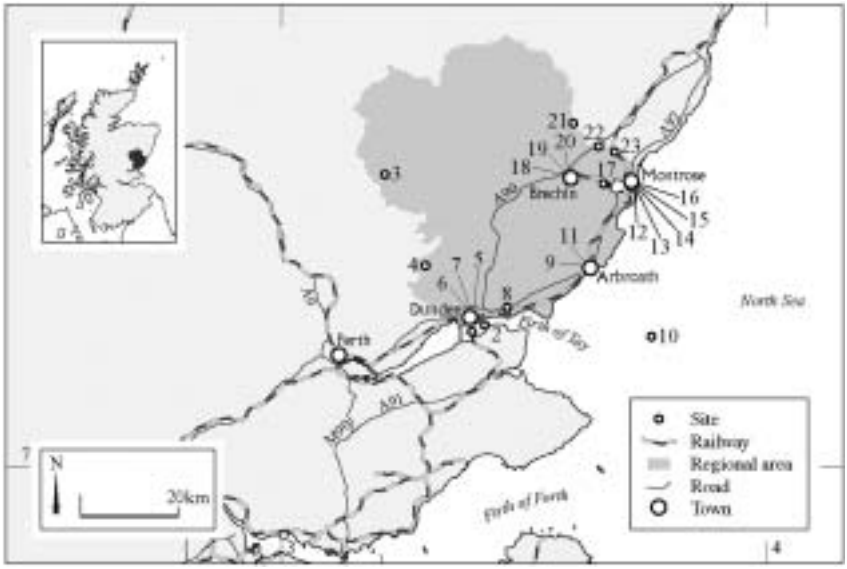


Angus

1. Tay Bridge (Railway)
2. Tay Road Bridge
3. Glen Isla School Footbridge
4. Newtyle Station
5. Dundee Harbour
6. Balgay Park Footbridge
7. Cox's Stack, Dundee
8. Linlathen East Iron Bridge, Dundee
9. Arbroath Harbour
10. Bell Rock Lighthouse
11. Keptie Hill Water Tower, Arbroath
12. Montrose Bridge
13. South Esk Viaduct (Railway), Montrose
14. Montrose Harbour
15. Fisherhills Viaduct (Railway)
16. Lower North Water Bridge, Montrose
17. Bridge of Dun, Montrose
18. Stannochy Bridge
19. South Esk Bridge, Brechin
20. Round Tower, Brechin
21. Gannochy Bridge, Edzell
22. Upper North Water Bridge
23. Marykirk Bridge

2. Angus

Introduction

Angus is entered from Fife either by road or rail via impressive bridges over the Tay some $1\frac{1}{2}$–2 miles long connecting with Dundee (2-1, 2-2). From the train can be seen the pier stumps of the 1878 bridge which fell the following year in one of the world's great bridge disasters, resulting from its design and construction being inadequate to resist strong wind pressure, and which ruined the reputation of its engineer Sir Thomas Bouch.

Dundee harbour (2-5), one of Scotland's major ports, owes its modern development to the skills of Smeaton, Telford, Leslie, Ower. It is now, with the added tourist attraction of the Antarctic exploration ship *Discovery* in a new dock within the former ferry harbour, an attractive place to visit. Smaller harbours included are at Montrose (2-14) and Arbroath (2-9), with its boat repair slipway and architecturally styled Bell Rock Lighthouse Signal Station, now a museum from which, on a clear day, 11 miles out to sea, can be seen the world famous Bell Rock Lighthouse (1811, 2-10), engineered by John Rennie and Robert Stevenson.

Although there is a 19th century water tower at Montrose, now a dwelling, the most prominent and architecturally extravagant water tower in the area is at Keptie Hill, Arbroath (1885, 2-11).

Masonry bridges are well represented at Brechin over the South Esk (2-19), part of which is thought to date from ca.1469; Upper North Water at Pert (ca.1520, 2-22); Gannochy at Edzell (1724, 2-21); Lower North Water near Montrose (1770–75, 2-16); Bridge of Dun (1785–87, 2-17); the bridges over the South Esk at Montrose, which constitute an instructive example of development of bridge building at the same site from 1796–2004 (2-12); a fine Robert Stevenson example at Marykirk (1814, 2-23); and Stannochy (1826, 2-18), influenced by it. An early iron suspension bridge was erected at Glen Isla by Justice & Company of Dundee in 1824 (2-3).

An unusual item requiring extraordinary skills in its construction is the remarkably well proportioned Round Tower at Brechin now some 1000 years old (2-20).

Other Dundee works noted are, the former Dundee & Newtyle Railway, planned in 1825 before steam locomotion was established – it crossed the Sidlaw Hills by means of steam-operated inclined planes (2-4); Linlathen East Bridge, possibly Scotland's earliest surviving iron bridge (2-8); Balgay Park cast-iron bridge (1872, 2-6); and Cox's Stack, at 282 ft 10 in., the tallest surviving example of an industrial chimney in Scotland. It is styled in the attractive form of an Italian campanile tower in polychrome brickwork (1866, 2-7).

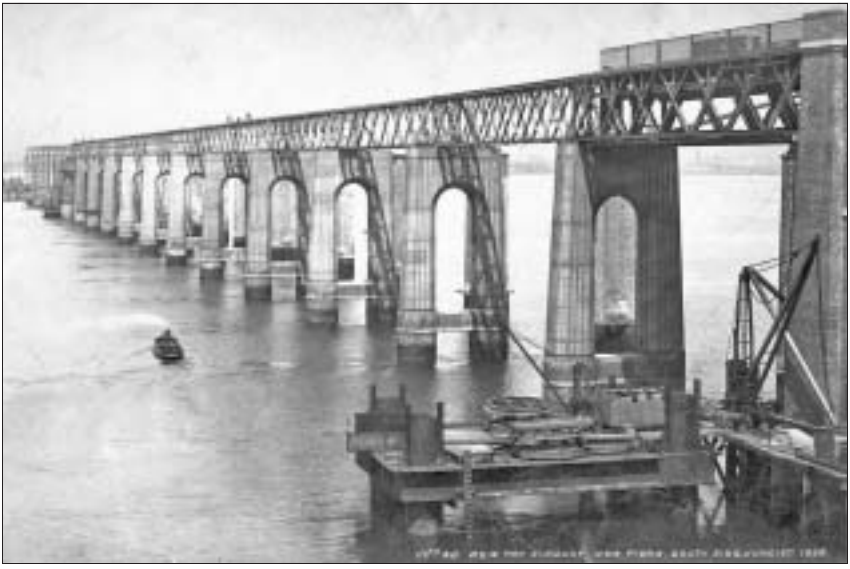
1. Tay Bridge (Railway)

HEW 0199
NO 3914 2785

The Tay is a shallow estuary, nearly 2 miles wide at Dundee, with many sandbanks and a depth of water rarely exceeding 50 ft. The present railway bridge is the second at the same site, the first having collapsed barely 18 months after its opening (see [3]).

The first Tay bridge was designed in the 1870s for the North British Railway by its Engineer Thomas Bouch and carried a single-line railway on 89 spans. Thirteen of these spans were navigation spans, higher and longer than the others. The spans were originally to have been carried on tall piers of brickwork founded on solid rock, but owing to faulty site investigation and difficulties with the foundations, the majority of the piers had to be lightened and were made of poorly constructed ironwork which was insufficiently anchored at its base. In a gale on 28 December 1879 all the navigation spans fell while a train was crossing and 75 lives were lost. Although the bridge had stood for only 18 months it had more than demonstrated its usefulness, and the North British Railway determined to rebuild it.

The present bridge, 10 711 ft in length and double track, was engineered by W. H. Barlow from 1881, assisted by his son and partner Crawford Barlow. Although structural



Tay Bridge under construction 1886

Roland Paxton

steel was coming into use, no substantial bridges in Britain had been completed using it, and it was decided to use 21 078 tons of wrought-iron girders capable of bearing 22 tons/sq. in. in tension, plus 3588 tons of steel in the flooring. The contractor was William Arrol, who designed innovative temporary works, including pontoon jack-up platforms (see foreground of illustration). He proved more than equal to this mammoth task.

Construction took place from 1882–87, on a parallel line 60 ft upstream from the old bridge. The spans were kept the same as Bouch's bridge, which allowed the original iron girders (which were sound, unlike the ironwork of the piers) to be reused as facing girders except on the navigation spans which were entirely renewed. The new piers were substantial and well-anchored.

Network Rail's recent sensitive refurbishment of the bridge won the Saltire Civil Engineering Award for 2003. [1–3]

2. Tay Road Bridge

NO 4156 2946

Although a high-level road bridge crossing of the Tay was considered as early as 1929, it was not until March 1963 that construction began on the present bridge which was opened to traffic in August 1966. It was then the longest river crossing of any road bridge in Britain, obviating a 50-mile detour.

The 7365 ft long bridge has 42 spans (31 of which are 180 ft span) with a deck rising from 32 ft above sea level at Dundee to 125 ft in Fife – a gradient of 1 in 81. To reduce the cost of construction the line chosen for the bridge had its north landfall at the old tidal harbour in Dundee, which was infilled and the site used as a fabrication yard by the bridge contractors.

Concrete foundations support twin columns of developing parabolic shape. These were founded on bedrock where the water was shallow and, in deeper water, carried on pile groups driven to the bedrock. The columns support steel-plate box girders 12 ft wide by 10 ft deep with a composite top flange of concrete forming the roadway. The girders range from 10 to 20 ft deep over the navigation channel. They were fabricated in the construction yard at Dundee, and then rolled into position along a service

bridge at low level before being lifted and positioned on the columns.

These beams, each weighing 200 tons, were fabricated of steel plate and stiffened internally to give them a maintenance free exterior profile. They act compositely with the concrete deck of the roadway to form T-beams which support, along their inner edge, precast concrete units that form both a central duct for services and a pedestrian footpath. Overall, 140 000 tons of concrete and 12 750 tons of steel were used. Each carriageway is 22 ft wide and the central footway 10 ft.

The cost of the bridge and its approaches, excluding land and interest charges, was £4.8 million. It was designed by W. A. Fairhurst & Partners. The main contractor was Duncan Logan (Contractors) Ltd. The box girders were fabricated by the Caledon Shipbuilding and Engineering Co. Ltd, Dundee, with Sir William Arrol & Co. Ltd, Glasgow. These firms were subcontractors to Dorman Long (Bridge & Engineering) Ltd, who had the contract for the steelwork and were responsible for the steelwork erection. [4]

3. Glen Isla School Footbridge, Angus

HEW 0413
NO 2127 6030

This light rod-stayed suspension footbridge was designed and erected in 1824 by John Justice Jnr of Justice & Co., Dundee. It is of light wrought-iron construction with a span of 62 ft and 3 ft 5 in. wide timber deck. There are four $\frac{9}{16}$ in. diameter inclined stays on each side extending from the simple H-section portals to the deck. In addition there are two suspension cables on each side extending between the portals at about half height and incorporated into the handrailing. Three back-stays on either side of the towers anchor the system to the rock. The portals are slightly off-plumb, probably due to foundation settlement.

A bold local effort probably influenced by earlier Scottish suspension bridges, accounts of which had been widely promoted by Robert Stevenson in 1821. [5, 6]

Dundee & Newtyle Railway

NO 3041–
NO 4030

This was one of Britain's most unusual railways conceived before steam locomotion was established. The $10\frac{1}{2}$-mile railway was planned in 1825, obtained its Act in 1826, and

opened in 1831 from the top of Dundee Law, and throughout in 1832, with an extension to Dundee Harbour in 1837. It linked Dundee with Newtyle in the fertile valley of Strathmore by an almost direct route over the Sidlaw Hills reaching a maximum height of over 500 ft above sea level.

The railway was an ingenious, popular but uneconomic venture. It required three inclines worked by stationary steam engines with level sections of track between, worked at first by horses and from 1833 by steam locomotives. By means of a 40 hp engine at the Dundee Law incline, the railway was lifted 233 ft at a gradient of 1 in 10, one of the steepest on a public railway, then, after about $4\frac{1}{2}$ miles, the Balbeuchly incline provided a further lift of more than 200 ft at 1 in 25. Finally, after another level $4\frac{1}{2}$ miles or so, the railway descended to Newtyle via the Hatton incline of just over 1000 yards at 1 in 13. Between 1860 and 1868 long loops replaced the inclined planes and allowed locomotive working throughout. The line was closed to passenger traffic in 1955.

The railway was planned and substantially executed by Charles Landale from 1825 to 1829, when he was replaced after the project encountered engineering and financial difficulties. The work was completed by George Lish. Matthias Dunn and Nicholas Wood also reported.

Vestiges of the track, earthworks and inclines can still be traced in many places to give an impression of the project, although the 330 yards tunnel which gave so much trouble to construct in soft volcanic rock is now sealed at both ends. [7–9]

4. Newtyle Station (Old)

HEW 2493/01
NO 2957 4147

The view shows Newtyle Station as it existed from ca.1835–50 with the Hatton incline and its engine behind. The three-opening train-shed does not seem to have existed when the line opened in 1831, being built within the next few years as passenger usage developed. The earliest surviving buildings in the view include the stepped base and post of the former swivel-crane to the left of the train-shed and the artisans dwellings built in consequence of the arrival of the railway.

The present large rubble masonry train-shed with elliptical arched openings on the site of the original train shed

Newtyle Station ca.1835–50 [40]

probably dates from the 1860s. The Caledonian Railway took over the line in 1865. The station closed in 1951. [10]

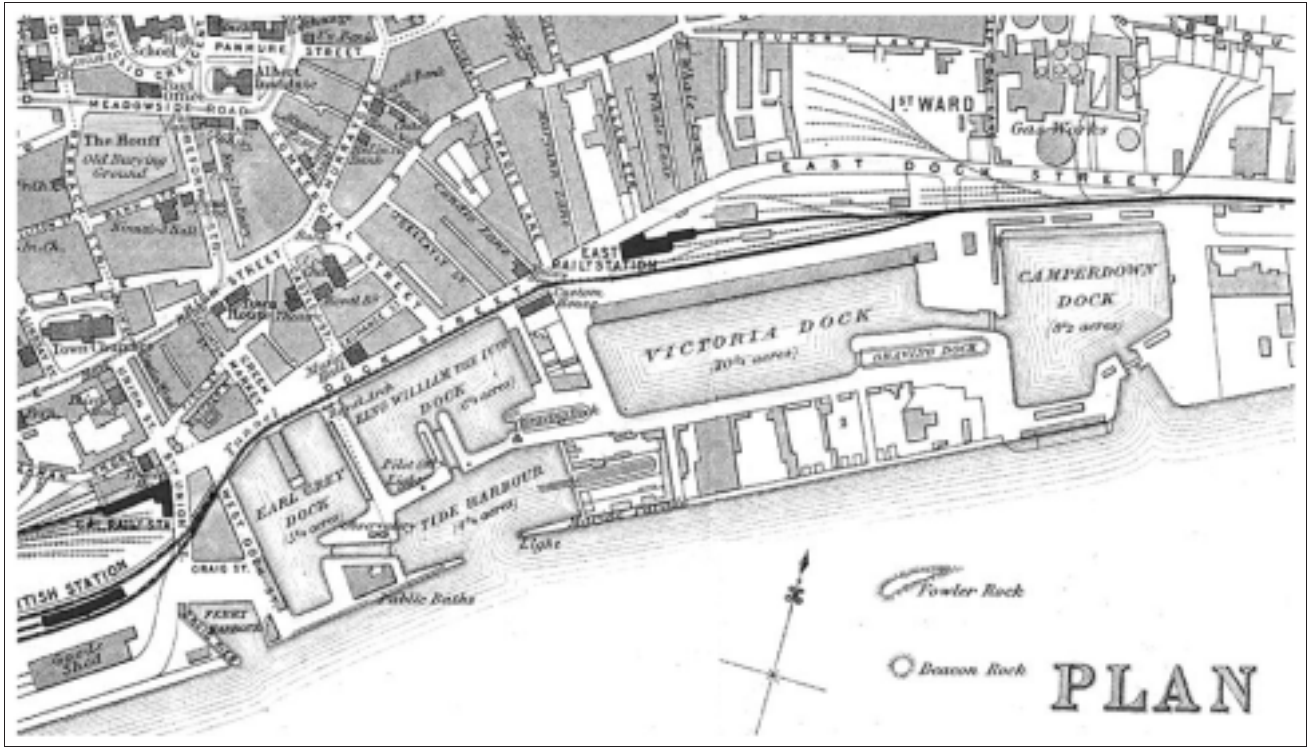
5. Dundee Harbour

HEW 1010
NO 4096 3037

Smeaton proposed improvements to the old harbour in 1770, which were partly executed, but it was not until 1814 that Telford made substantial plans for a modern harbour. Work began in 1815 and in 1825 the first floating dock, later named the King William IV, with an area of $6\frac{1}{4}$ acres and a depth of $19\frac{1}{2}$ft, was opened. David Logan was the resident engineer from 1815–21 and was succeeded by his cousin Peter Logan.

From 1829 James Jardine, presumably in consultation with Telford, made proposals for a considerable eastward extension of the harbour involving two floating docks and another tidal harbour. In 1830, Telford employed John Gibb to plan the Earl Grey Dock, five acres in extent and $19\frac{1}{2}$ft deep, which was completed in 1834. James Leslie acted as resident engineer for this work from 1832.

These improvements at Dundee Harbour from 1815–34, carried out under Telford's direction, were then second only in importance in Scotland to those at Aberdeen. An idea of the harbour's extent can be gained from the plan



Dundee Harbour plan [Groome's *Gazetteer of Scotland* (1885)]

Dundee Harbour from east side of entrance [engraving of a drawing by W. H. Bartlett, Virtue, 1840]

and engraved view looking towards Earl Grey Dock from the east side of the tide harbour. On the right is the entrance to King William IV Dock, on the west pier of which can be seen the lighthouse which is all that now survives in the extensive redevelopment that has taken place since the Tay Road Bridge was built.

To the west of Earl Grey Dock, Craig Pier and the small adjoining harbour designed by Telford for the Tay Ferry became operational by 1821. This harbour, part of the original masonry of which can still be seen, provided in 1993, at its west side, an appropriate home for the new dock created for the historic Dundee-built Antarctic exploration ship *Discovery*, of Scott, Wilson and Shackleton fame, now a major tourist attraction.

For more than a decade, until 1846, Leslie acted as Harbour Engineer conducting extensive further improvements, including an East Tidal Harbour (see view). Leslie's successor, Charles Ower, was responsible for extending the East Tidal Harbour into the Camperdown and Victoria floating docks, opened in 1865 and 1876 respectively.

The fish dock was commissioned in 1900 under the supervision of Ower's successor, George Buchanan, and in 1903 the old timber sea wharves were replaced with reinforced concrete using the Yorkshire–Hennebique system under the supervision of J. Hannay-Thompson, the general manager and engineer. This work included the first reinforced-concrete bridge in Scotland, a Hennebique

Discovery Dock at former Craig Harbour

arch bridge of 28 ft span over a sett-paved slipway, now redeveloped [NO 4120 3025].

From 1964 to 1967 the King William IV and Earl Grey docks were in-filled to accommodate the Tay Road Bridge approaches. The modern *Discovery* dock was constructed in the ferry harbour formed by Craig Pier. Little of its original construction is now visible.

The harbour now comprises a tidal basin (the old fish docks) and the Camperdown and Victoria floating docks. The walls are of sandstone blocks, founded on rock or stiff clay. The wharves generally are of reinforced concrete, of which some 500 ft are provided. There also remains an impressive Customs House built in the Greek style of architecture in 1843 to the design of James Leslie and John Taylor. [11–13]

6. Balgay Park Footbridge

NO 3759 3074

This elegant cast-iron arch footbridge, with a main span of $77\frac{1}{2}$ ft clear and an ornamentally bracketed horizontal span on each side of $16\frac{1}{2}$ ft, was erected in or soon after 1872 by Dundee Town Council. It crosses a valley separating the Western Necropolis cemetery from Balgay Park, the

Balgay Park Footbridge [photograph ca.1890]

opening of which in 1871 is recorded on the bridge plaque. Each main arch 'I' beam is cast in three parts, bolted at their ends, and has a rise of $10\frac{3}{4}$ ft. The footway, originally timber, has a clear width of 8 ft and is about 42 ft above the roadway.

The bridge was designed by George Hird of the Burgh Engineer's Department and the tender of Messrs. Macdonald of £500 for its erection was accepted in April 1872.

A proposal of 1902 to place three strands of barbed wire horizontally along the bridge, on brackets adjoining each parapet, to 'ensure greater safety to the public' was approved and then rescinded. In 1929 the bridge, by then with a reinforced concrete deck, was repaired and strengthened by the Council's works department and Caledon Shipbuilding and Engineering Co.

This bridge is an outstanding local example of a traditional type which by 1900 had been largely superseded by the steel bridge. It is in a popular and environmentally dramatic setting. Although the bridge is superficially in a poor state of repair and closed at present it is well worthy of refurbishment. The origin of its lattice spandrel bracing stemmed indirectly from Telford's development of this concept from 1810–26. [14]

7. Cox's Stack, Dundee

NO 3828 3164

Cox's Stack is the tallest surviving example of an industrial chimney in Scotland and is splendidly ornamental. It was

Cox's Stack

erected in 1865–66 and is said to be 282 ft 10 in. high and is in the form of an Italian campanile in polychrome brick on an ashlar base. The battered-sided base is surmounted by a tall square cross-section plinth with angle pilasters and corbels in yellow brick. The main shaft has angle pilasters with alternate red and yellow horizontal bands, topped by a large cornice above which is an octagonal top section, from which the coping has been removed. The stack is of square cross-section externally with a circular section lining within.

The architect was James MacLaren and the engineer George A. Cox, one of the three brothers who owned the 30-acre Camperdown Works complex, then the biggest jute mill in the world. Cox also designed other buildings on the site such as the fire-proof High Mill (1857–68) which contains a great quantity of cast-iron in its bell tower and Gothic roofs.

Remarkable Scottish chimneys now long demolished existed at St Rollox Chemical Works, Glasgow, 455 ft high which was 13 ft diameter at the top tapering to 41 ft at the base. At Edinburgh Gas Works, New Street, the chimney, designed by George Buchanan and erected in 1845–46 mainly of brickwork, was 341½ ft high and accommodated smoke from 68 furnaces heating 178 retorts. Its design parameters which were known may have influenced those adopted for Cox's Stack. At Edinburgh bricks were used with a tested crushing strength of 440 ton/sq. ft. The chimney's internal diameter was 11 ft 4 in. at the top and 20 ft at the bottom, but the bottom 70 ft had an additional lining of fire bricks which reduced the diameter to 13 ft. Buchanan designed for a vertical pressure on the base of 8 ton sq. ft, a wind pressure of 40 lb/sq. ft, and adopted a minimum wind overturning safety factor of 2.6. [15, 16]

8. Linlathen East Iron Bridge, Dundee

NO 4639 3286

This historic cast- and wrought-iron arch bridge, 9 ft wide and with a clear span of 35 ft carrying an estate road over the Dighty, dates from the early decades of the 19th century ca.1804 or soon afterwards which, if confirmed, would make it Scotland's earliest surviving iron bridge. The designer and maker are now unknown, but the structure's origins are almost certainly Dundonian. The circles in its spandrels were probably influenced by the elevation of Sunderland Bridge (1796). The bridge was a bold effort

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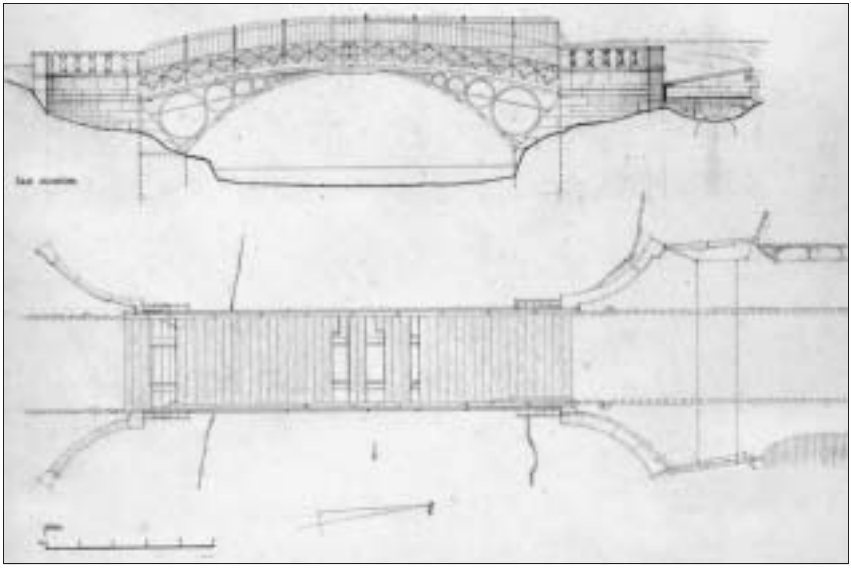
Linlathen East Bridge from underneath



Linlathen East Bridge – elevation and plan

for its time with hand-crafted, substantially unique ironwork, including transverse trusses carrying intermediate bearers supporting timber deck beams.

The crude strengthening of the bridge for farm use last century with deep timber beams from the crown to heightened abutments has resulted in the roadway on the north being lifted above the balustrades. The original elevation is shown dotted on the parapet line in the elevation. The land arch may have been for a mill lade.

The bridge is now closed because of its poor state but is worthy of being preserved. Its main members appear to be intact. Fortunately, after expressions of interest in conserving the bridge by the Dundee Civic Trust, Broughty Ferry Community Council and others, with support from PHEW, the Dundee City Council has now made its conservation a condition of planning consent for adjoining residential development and hopefully the bridge will soon be authentically restored to its former glory. [17]

9. Arbroath Harbour

NO 6418 4044

The present harbour, built 1841–46, was largely designed by James Leslie, and included modifications to an earlier

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Arbroath Harbour slip

harbour built by John Gibb. The main work associated with the harbour was the construction of a massive rubble-filled, ashlar-faced seawall founded on a rock strata that shelved gently towards the sea. The seawall was constructed of trenailed and dovetailed sandstone masonry with ashlars that varied in size from 5 to 30 cu. ft each. The slip for boat repair may date from this time. A Morton's Patent Slip of earlier date is shown on Gibb's plan of 1838.

The area enclosed by the breakwater totalled 7 acres and included the Old and New Harbours of 2 and 3 acres respectively, and a new outer harbour of 1 acre. These harbours provided 800 yards of wharfage and had a depth of 12 ft at spring tides. The Old Harbour was reconstructed in 1871–77 to form a wet dock, and the depth of the tidal harbours was increased by dredging.

An outstanding building in architectural and functional terms is the Bell Rock Lighthouse operation shore and signal station designed and completed under Robert Stevenson's direction in 1812. The buildings also provided accommodation for the light keepers and their families. The station is now a museum. A Bell Rock Lighthouse signal book of 1812 survives which was used in sending messages to and from the station, Northern Lighthouse Board vessels and the lighthouse 11 miles distant from the shore.

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Bell Rock Lighthouse shore station 1812

Engineers will be fascinated to note that the signal book includes Robert Stevenson's own flag to be flown when he was aboard the lighthouse vessel! [18]

10. Bell Rock Lighthouse

HEW 0078
NO 7616 2681

The Bell Rock is a treacherous reef in the North Sea covered with about 14 ft of water at high tide and about 12 miles offshore from Arbroath. In the past it was notorious for shipwrecks and from 1800 Robert Stevenson, then Smith's assistant at the Northern Lighthouse Board, proposed the erection of a stone lighthouse. The eventual construction of the lighthouse built from 1807 to 1811 ranks as one of the world's greatest civil engineering achievements in the maritime field.

Initially there were doubts as to the practicability of the project and the Board enlisted the support of the eminent Rennie to obtain the necessary act of parliament for the lighthouse in 1806. Rennie was appointed 'Chief Engineer' with Stevenson as 'assistant engineer to execute the work under his superintendence'. Rennie's contribution related chiefly to the hydraulic and structural design of the tower, and Stevenson's to the execution by direct labour, involving novel temporary works such as the beacon,

Bell Rock Lighthouse – work in progress 1810 [49, pl.18]

cranes and railway, and the provision of state-of-the-art lighting.

The tower is 115 ft high, 42 ft diameter at the base tapering to 15 ft diameter at the top and containing some 28 000 cu. ft of four different types of stone weighing some 2100 tons, the bottom 30 ft of which is of solid dovetailed masonry. The cost, which exceeded £60 000, included the erection of a work yard at Arbroath where each course of stone was prepared, cut to shape and assembled on a platform before being shipped out to the rock. At the rock the stones were handled by ingenious cranes and transported over its irregular surface on a cast-iron railway, much of which still exists. These innovations, including the iron balance crane, forerunner of the modern tower crane, were invented by Francis Watt working under Stevenson's direction.

In 1824 Stevenson's classic account of the project was published, which although very detailed, does less than justice to Rennie's fundamental contribution. In 1848 the sons of both men fuelled a great engineering controversy by publicly claiming that it was their father who had 'designed and built' the lighthouse, a matter now better understood with the ready availability of the papers of both families. Its successful accomplishment reflects great credit on both, particularly on Stevenson for overcoming the exceptional difficulties of its execution.

The lighthouse, the oldest surviving rock lighthouse in the United Kingdom, has a nominal range of 28 miles and is now fully automated. [19–21]

11. Keptie Hill Water Tower, Arbroath

NO 6353 4078

With its battered coursed red-rubble sandstone walls topped by machicolated battlements this water tower is a dramatic feature of the Arbroath skyline and an impressive example of high Victorian achievement in a local context. Its details from a plaque on the tower read:

> 'THE WATER TOWER. The drought of 1870 and the increase in housing around Arbroath precipitated the Arbroath Corporation to seek a supplementary water supply. By 1882 the Water Committee of the Police Board had resolved to sink the wells between Holt Loans and Keptie Hill on ground leased from Mr. Colvill's patrons and to erect distribution tanks on the hill with a pumping station at the wells.

Keptie Hill water tower

The Police Board sought permission from Mr. Colvill's patrons to erect a tank on Keptie Hill. However, the Patrons

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disapproved of the building sketched for them by the Superintendent of Police and were of the opinion that ''having regard to the prominent situation the building will occupy, it is essential that the proposed erection shall be of an ornate character''.

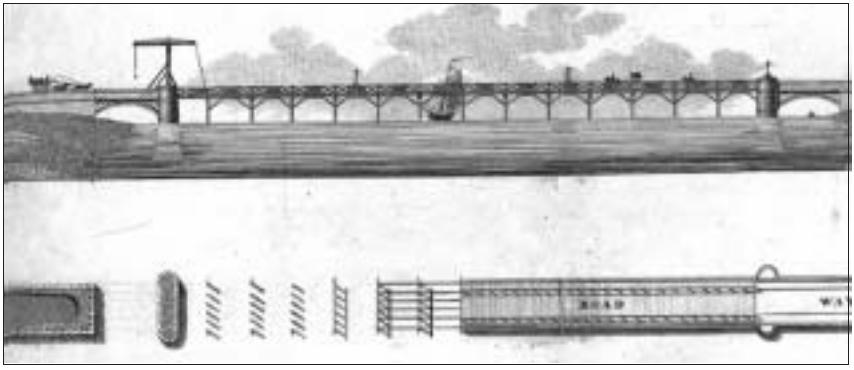
Friockheim architect, W. Gillespie Lamont designed the water tower for a fee of £55 and Archibald Anderson was the builder of the project which cost roughly £8,000. In July 1885 the water was turned on from Keptie Hill. When full the three tanks held almost 200,000 gallons, each tank weighing 284 tons. However, the water tower proved insufficient for the increasing demand for water and a plan to take a supply from the Noran Water at Glenogil was completed in 1908, thus making the water tower surplus to requirements.'

Lamond (1854–1912), his name is incorrectly spelt above, also practised as a civil engineer. After a dispute, the building of the tower was supervised by the Corporation's Surveyor, hence the smallness of Lamond's fee. [22]

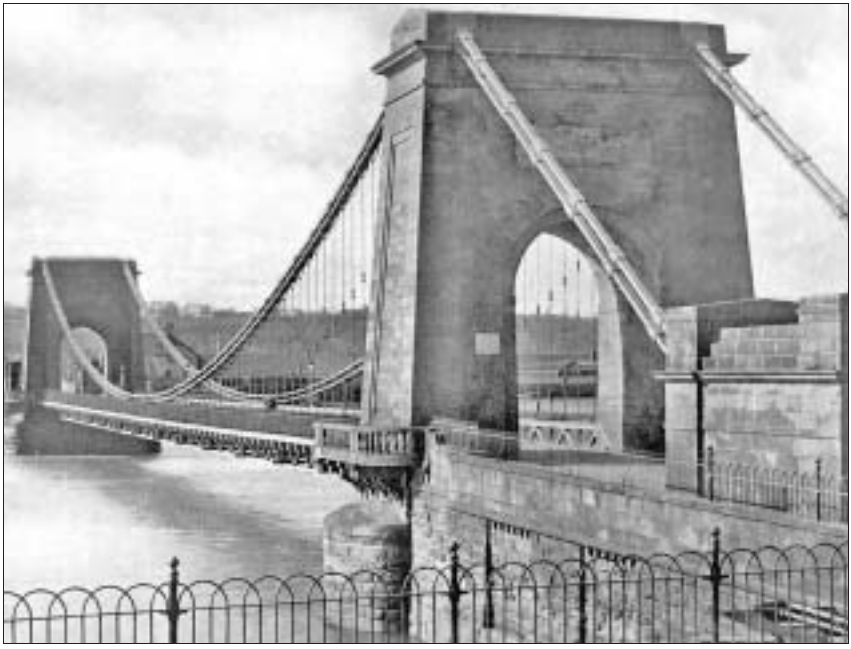
12. Montrose Bridge

HEW 2193
NO 7099 5722

The three-span bridge recently constructed by Balfour Beatty Civil Engineering Ltd (2005) will be the fourth bridge to span the river South Esk at this site. The first bridge (1796–1828) was designed by Alexander Stevens and built in partnership with his son Alexander. It was of traditional knee-braced timber-trestle construction 700 ft long with 13 fixed and one lifting span and considered at the time, because of its magnitude and difficulty of construction, 'the most remarkable of the kind in the kingdom'. The river varied from between 16 ft and 32 ft



Montrose timber bridge 1796–1828 [53]



Montrose suspension bridge 1828–1931 [photograph ca.1900]

deep between low and high water and because of this, and a fast current and a gravelly bottom, great difficulty was experienced in pile-driving.

The second bridge (1828–1931) was a suspension bridge designed by Capt. Sir Samuel Brown RN that had a suspended span of 432 ft. The cast-iron deck beams, supporting the timber deck, were suspended from multi-bar, wrought-iron chains carried on masonry towers. This bridge failed partially on two occasions: in 1830 when it was crowded with people watching a boat race, and in 1838 in hurricane force winds. J. M. Rendel reconditioned the bridge after the second failure and successfully inhibited deck oscillation by introducing substantial timber trussing longitudinally independent of the hangers, an early instance of such practice.

The third bridge (1931–2004), a double-balanced cantilever with a suspended span, was designed by Sir Owen Williams, and the contractor was Sir Robert McAlpine and Sons Ltd. The bridge had a central span of 216 ft and side spans of 108 ft. Reinforced concrete was used as the construction medium, an inappropriate material for use

Roland Paxton

Montrose Bridge 1931–2004

in the upper chords of the bridge structure which were subject to tensile forces. This bridge fell prey to alkali agreggate reactivity causing massive cracking. Its slender steel replacement, with slightly curved beams spanning 131 ft, 216 ft and 131 ft, for which Balfour Beatty were the engineers, was completed in 2005. [23–26]

13. South Esk Viaduct (Railway), Montrose

NO 7086 5726

This multi-span 475 yards long railway bridge serving the East Coast Main Line was built in 1881–83 to a design by W. R. Galbraith as a replacement for a viaduct designed by Sir Thomas Bouch. Screw piles beneath the columns of the former viaduct failed during construction. Galbraith's bridge carries a single rail track on a series of bowstring girders that are supported on concrete-filled piers. William Arrol & Co. were the contractors. [27]

14. Montrose Harbour

NO 7136 5713

The wet dock at Montrose, constructed from 1839–41, was designed by James Leslie. The dock, a rectangular basin formed of coursed rubble walls, enclosed an area of $3\frac{1}{2}$ acres and could accommodate vessels drawing $19\frac{1}{2}$ ft of water at spring tides and 16 ft at neap tides. It provided 1500 ft of

sheltered quays for the harbour that were sealed from the tidal water of the River South Esk by cast-iron lock gates. In addition the town had about 1700 yards of tidal quays.

Leslie's dock was filled in from 1980–82, and the harbour is now wholly river berths formed by quay walls and totally tidal. It is mainly used by oil service vessels, and can accommodate boats drawing up to 18–24 ft of water depending on the tide. It is managed by the Montrose Port Authority and its harbour master. [28]

15. Fisherhills or North Water Viaduct (Railway)

NO 7250 6225

This large masonry viaduct was built to carry the Montrose and Bervie Railway, opened 1865, over the Upper North Water. It is partially curved on plan and has 12 spans, seven land arches and five larger skewed arches over the river. The latter are supported by heavier piers particularly those on the river banks. This section of the former railway from the viaduct to St Cyrus is intended to form part of the National Cycle Network.

16. Lower North Water Bridge, Montrose

HEW 1189
NO 7246 6218

This fine bridge, of seven segmental masonry arches, was built from 1770–75 and carries the A92 road over the North Esk some 3 miles north of Montrose. The arch spans are graduated so that the bridge has a 63 ft centre arch and 40 ft span side arches. Although featuring dressed arch-rings, quoins and mouldings, the bridge's piers and spandrels are of scrabbled masonry. This practice of Smeaton's at Perth influenced similar finishes being adopted on most large Scottish bridges for a considerable time.

The inscription at the south end of the bridge attributes the design of the bridge to Smeaton, John Adam and Andrew Barrie, but it was the last named, a mason in Montrose, who made the major input to the as-built design. He based this on a design and details prepared previously by Smeaton for a bridge at another site. Adam offered advice to the bridge trustees and prepared a

draft of the contract. Barrie and Patrick Brown were joint contractors for building the bridge. [29]

17. Bridge of Dun, Montrose

NO 6627 5842

The Bridge of Dun spans the South Esk at the west end of the Montrose Basin and was erected from June 1785 to January 1787. It was designed and built by Stevens whose use of classical ornamentation transformed the bridge from being a purely utilitarian structure. The contract price was £3128.

The bridge is symmetrical with three segmental arches, the centre span being 68 ft and the side spans 50 ft. At both ends of the bridge the roadway rises steeply from low-lying ground on embankments enclosed between masonry walls that are pierced by 20 ft span flood relief arches. The piers are carried on piled foundations, and the masonry above the bases of the abutments and piers was built solid across the structure to a height of 4 ft, above which the road, 18 ft wide, is carried on pends (arched or slabbed longitudinal cavities) along the length of the bridge. The

Tom Day

Bridge of Dun

external masonry, the refuges above the piers and the approaches are constructed in dressed ashlar with decorative features. [30, 31]

18. Stannochy Bridge, Brechin

NO 5837 5911

This bridge, about 1 mile west of Brechin, crosses the South Esk with a single segmental arch of 100 ft span, one of the largest masonry spans in Scotland. It was built in 1826 by James Smith. Some details used in its construction are similar to those used at Marykirk Bridge and it is possible that Robert Stevenson was engineer for both or, at least, influenced the Stannochy design through its builder James Smith who may have been the brother of one of the contractors for Marykirk Bridge.

The voussoirs of the arch, constructed of local Brechin stone, are indented and are 3 ft 3 in. deep and 1 ft 3 in. wide. The roadway is level, but the curvature of the projecting string course suggests that it may originally have risen from lower approaches either side of the bridge and that these were subsequently raised. There is a prominent archivolt on each elevation and the abutments have

Stannochy Bridge

Roland Paxton

an attractive vertically-curved batter. It is a handsome and neatly detailed bridge that deserves to be better known.

19. South Esk Bridge, Brechin

NO 6044 5926

The first bridge to span South Esk at Brechin is thought to date from ca.1220. In ca.1469 it was replaced by a masonry bridge of two spans, but only the south arch is still in service, now carrying the A933 road. The north arch fell during the 18th century and was replaced in 1787 with a segmental arch built by Stevens. The cost of the bridge was £350.

20. Round Tower, Brechin

NO 5963 6009

This round tower is one of three in Scotland. There are 76 in Ireland. These towers, possibly built by Irish masons,

Brechin Round Tower

are believed to be of religious origin and date from about the 10th century and may have contained bells. Their purpose is unknown but possibly were intended as a lookout or place of safety in times of trouble.

The tower is about 85 ft high, built of coursed masonry, with a number of timber-floored storeys connected by ladder. A conical roof was added later. The entrance is about 7 ft above ground level. Another tower at Abernethy is about 72 ft tall and of similar construction. A third round tower survives at Egilsay in the Shetlands. It is now only 50 ft high, having been shortened in the 19th century.

In civil engineering terms the towers were well sited and designed with tapering walls. It is conducive to the stability of Abernethy tower that its walls are about 8 in. thicker on the outside at their base, which is about $3\frac{1}{2}$ ft wider than at the tower top. [32, 33]

21. Gannochy Bridge, Edzell

HEW 2504
NO 6002 7089

This bridge, completed in 1724, spans the South Esk at a height of 65 ft by means of a single arch of 52 ft span at a point where it flows through a deep gorge cut through the local red sandstone. It was a bold effort for its time, built at the expense of James Wood, a local farmer, who employed a mason to build the arch but constructed the parapet walls himself. [34]

22. Upper North Water Bridge, Pert

HEW 2505
NO 6527 6614

This substantial bridge, of the pre-reformation era at the intersection of the old military roads from Edinburgh to Aberdeen and Fochabers, was built in the 1520s to span the North Esk. It has three spans of about 50 ft and ribbed semicircular arches and is of similar construction to the Bridge of Dee, Aberdeen. Both bridges were built under the aegis of Bishop Gavin Dunbar by Thomas Franche, master mason, to the design of Alexander Galloway Minister of Kinkeld.

The Bridge of Dye, with a single span of 43 ft some 12 miles due north, is of similar ribbed-arch construction but was built in 1680. [35]

23. Marykirk Bridge

HEW 1302
NO 6860 6501

A handsome masonry bridge over the North Esk between the shires of Forfar and Kincardine, built from 1811 to 1814 with four equal segmental arch spans of 58 ft and 14 ft rise. The engineer was Robert Stevenson and his assistant and resident inspector was David Logan, former clerk of works at Bell Rock Lighthouse, then nearing completion, who by early in 1811 had started work on this project.

Logan prepared designs and businesslike specifications for both elliptical and segmental arch bridges, on which he was complimented in a letter from Stevenson in February 1811. 'Your drawings are finely executed indeed … [but it is] necessary to give the bridge a greater rise or increase the number of arches to at least four.' Logan set out the work in December 1811 and when Stevenson visited the site with him in the following July, the south abutment was up to low water mark and because of the war with France some of the workmen were 'absent on duty with the local militia'.

By February 1813 the southernmost arch had been successfully turned and the keystone driven in. Logan was instructed to prepare the plan for the toll house at the south end of the bridge. The bridge was completed in 1814. The contractors were Ross & Smith and the estimate £7266. The out-turn cost was about £10 000. The view, which shows the toll house, is from a drawing by Stevenson's chief assistant John Steedman.

Marykirk Bridge

Roland Paxton

This bridge undoubtedly influenced the design of Stannochy Bridge near Brechin (2-18). [36, 37]

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