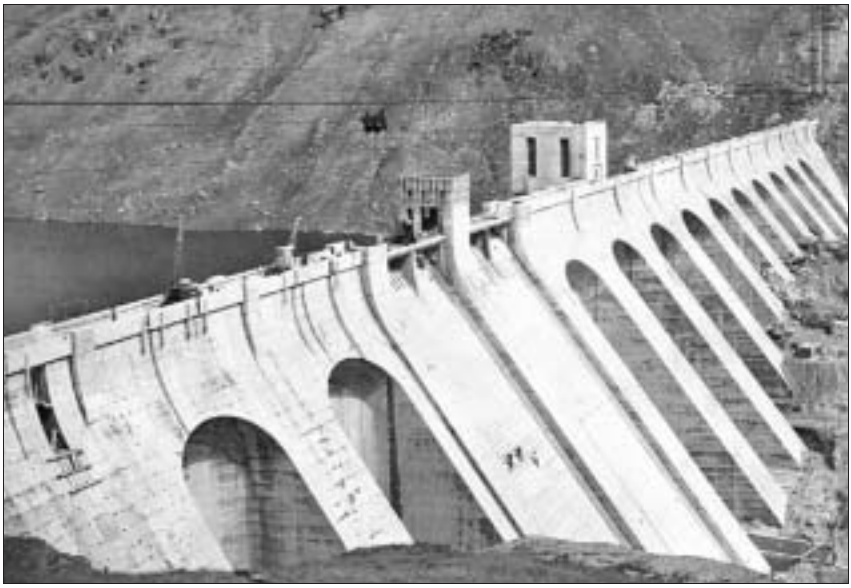
This jetty is an early reinforced concrete structure on the west side of Loch Long constructed ca.1915 for the Admiralty Torpedo Testing Station. The jetty comprises a deck with supporting columns and bracing, and bears a strong resemblance to a similar jetty at Suishnish, Isle of Raasay. Both are understood to have been designed about the same time by F. A. MacDonald & Partners of Edinburgh but are also included in Sir Robert McAlpine's *McAlpine Contracts* (ca.1919, 85) as being built by them. McAlpines also state that they 'were wholly responsible for the design of the reinforced concrete pier'. We have not been able to resolve this apparent contradiction! No public access is allowed. [25]

24. Loch Sloy Hydro-Electric Scheme

NN 2887 1107

The scheme in the mountains to the north-west of Loch Lomond, opened in 1950 by Her Majesty the Queen, involved raising the level of the loch 150 ft by creating a dam 160 ft high.

The dam is of the concrete massive-buttress type, the first of its type in Scotland, 1200 ft long, and comprises 13 solid buttresses, each 26 ft wide and 65 ft apart. There are solid gravity-dam sections at either end running into the



Loch Sloy Dam [46]

adjacent hillsides. A roadway 10 ft wide is provided along the dam top (see figure and note the three men working on the spillway).

Because of faults and irregularities in the mica schist under the dam it was necessary in one place to excavate to 60 ft below rock level. This rock was unsuitable for concrete aggregate and a quarry of suitable hard stone was opened near Coiregrogain about 2 miles from the dam. Nearly 300 000 tons of crushed rock were transported from the quarry to site on an electrically driven conveyor belt at gradients of up to 1 in $6\frac{1}{2}$ along the boulder strewn shoulder of Ben Vane.

During construction, two cableways with a span of 1350 ft were used to lay 3000–4000 cu. ft of concrete per week. The tunnel from the reservoir passing under Ben Vorlich to the pipelines above the power station is from 13 ft 6 in.–15 ft 4 in. diameter, in reinforced concrete and about 10 000 ft long. The work had to proceed in appalling weather and, in 1947, 1948 and 1949 respectively, rainfalls of 106 in., 163 in. and 153 in. were recorded. Severe gales occurred frequently.

An important safety feature within Ben Vorlich, required to limit the great fluctuations of pressure possible when the

Loch Sloy Power Station [46]

flow of water in the tunnel is suddenly stopped or started, is a concrete-lined vertical shaft in the tunnel top of 26 ft diameter and 273 ft high feeding horizontal surge chambers.

The turbine hall at the power station contains four vertical shaft Francis-type turbines designed to give a full output of 46 000 hp on a gross head of 910 ft. When all are running at full load nearly 1 000 000 gallons/minute passes through them generating 130 MW.

The consulting engineers were James Williamson & Partners, and the main contractors, Balfour Beatty & Co. Ltd (dam); Edmund Nuttall & Sons & Co. (London) Ltd (main tunnel); Sir William Arrol & Co. Ltd (pipelines), and others. [26, 27]

Callander & Oban Railway

This 71-mile railway was incorporated in 1864 and obtained its Act in 1865. It was completed in stages owing to a persistent shortage of capital, limiting its construction. It is notable for some early mass concrete construction at underpasses, culverts and bridges. The line owed its

existence almost solely to the energy and perseverance of its first secretary, John Anderson.

The first section from Callander to Killin, $17\frac{1}{2}$ miles, was engineered by Blyth & Cunningham, built by John Mackay, and completed in 1870. A striking scenic feature was the climb through the pass of Glen Ogle. The second section ran from Killin to Tyndrum, a further 17 miles, and was opened in 1873. The contractor was Easton Gibb of Cardiff.

A further 12 miles to Dalmally formed the third section, opened in 1877, and the final section of $24\frac{1}{2}$ miles to Oban was completed in 1880. This section had a new engineer, John Strain, and different contractors for approximately equal 12-mile lengths. The line was partly closed in 1965 after a rock landslide in Glen Ogle, but the Crianlarich–Oban section remains in operation. [28, 29]

25. Etive Bridge and New Glencoe Road

NN 2650 5390

Etive Bridge

This striking if rather heavy-looking reinforced concrete bridge carrying the A82 over the Etive was built in 1931–32 by W. Tawse Ltd to the design of Messrs. J. McGregor, L. R. Sutherland and W. H. Hunt at a total cost of £3352.

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Glencoe – road cutting and bridge [J. B. White Ltd, Dundee ca.1932]

The bridge has a single span of 99 ft and an 18 ft wide carriageway suspended from the arch by reinforced concrete hangers. The hinges and rockers are of the same material.

The construction of each tied arch required substantial formwork, steel fixing and the pouring of concrete high in the air. The arch had to be propped for some time to allow the concrete to set. This propping had to be supported by the bridge deck which, in turn, had to be supported from the river bed. Similar bridges were built at the Water of Tulla, Glenorchy (NN 3130 4440), on the same road about 6 miles south, and Strathy, Sutherland (NC 8362 6519, 5-47), now replaced.

The 30.3-mile road project across Rannoch Moor and through Glen Coe, of which these bridges and also the 4/3 span awkward skew Gorge Bridge (illustrated) formed part, was a job creation measure costing about £512 000, financed by the government's Road Fund obtained from vehicle taxation. The 18 ft wide new carriageway commenced at Glencoe village and connected with the Dalmally Road near Tyndrum, and gradients were reduced from 1 in 5 maximum to 1 in 20 maximum, the Rannoch Moor summit was reduced from 1457 ft to

1144 ft above sea level, and there was a saving in rise and fall of 1155 ft. The work was carried out under annual rainfall conditions of about 100 inches per annum from 1928–32. The contractors were Wm. Tawse Ltd, John McColville, Cardiff, Alston Limestone Co. Ltd, Newcastle upon Tyne. [30, 31]

26. Ballachulish Bridge

NN 0520 5975

This bridge over Loch Etive, erected in 1974, replaced the Ballachulish Ferry on the A82 road between Glencoe and Fort William. An arch bridge was originally suggested because of the scenic nature of the site, but eventually the somewhat utilitarian asymmetrical N-truss was chosen. Various paint schemes have been tried of which the present dark green olive colour blends in well with the landscape.

Jim Shipway

Ballachulish Bridge

The bridge has spans from the south of 95 ft, 600 ft and 269 ft in the form of a continuous beam. It was created as a design and build project and constructed in steel by the Cleveland Bridge & Engineering Company and superintended by consulting engineers W. A. Fairhurst and Partners.

By way of contrast, about 25 miles west is the Ardtonish Estate suspension footbridge [NW 6992 501] erected in 1892. Although of less than 40 ft main span, and late for a wrought iron example, it is probably unique in Scotland in having a single Catenarian suspension cable (iron rod) with walk-through cradle-type hangers beneath supporting a timber deck. It crosses the Abhainna Ghlinne Ghill water and was designed by Samuel Barrham, architect.

27. Killin Viaduct

NN 5743 3275

The Killin Railway joining Loch Tay to the Callander & Oban Railway at Killin Junction was built from 1883–85 and is now disused and walkable. It crossed the Dochart on this 45° skew, mass concrete and masonry viaduct. The piers, spandrels and parapets are of masonry and the arch-rings of concrete. Completed in 1885, the structure has a claim to be Scotland's earliest concrete viaduct. Its five mass concrete arches, which are 2 ft thick, span 30 ft on the square and 42 ft 5 in. on the skew.

The arches were each built in a day, their 2 ft thickness being built up in 6 in. layers. The Board of Trade inspector asked for a core to be cut from one of the rings as proof of its homogeneity. A masonry arch of this thickness would normally have taken about 20 minutes to core but, in this time, much to the contractor's satisfaction, the core had penetrated only 7 in. The concrete is a 1 to 5 mix of cement and crushed rock.

The engineer was John Strain and the contractor, John Best (MacDonald of Skye, the original contractor for line, went bankrupt before the viaduct was completed). [18]

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