1841. Notice of a model of the Schuylkill ... coal-field ..., *Silliman J*, **xli**, 80–91
[1843]. On the geology of the north-east part of the island of Cuba, *Am Phil Soc Trans*, **ix**, 1846, 204–218
1845. On the authoritative and bituminous coal-fields in China, *Franklin Inst J*, **x**, 51–57
1848. *Statistics of Coal*
[1849]. *Table ... in Regard to the Daily Temperature ... Panama, Port Royal in Jamaica, and on the Return Voyage to New York ... October 1849*
[1849]. Substance of notes made during a geological reconnaissance in the auriferous porphyry region next to the Caribbean Sea ... Panama, *Philadelphia Acad Nat Sci J*, **2**, 1850–1854
[1854]. On a view of asphaltum at Hillsborough ... New Brunswick..., *Am Phil Soc Proc*, **5**, 241–243

TELFORD, John (*c.* 1771–d. 1807), civil engineer, probably a kinsman of Thomas Telford (q.v.), worked for him in Shropshire in the 1790s. He acted as his draughtsman there, preparing plans for St. Mary Magdalene Church, Brignorth (*c.* 1792). In June 1797 he was appointed Toll Collector on the Wirral line of the Ellesmere Canal. He displayed sufficient competence and honesty to be recommended by Telford to William Jessop (q.v.) in June 1804, to superintend work at the Corpach (western) end of the Caledonian Canal 'as [has] to my own and your knowledge, for ten years past, been employed upon works of a similar nature whose abilities may be relied on and who [is] likely to enter with zeal into the spirit of the undertaking'. In August Jessop wrote 'Instructions ... to Mr. John Telford for marking out the Caledonian Canal', and provided a number of drawings, some of which John Telford then copied into his notebook. This suggests John was relatively inexperienced in canal construction. He was perhaps fortunate that the massive sea lock for which he was responsible was founded on rock, rather than the more treacherous ground of the eastern end where Matthew Davidson (q.v.) was in charge. That said, much pumping was necessary to keep the excavation dry.

Telford remained in charge of the work at Corpach until his death in April 1807, aged 36. Much of his correspondence survives, revealing that management, particularly the availability of pay for the workforce, was as much an issue as the engineering of the canal. He was succeeded as Resident Engineer at Corpach by Alexander Easton (q.v.).

MIKE CHRIMES

[Telford collection, ICE archives; John Telford letterbook, transcript, Gibb collection, ICE archives; Commissioners for the Caledonian Canal (1804–1808) *Reports*; A. Gibb (1935) *The Story of Telford*; L. T. C. Rolt (1958) *Thomas Telford*; A. Penfold (ed.) (1980) *Thomas Telford: Engineer*; C. Hadfield (1993) *Thomas Telford's Temptation*]

Works
1804–1807. Caledonian Canal, western end, superintendent of works

TELFORD, Thomas, FRS, FRSE (1757–1834), first President of the Institution of Civil Engineers, second son, the first of the same name having died in infancy, of John Telford, an Eskdale shepherd, was born at Glendinning sheep-farm, Westerkirk, Dumfriesshire on 9 August 1757. Four months later his father died and Telford was brought up by his mother Janet (*née* Jackson, d. 1794). The closely knit Eskdale community, in particular his mother's brother Thomas Jackson, believed to have been factor to Sir James Johnstone of Westerhall, helped to support the family. He gained a good basic education at Westerkirk parish school and obtained occasional farm work whenever he could to help support his mother and himself. At school he met the younger generation of leading local families, and formed a close friendship with Andrew Little, schoolmaster in Langholm and later the postmaster there, James Little, his correspondence with whom, now in the ICE archives, represents the main source of information on his early life and his life-long connection with Eskdale.

On leaving school *c.* 1772 Telford was at first apprenticed to a stone-mason at Lochmaben, from whom he is understood to have run away after being ill-treated, and then to Andrew Thomson at Langholm working on the simple buildings of the area. Langholm Bridge built *c.* 1778 bears mason marks that are said to be his and he is reputed to have carved both the Pasley family memorial and the headstone to his father's grave in Westerkirk churchyard. From a recent study of mason marks in the locality the question has been posed that Telford's mark as illustrated in the earliest known published reference (Smiles, 302), might be incorrect and this subject requires further investigation. Whenever he could Telford diligently gleaned knowledge from any books he could find, for example, on literature and poetry from the elderly Miss Pasley of Craig who befriended him. In 1780 having mastered such mason-work as Eskdale could furnish he went to Edinburgh to improve his prospects and is reputed to have worked on its 'New Town'. Whilst at Edinburgh he learned to draw and studied the architecture of the locality. He particularly admired the Gothic splendour of Melrose Abbey and Rosslyn Chapel, a style which later influenced the elevations of much of his own work when it could be afforded.

In February 1782 Telford's restless ambition drove him to seek more challenging and better paid work in London where, through John Pasley an eminent merchant and relative of Miss Pasley, he met the architects Robert Adam (q.v.) and Sir William Chambers and obtained employment as a stonemason on the building of Somerset House. The following year he seriously considered, but eventually decided against, entering into business with a fellow stonemason, Mr. Hatton, to contract for work at Somerset House. Whilst in London

Thomas Telford FRS, FRSE

Telford was consulted by Sir James Johnstone of Westerhall about alterations to his house in Eskdale, possibly the present main entrance, and received his instructions from Sir James's brother William Pulteney (1729–1805). Pulteney, who had changed his name from Johnstone on marrying the heiress of the Earl of Bath, was impressed by Telford and his work and employed him on the restoration of Sudborough Rectory, Northamptonshire in 1783–1784. Other commissions followed and within a decade a close friendship had developed between them to the extent that Telford was known as 'young Pulteney'. His subsequent early career owed much to Pulteney's powerful patronage.

In 1784 the funding for building Somerset House became exhausted and Telford obtained employment in Portsmouth working on the Dockyard Commissioner's house and chapel designed by Samuel Wyatt (q.v.). Before long he was superintending the contract for this work, his first important position of independence and responsibility. Whilst at Portsmouth he widened his knowledge and experience by observing harbour and dock work under construction and by studying limes and mortars from copies of the lectures of Black and Fourcroy. He wrote down the information gleaned in his pocket-book compilation of useful data which became his vade-mecum, some of which was later published in text books and in his *Life*. Telford was by now a Freemason and on 1st February 1786 was about to direct the fitting up of a masonic lodge room to his plans at the George Inn, now demolished. On completion of the dockyard buildings, later in 1786, Telford went to Shropshire at Pulteney's invitation, to undertake the restoration of Shrewsbury Castle for his use as an occasional residence in connection with his duties as an MP for Shrewsbury. In July 1787, with a reference from Robert Adam, Telford became clerk of works for the new county gaol at a salary of £60 p.a. Soon afterwards he became County Surveyor of Public Works, a post that he held for life, later through his able deputy Thomas Stanton (q.v.) at Ellesmere, with responsibility for public buildings and the provision of at least forty-two bridges.

During and after restoring Shrewsbury Castle in the Gothic style Telford lived in and practised as an architect from the castle. His church work included restoration of St. Mary's, Shrewsbury and All Saints', Baschurch, building the new churches of St. Mary Magdalen, Bridgnorth, which Pevsner (1958) calls 'a remarkable design, of great gravity inside and out, and apparently done in full awareness of recent developments in France', St. Michael's, Madeley and, almost certainly, the planning of St. Leonards', Malinslee. From 1787 to 1793 his other work included the county infirmary, private houses, and street improvement and drainage. In 1788 at Pulteney's request Telford advised on St. Chad's, Shrewsbury, accurately predicting its fall just before the actual event. He also superintended the excavation of the ruins of the Roman city of Uriconium, on Pulteney's estate near Wroxeter, the plan and sections for which, in *Archaeologia* 1789, are his earliest-known published drawings. In 1793 he added greatly to his knowledge of architecture and antiquities from a study tour of Bath, Oxford, London and other cities. The considerable extent of his architectural knowledge by the early nineteenth century is indicated by the content of his substantial 'civil architecture' article in the *Edinburgh Encyclopaedia*.

In 1790, at Pulteney's instigation as a director of the British Fisheries Society, Telford's life-long connection with the Society began. He advised on the improvement of numerous harbours and settlements in northern Scotland including Lochbay, Tobermory, Ullapool, Keiss, Staxigo, Broad Haven, Wick, Sarclet, Clyth, Lybster, Forss, Dunbeath, Helmsdale, Brora and Portmahomack. The largest, Pulteneytown, at Wick, executed to his designs over several decades, with its impressive Argyll Square, still survives as a fine testimonial to his architectural and planning skills. In 1796 Telford tested and soon afterwards used at Lochbay pier on Skye, an aluminous hydraulic cement patented by James Parker, later known as 'Roman cement', which set to a very considerable extent in about twenty minutes. His support for and extensive use of Roman cement to inhibit water penetration influenced its nationwide adoption for many years in facing, pointing and brick-jointing mortars.

Telford's honorary work for the British Fisheries Society led to his involvement in governmental surveys of the Highlands in 1801–1802 and to his wide-ranging recommendations for

improvement of inland and maritime communications including harbours, partly with a view to stemming emigration, and to facilitate naval protection for the fisheries. His reports paved the way for the setting up in 1803 of Commissions for making the Caledonian Canal and many Highland Roads and Bridges, particularly north and west of the Great Glen. Recognition of Telford's outstanding contribution to the development of the Highlands was reflected in his election as a Fellow of the Royal Society of Edinburgh in 1803 when, in his own words, 'I had the honour of being proposed by three professors' (Little Mss, ICE). In 1834 the Society made Telford a present of inscribed silverware 'in grateful acknowledgement of the numerous and valuable professional services gratuitously rendered during a long course of years' (Dunlop, 59).

Canals

Telford's civil engineering career developed from 1793 on his appointment as 'General Agent, Surveyor, Engineer, Architect and Overlooker' to the important 68 mile Ellesmere Canal, intended to join the rivers Mersey, Dee and Severn. This canal, now a thriving leisure facility, still utilises many buildings and structures designed and built under Telford's direction. The most remarkable structure is Pontcysyllte cast iron aqueduct over the Dee, a development of his embryo sketch design dated March 1794, except for the piers, but not developed until after the novel iron trough concept had been proved operationally at Longdon-on-Tern aqueduct on the Shrewsbury Canal, in 1795–1796. At Pontcysyllte, with the support and approval of William Jessop (q.v.) the principal engineer for the canal, Telford deviated from traditional masonry aqueduct construction by building abutments and eighteen slender masonry piers joined by nineteen arches with cast iron ribs supporting a iron trough with 1 in. thick sides 1007 ft. long and 126 ft. above the river. The ironwork was made and erected by William Hazledine (q.v.), the masonry was built by John Simpson (q.v.), and the whole supervised by Matthew Davidson (q.v.). The result was the supreme structural achievement of the canal age. Sir Walter Scott thought it 'the most impressive work of art he had ever seen'. A misleading attempt by Hadfield in 1993 to question the traditional attribution of the concept and design of the aqueduct to Telford is incompatible with authoritative early evidence that it was designed and executed under his direction.

The 60 mile Caledonian Canal constructed from 1804 to 1822 was engineered by Telford and Jessop jointly until 1812, afterwards solely by Telford, basically with the same team that built the Ellesmere Canal aqueducts. Matthew Davidson superintended work at the eastern end and John Telford (q.v.), succeeded by Alexander Easton (q.v.), at the western end. John Simpson was the main masonry contractor with John Wilson and John Cargill (qq.v.) working as his partners. In engineering terms the 100 ft. wide ship canal with its twenty-eight immense locks and deep summit cutting at Laggan, was then the most advanced of its kind in the world. Interesting features included the use of railways, comprising plateways formed with 3 ft. long Jessop pattern cast-iron rails, to facilitate excavation and banking, purpose designed and built machinery and equipment, steam engines for pumping and dredging, and ingenious and unprecedented lock construction. For example, at the Beauly Firth (Clachnaharry) entrance lock a 55 ft. depth of mud was pre-consolidated by the weight of imported clay fill loaded with stone from which, after removal of the stone, the lock-pit was excavated.

Despite the hard-won achievement of the Caledonian Canal and the much-needed work that it provided in the Highlands, (1385 men were employed in 1811), the project was less successful in other respects. Costs escalated with high inflation and unforeseen difficulties, additional funding was difficult to obtain, and further problems arose through defective workmanship, for example at Banavie and Fort Augustus locks, where ground water penetrated through the walls. Penfold attributed the defective workmanship to a lack of close site supervision arising from a management structure that favoured the contractors. The canal eventually opened in 1822 with an operational depth of 12 ft. instead of 20 ft. as planned at the outset. It had cost about twice the original estimate and taken eighteen instead of seven years to construct. By then, through no fault of Telford's, the reasons for creating the canal had been overtaken by events with the end of the Napoleonic wars and the development of the steamboat. Although important locally, relative to its capacity the canal has never been much used, except in 1918 when there were 6,254 passages associated with mine-laying in the North Sea. It is now a major tourist attraction and more traffic is expected on completion of the Forth & Clyde Canal regeneration in 2001.

In Sweden the Trollhätte Canal, comprising the western end of the Gotha Canal, had been completed in 1800 under the direction of its promoter Count von Platen and the Swedish engineer Samuel Bagge. From 1808 Telford, at the invitation of the King of Sweden, acted as consulting engineer for the canal's 114 mile eastwards extension from Lake Vänern to the Baltic at Söderköping, with at first Bagge and later Lagerheim, superintending operations on site. In 1808 Telford, with his assistants William Hughes and Hamilton Fulton (qq.v.), met and surveyed the line with von Platen. It was the start of a close friendship between Telford and von Platen which lasted until the latter's death in 1829. Construction commenced in 1809 and four years later seven thousand men were employed including John Wilson (q.v.) and James Simpson who had accompanied Telford on a visit in 1813 but did not return with him. There were delays in constructing the canal, which was not completed until 1832. Telford's advice was transmitted to Von Platen in a voluminous

correspondence. In 1809, Telford was made a Knight of the Swedish Royal Order of Vasa in recognition of his valuable services, his letters from Sweden afterwards being addressed to 'Sir Thomas Telford'. His international reputation on canal construction was now such that he was also consulted by the Russian government on canal navigation schemes, as well as schemes such as the Darien and Welland Canals in central and British North America.

Telford can be considered the last of the great canal engineers of the Industrial Revolution. Of his later projects, Harecastle Tunnel more than 2,700 m long and constructed, in exact accordance with his plans under the supervision of the resident engineer, James Potter (q.v.), in less than three years from fifteen shafts, was one of the most remarkable feats in tunnelling history. The Birmingham Canal improvement engineered to Telford's characteristically direct line, and with a particularly deep cutting at Smethwick, saved 8 miles in length and thus maximised user-benefits. This canal was one of the finest achievements of the canal age. Similarly, the Birmingham & Liverpool Junction Canal, with a 12 mile saving in length, but requiring long cuttings up to 90 ft. deep, in what proved to be slip-susceptible marl, and a diversion at Shelmore to avoid Lord Anson's game preserves involving a mile-long embankment up to 60 ft. high. Both features presented great problems as Telford's health declined but they were eventually overcome by the contractor, William Provis (q.v.), under William Cubitt's (q.v.) direction from 1833 to 1835. Telford's canal–seaport warehouse interchange at Ellesmere Port on the River Mersey that was greatly used for over a century represented a peak of efficiency of the canal age.

Telford acted as engineer on a number of other canals, beginning with the completion of the Shrewsbury Canal, designed by Josiah Clowes (q.v.) before his death. Others included the Glasgow, Paisley and Ardrossan Canal, not completed because of financial problems, the Weston Canal for the Weaver Navigation, the repair and upgrading of the Crinan Canal and work on the Trent and Mersey Canal and the completion of the Gloucester–Berkeley Ship Canal. Elsewhere he was regularly consulted about the Grand Junction (1805–1818), Carlisle (1808–1819), Bude (1818–1823), Edinburgh and Glasgow Union (1816–1822), and Ulster Canals (1826–1834). Telford's work for the Exchequer Bill Loan Commissioners led to further consultations (see below). He also reported on the Leicester and Northamptonshire (1803), Grand Union (1803), Aberdeenshire (1806), Forth and Clyde (1807), and Oxford (1830–1834) canals. His involvement with the Macclesfield Canal was largely confined to the Parliamentary survey; he was also responsible for surveying schemes which came to nothing such as the Stamford Junction to Oakham (1810), the English and Bristol Channel Ship Canal (1824–1826), the London–Birmingham (1828) and Dee and Mersey Ship Canal across the Wirral (1828).

Telford also worked on river navigation improvements on the Dee (Chester), Severn, Weaver, Thames, Mersey, Avon, Aire and Calder, Clyde, Dee (Aberdeen), Tay and Forth. He also investigated the development of fast canal boats and in 1832–1833 hundreds of experiments were made at the Adelaide Gallery, London by his chief assistant John Macneill (q.v.) in an unsuccessful attempt on behalf of canal interests to compete with railway travel. Further, full-scale, experiments were carried out on canals, and continued by Macneill after Telford's death.

Road making

Telford's main achievements in road-making were the London to Holyhead and Bangor to Chester roads as Engineer to the Holyhead Road Commissioners from 1815 to *c.* 1830, and the Glasgow to Carlisle, Lanarkshire, and Highlands of Scotland roads as Engineer to the Highland Roads Commissioners from 1803 to *c.* 1830. Although many of these roads declined in use from the 1840s as the railway network advanced, they entered into a new lease of life in the early twentieth century with the advent of the motor vehicle. Abroad Telford advised the Russian government on the 100 mile Warsaw–Brzesc road completed in 1825 on the route to Moscow. He also advised on the provision of a causeway at Bombay (Salsotte). Unexecuted or partially completed improvements on roads that he surveyed for the government or others included, the Carlisle to Portpatrick, Birmingham to Liverpool, Carlisle to Edinburgh, London to Milford Haven and South Wales, and the Great North Road from London via York and Edinburgh to Inverness.

In the Highlands, with the valuable assistance of John Rickman, James Hope and John Mitchell, respectively, Secretary, Agent and Chief Inspector to the Highland Road Commissioners, Telford was responsible for the provision of about 1200 miles of new or improved roads. These roads, authoritatively described in parliamentary publications and by Haldane, opened up Scotland west and north of the Great Glen, in Telford's own words, 'advancing the country at least a century' (Smiles, 389). His connection with the Holyhead and Scottish roads continued through inspections for most of the rest of his life. In terms of construction his major roads were commodious, well drained and incorporated a hand-pitched stone foundation beneath a layer of conventional road metal. Unlike McAdam's roads, they were properly engineered to improved lines and gentle gradients, and although more expensive initially, facilitated traction and reduced maintenance costs. On its completion the Holyhead Road was described as 'a model of the most perfect road making that has ever been attempted in any country' (Parnell, 35). Much of the road is still in use and in 1998 nearly a mile of the original retaining wall up to 40 ft. high and Pont Pen

Benglog Bridge in the Nant Ffrancon Pass were economically and tastefully conserved by the Welsh Office. The road in North Wales is now designated an 'Historic Route' with information signing to encourage environmental and leisure use, which is entirely fitting for this 'long-lasting memorial to Telford's skill and vision' (Penfold, 58).

Masonry bridges

Throughout his lifetime Telford planned, built or advised on several thousand masonry bridges, including 1,100 to a standard specification on Highland roads alone. His bridges ranged from simple culverts to the sophisticated 150 ft. elliptical span of Over Bridge, Gloucester 1826–1830, influenced by Perronet's work. Telford's first major bridge was erected over the Severn at Montford from 1790 to 1792 using convict labour. Six years later it was followed by Bewdley Bridge, which, with its segmental arches and classical balustrades in a gentle arc, has been described as 'one of the most elegant bridges in England' (Ruddock, 154). Telford's most notable Scottish bridges include Dunkeld (1805–1809), also with its extrados on a large radius arc and, his finest development of architectural experimentation and excellence of construction, Dean Bridge, Edinburgh (1829–1832) with its intricately achieved slenderness. In terms of its elevation Telford's 'elegant' five-arch bridge at Pathhead, Midlothian, with its visually less pronounced 'ascititious' (Telford's *Life)* arches to some extent 'served as the prototype' for Dean Bridge (Paxton, 1998).

Telford's bridges at Broomielaw, Glasgow (1833–1835) and Dean have been described as 'a fitting crown to his creative life' (Gibb, 26). Both bridges were constructed by John and Alexander Gibb (q.v.) under the competent supervision of resident engineer Charles Atherton (q.v.). In construction terms, from the 1790s Telford developed, and widely influenced, the beneficial adoption of hollow piers and spandrels in large-span bridges by Robert Stevenson and others. This practice resulted in a stronger structure, facilitated its internal inspection and reduced the weight bearing on foundations. Telford's architectural experience enabled him to impart grace and beauty to the appearance of many of his bridges.

Cast iron bridges

Telford's innovative design practice was also effectively applied to cast-iron bridges carrying roads. Buildwas Bridge 1796, said to have been the second major cast iron bridge to be completed in Britain, just before Sunderland Bridge, differed considerably in concept from Coalbrookdale Iron Bridge, achieving a bridge of half the weight of that at Coalbrookdale with a considerably increased span of 130 ft. Four years later Telford, in association with James Douglass, made a very bold proposal for a 600 ft. cast iron arch over the Thames to replace London Bridge. Expert opinion on its practicability was widely canvassed by a parliamentary committee and varied greatly. For example, in respect of horizontal thrust, Dr. Maskelyne thought that there would not be any, Professor Playfair calculated it at 11,100 tons and Professor Robison at 20,550 tons (Paxton (1975), 80). Although the project was seriously considered for many years it was not implemented because of 'the unprecedented scale of the project, coupled with lack of knowledge of and agreement on the technical factors involved' (Skempton, in Penfold (1980), 79).

In 1810 Telford designed an economical prefabricated, lozenge lattice spandrel arch based on his practical precepts for use at locations where it would be more expensive or impracticable to construct a masonry bridge. At least nine arches with standardised spans of 105 or 150 ft. were cast and erected by William Hazledine (q.v.) from 1812 to 1830 of which those designed by Telford at Craigellachie and another at Tewkesbury of larger span, are still in use although strengthened. The prototype at Bonar Bridge over Dornoch Firth erected in 1812 lasted until 1891. The similar bridge, which still spans over the Birmingham Canal at Galton was cast by Horseley Ironworks, who also supplied a number of smaller bridges over the canal. Some of these were to a similar design to that developed by Telford with his assistant Thomas Stanton (q.v.) for small spans in Shropshire. Of Telford's cast iron bridges it has been aptly written, 'No other man has ever handled cast iron with such complete assurance and understanding, his exact knowledge ... enabling him to achieve that perfection of proportion which gives strength the deceptive semblance of fragility' (Rolt, xiii).

Suspension bridges

Telford's creation on the Holyhead Road of the elegant Menai wrought iron suspension bridge over the Menai Straits, with an unprecedented span of nearly 580 ft., was the most outstanding bridge development of the early nineteenth century, and sealed his international reputation among contemporary engineers. Its final form evolved from his experimentally based proposal of 1814–1818 for Runcorn Bridge, further experimental work and an almost continuous design process from 1819 to its opening in 1826. In 1814 Telford had correctly anticipated modern practice in envisaging parallel wire main cables and had erected and load tested a 50 ft. span model of the earliest known wire bridge, but he eventually opted for flat chain-bar links as being more practicable to achieve and maintain at that time. The masonry, which is of exceptional quality, was executed by John Wilson. Hazledine manufactured the ironwork, the testing and fixing of which with newly invented equipment under the supervision of resident engineer William Provis, his brother John, and Thomas Rhodes (q.v.), was at the forefront of technology of its day. Nothing that could be quantified was neglected and, although it could not quantified, the probability of deck

trussing being required to counter undulation. Nearly 36,000 bars and plates, including all those used in the bridge, were tested to about twice their design load. The ironwork, which is believed to have been painted white originally to minimise temperature movement, continued in use until 1940 when the bridge was tastefully reconditioned by Sir Alexander Gibb to accommodate modern traffic, which it still does.

Telford's experimental results on the strength of iron wire and bars were widely propagated in leading text books from 1817 and in 1828 William Provis published the definitive account of the design and construction of Menai Bridge, then the world's largest bridge span. The project led to a surge of interest in suspension bridge building and exercised a fundamental influence on practice and development by Isambard Kingdom Brunel, William Tierney Clark, James Meadows Rendel (qq.v.) and others from 1819 to 1840. It established this type of bridge 'in its true role as the most economic means of achieving the largest spans' (Paxton, in Penfold (1980), 113).

A minor shortcoming of the design of Menai Bridge was that the then unquantifiable phenomenon of wind-induced undulation proved to be a greater problem than had been foreseen. This became apparent in 1825, as the bridge was nearing completion and caused Telford great anxiety. Measures were taken which proved partially effective and it was not until 1839, five years after Telford's death, that timber shrinkage contributed to the destruction of part of the deck in a gale. For a while the bridge was widely regarded as a 'complete failure' but this was 'an over-reaction' (Paxton (*ibid.*, 1980), 112). The bridge was fully reopened a fortnight later and then underwent strengthening under Provis's direction for about 5% of its initial cost. Nevertheless, from *c.* 1840, 'Telford's great achievement was mistakenly left unappreciated and greatly undervalued' (Roebling).

Telford's other suspension bridge projects included Conwy Bridge, also opened in 1826 which still has its original ironwork and his controversial Clifton suspension bridge proposal of 1830 for a three-span bridge with two ornate 'Gothic Revival' towers rising dramatically from the floor of the gorge. In order to understand Telford's reasons for allowing his innate admiration for the Gothic style full reign, apart from the fact that this style was then much more popular that it is now, it is necessary to know something of the project's background. This crossing of the Clifton Gorge had been contemplated for many years and was considered to offer an environmental and an artistic opportunity rather than one for a little-needed national road. Apart from its architectural appeal to Telford, this proposal also reflected his understandable concern about extending the spans of suspension bridges much beyond that of Menai Bridge, at an exposed location 200 ft. above the river, until more was known about undulation. His design is said to have received general approval at the time, but it failed to attract sufficient funding. To the modern eye Telford's most visually attractive bridge elevations are those in which the Gothic Revival influence was either muted or absent.

Railways and steam-carriages

Telford believed that steam power could best be applied to land transport in the form of self-propelled vehicles operating on roads rather than on railways. He was concerned that the railway companies would establish a monopoly to the detriment of road use. He supported the setting up of and gave evidence to a parliamentary Select Committee in 1831, which reported that steam carriages were practicable, safe and should be protected from high tolls to encourage their adoption and use. By 1833 Telford was a leading promoter in a steam carriage company intended to operate on the London to Holyhead Road and took part in an experimental journey on the London to Birmingham section in Dance's steam carriage. The size of the engine proved to be insufficient and the carriage only reached Stoney Stratford 57 miles from London, at an average speed of 7 m.p.h. High tolls, opposition from vested interests, mechanical shortcomings, and Telford's death in the following year, all contributed to the demise of this initiative.

Despite this perceived anti-railway bias Telford was involved, generally as consultant with the majority of the railway schemes of the 1820s, most of which were not realised. Railway projects upon which Telford advised generally in his capacity as consultant to the Exchequer Loan Commission included the Stratford & Moreton (1821–1826), operated with horse traction; Clarence (1828–1829); Newcastle & Carlisle (1829–1834); and the Liverpool & Manchester (1827–1829), whose directors had offered him the post of engineer in 1825, an offer that he declined. He was however instrumental in persuading the company to abandon the idea of fixed engines and inclined planes in favour of a level line suitable for locomotive haulage. Important railway proposals which he planned, but which were not executed, included the Glasgow to Berwick Railway (1810), intended to be operated with horse traction and steam-powered inclined planes; the locomotive operated London to Dover (1824); the East & West India Docks (1828) and the Glasgow, Forth & Clyde Canal to Broomielaw (1829), which was mainly in tunnel.

Fen drainage

From 1818 to 1821, Telford advised on behalf of the Navigation Commission on the execution of the Eau Brink Cut designed by John Rennie (Sr.) (q.v.) which bypassed the meandering Ouse above Kings Lynn. The Cut, the width of which had been specified by Joseph Huddart (q.v.), proved to be insufficient and soon afterwards it was widened by Telford and John Rennie (Jr.) (q.v.) with most beneficial effects. Telford also worked with Rennie (Jr.) on the Nene Outfall Cut from Wisbech to Crab Hole in The Wash,

executed from 1827 to 1830 for about £200,000. It was on this work, whilst visiting Crab Hole with Rennie, that he was soaked to the skin in a storm and caught a severe chill. While returning to London, Telford was taken ill at Cambridge where he was confined for a fortnight and nearly died. His health never fully recovered.

On this work Rennie (Jr.) found Telford 'a most agreeable facetious companion' (Rennie, 201). This relationship contrasts with that of his father who wrote in a letter to Robert Stevenson (q.v.) in 1806 that Telford 'has no originality of thought and has all his life built the little fame he has acquired upon the knowledge of others which he has generally assumed as his own' (NLS. Acc. 10706, 73, 55). Rennie's comment provides substance for references in a letter Telford wrote to Watt in 1805. 'I am sorry to inform you', he wrote, 'that Mr. Rennie's conduct prevents me from benefiting by his acquaintance. Altho' I never had any connection with him in business or ever intentionally did anything to injure or interfere with him I, in every quarter, hear of his treating my character with a degree of illiberality not very becoming. This is so marked a part of his conduct, that I really believe it does him a serious injury ...' (Boulton & Watt Collection).

Telford's most important achievement in the Fens, made possible by the Nene Outfall Cut, was the drainage of about 48,000 acres of the North Level. For this major work, carried out from 1830 to 1834, he was the sole engineer.

Docks, harbours and piers

Telford advised on or acted as engineer for the improvement of more than 100 harbours, docks or piers, including many in Scotland for the Highland Road Commissioners. In addition to the British Fisheries Society harbours already mentioned, these included: Aberdeen, Peterhead, Ardrossan, Glasgow, Fraserburgh, Dundee, Leith, Belfast, Holyhead, Dublin, Howth and Dunmore, St. Katharine's Dock, Leith, Greenock and Dover. In some cases, such as Aberdeen this represented the design of several works over a period of more than twenty years. Elsewhere, such as Belfast and Glasgow, there were several consultations, but little work. Work at Fraserburgh, Leith, Holyhead, Howth and Greenock generally represented the overseeing of works designed by others, notably John Rennie. At St. Katharine's Dock, on a restricted and awkwardly shaped site which had required the demolition of over 1,250 houses and the excavation of 27 acres, Telford designed an entrance lock giving access to a basin interconnecting two irregular-shaped docks. This arrangement enabled each dock to be cleaned out separately without interrupting shipping operations. The loss of water through lockage was compensated for by an ingenious arrangement of pumps which delivered water from the river either into the lock or basin as required. This work, which was then the most advanced of its kind, was executed under the diligent supervision of Peter Logan, John Hall (q.v.) and Thomas Rhodes as resident engineers.

Water supply

Telford advised on several water supply schemes, one of the earliest, from 1799 to 1802, being a piped supply to Liverpool pumped by steam engines from springs at Bootle. In 1806 he was appointed engineer of the Glasgow waterworks and, in association with James Watt (q.v.), completely reorganised its defective and impure supply. An innovative feature was a cast iron main with flexible joints specially invented by Watt to enable the water to cross the Clyde. From 1810 to 1822 Telford was consulted on Edinburgh water supply and in association with local engineer James Jardine (q.v.) was involved in the construction of Glencorse reservoir, with what was then one of the tallest earth dams in Britain. With characteristic attention to detail, every iron pipe in the main leading into the city was proved at a pressure equal to that of a column of water from 300 to 800 ft. high and they are still in service. *The Scotsman* in 1825 considered these works 'the most extensive, perfect and complete ever executed in modern times' (IX No. 603). From 1827 to 1834 Telford, with assistants John Macneill and James Mills (q.v.), was engaged on his largest water supply project, to supply London much-needed pure water. In 1834, Telford proposed to bring in water from the Verulam near Watford and the Wandle at Beddington at an estimated cost of £1.177 million. Although not implemented, according to Smiles, these proposals strongly stimulated the water companies and eventually led to great improvements.

Highland churches

From 1823 to 1834 Telford superintended the design and provision of Highland churches and manses at forty-three sites from Islay northwards to the Shetland Islands. As superintending surveyor to the Highland Churches Commission, he prepared plans, specifications and estimates for standardised structures based on the proposals of his three surveyors, of which those of William Thomson (q.v.) for the churches were closest to the form finally adopted. The basically austere structures, most of which still exist, are often enlivened by a touch of Telford's architectural artistry. He estimated that the churches were capable of containing about 22,000 persons without inconvenience.

Exchequer Bill Loan Commissioners

Telford's appointment as Engineer to the Holyhead Roads Commission confirmed his status as a leading consultant on civil engineering matters to the British Government. His only challenger in this regard was John Rennie, who dominated dockyard work. Telford's position was consolidated in 1817 when he became Engineer to the Exchequer Bill Loan Commissioners, established by the Poor Employment Act (57 Geo. III c.34). He was appointed their adviser 'on all works

requiring the information of a civil engineer'. In the period of high unemployment which followed the end of the Napoleonic Wars the Government was increasingly concerned at associated political and serious unrest; it was also being besieged by requests from various canal companies which lacked the funds to complete their navigations. To address these issues the Act, recognising the 'great Advantage ... in affording Employment for the labouring classes of the Community', authorised loans for public works, and other initiatives such as fisheries and mines. From 1817 to 1834 more than £4½ million in loans was authorised, the bulk involving public works, and on many of these schemes Telford's recommendations were sought. Aided by a growing team of assistants, notably James Mills, Telford produced a stream of reports. Nearly four-hundred applications were successful, and many more fell, either because Telford's report was critical, or the scheme was otherwise found wanting. Telford's role varied from recommending against such as that for the Wiltshire and Berkshire, and Lechlade canals, to putting forward schemes such as that for the ferries across the Tay where he was engineer. With some schemes he had had earlier involvement as a consultant, such as the Union Canal in Scotland, whilst on the Gloucester–Berkeley Canal he became Engineer when the Commissioners took over responsibility, and on the Ulster Canal he also he became the leading consultant. The overall result was for Telford to be consulted about almost every civil engineering scheme of any size undertaken outside the dockyards in the period 1817–1834, giving him an unprecedented, and probably unparalleled, view of civil engineering work. Coincidentally, the Commission changed its policies in 1834, the year of Telford's death, concentrating its resources on the construction of work houses, which meant that Telford's successors as engineering consultants to the Commission could never attain his overall insight into the profession in that way.

Publications

Telford's technical publications consisted mainly of engineering reports. His earliest known publications were poems. In addition, he wrote authoritative articles for the *Edinburgh Encyclopaedia*, of which he was a leading proprietor. These were 'Bridge' with co-author Alexander Nimmo (first published 1812), 'Civil Architecture' (1813), 'Navigation Inland' also with a contribution by Nimmo (1821, partly written in 1814), and almost certainly 'Jessop' (1817). Altogether they amounted to in excess of three-hundred pages with eighty-two plates and were particularly influential before 1830 when the whole encyclopaedia was issued. The drawings for at least forty-six of the plates were made by Telford's assistants and at least twenty-seven by outside draughtsmen. It is unlikely that he drew any himself.

Telford's periodical publications included articles in the *Philosophical Magazine* on the proposed iron arch replacement for London Bridge (1801), canals (1803), his Highlands report (1803), Stamford Junction Navigation (1810), and later, on the effect on the River Thames of rebuilding London Bridge (1825). Telford's proposal to suspend arch bridge centering by means of radiating iron stays in *Nicholson's Journal* (1813) encouraged the design of suspension bridges generally. His compilation *General Rules for Repairing Roads* widely circulated from 1819, and from 1833, Parnell's *Treatise on Roads*, both propagated his improved road-making practice as applied on the Holyhead Road and exercised a fundamental influence on road authorities for more than a century. It is evident from Telford's surviving diary that he spent considerable time on editing Parnell's book.

Several publications were dedicated to Telford of which the more important were W. A. Provis's *Account of the Suspension Bridge over Menai Strait* (1828), G. Bradshaw's 'Map of Canals ...' (1828–1833) and, of more general interest, that of the writer Robert Mudie in *A Second Judgement of Babylon the Great* (1829). Mudie wrote, 'To Thomas Telford, The Engineer, who in the intervals of an important, arduous and successful professional life, has found time to do more real kindness than any advertising philanthropist, who has rescued more genius from oblivion and turned more talent to the best interest of his country than any maecenas of any age'. He concluded, that Telford, by 'instituting the Royal Society of Civil Engineers' (the ICE) has given 'stability' to the nation's 'best art'.

Telford's most important publication, despite its deficiencies as a personal narrative, was his autobiographical *Life* ..., edited by John Rickman, 1838, written from 1831 as his health, hearing, and new commitments declined. Although its magnificent atlas of engraved plates, text and appendices constituted an invaluable record of his practice and achievement, the book was not very successful commercially at a price of 8 guineas. By the time it was eventually published, four years after his death, the nation was in the grip of railway expansion and it was to some extent outdated as a working manual. The unsold stock was bought by James Walker (q.v.), who succeeded Telford as president of the Institution of Civil Engineers, and was used for Telford premium prizes for many years, for example, to James Leslie in 1846.

Poetry

Telford's enjoyment of the books loaned to him by Miss Pasley marked the start of his life-long love of poetry and an almost excessive admiration for literary ability. This interest led to his friendship with the Rev. Archibald Alison, author of an essay on *Taste* in 1790, whom he had met at Sudborough rectory c. 1783, and who had introduced him to Thomas Campbell. In seeking support for a quarto publication of Campbell's

Thomas Telford: grants approved for the Exchequer Bill Loan Commissioners

Date of grant	Work description	Value of loan (£)	Surveyor (for Telford)	Engineer
1817	Southwark Bridge	78,000	–	John Rennie
1817	Folkestone Harbour	10,000	J. Upton	–
1817	Hay Railway	8,000	–	None (in 1817)
1817, 1820	Llanfihangel Railway	2,000, 3,000	–	None (in 1817)
1817	Llansamlet Tramroad	–	–	–
1817	North Stafford Railway	8,000	–	–
1817	Grosmont Railway	5,000	–	–
1817	Middle Level Drainage	350,000	–	John and Sir John Rennie
1818, 1821	Regent's Canal (completion of canal; Islington Tunnel)	250,000	–	James Morgan
1817–1833	Eau Brink Cut	15,000	Townshend, Casebourne, Swansborough	John and Sir John Rennie
1818	North Wiltshire Canal	–	–	William Whitworth
1818	Montgomeryshire Canal, Western Branch	6,000	–	George Buck
1818–1826?	Gloucester and Berkeley Canal (completion) *Note*: The Commissioners took over the canal in 1821	160,000	–	Thomas Fletcher, William Clegram
1820, 1823	Edinburgh and Glasgow Union Canal	100,000	–	Hugh Baird
1820, 1823	Plymouth and Dartmouth Railway	28,000	–	James Rendel
1820, 1823	Portsmouth and Arundel Navigation	40,000	–	James Hollinsworth
1820–1823	Holyhead Road, eight grants	44,000	John Easton	Thomas Telford
1821 (1826?)	Thames and Isis Navigation	13,000	–	–
1821	Black Sluice Drainage	5,000	–	–
1822	Tay Ferry	25,000	–	Thomas Telford
(1823), 1824, 1826	Bude Harbour and Canal	20,000	Alexander Easton	James Green
1823	Porthleven Harbour	23,000	–	–
1823	Isis Bridge, Oxford	6,000	–	–
1825	Kingston Bridge	40,000	–	Edward Lapidge
1826	Teignmouth Bridge	8,000	James Green	Roger Hopkins
1826	Bridgwater and Taunton Canal Navigation	15,000	–	James Hollinsworth
1826	River Witham Drainage	–	–	–
1826	New Shoreham Harbour	15,000	John Upton	William Clegram
(1826), 1827	Exeter Canal	10,000	–	James Green
1827	Liverpool and Manchester Railway	100,000	James Mills	George Stephenson
1827	Hackbridge and Wentbridge Railway	7,600	–	–
1827	Courtown Harbour	6,000	–	Nimmo and Giles
1828	Ulster Canal	120,000	Thomas Casebourne	Casebourne
1829, (1824)	Hertford Union Canal	20,000	–	Francis Giles
1831	Glastonbury Navigation and Land Drainage	5,000	–	Sir John Rennie
1832?	Norwich and Lowestoft Navigation	54,000	–	William Cubitt
1832	Clarence Railway	111,000 (second grant 1835)	T. Rhodes	–

Thomas Telford: grants approved for the Exchequer Bill Loan Commissioners (contd.)

Date of grant	Work description	Value of loan (£)	Surveyor (for Telford)	Engineer
1832	Newcastle and Carlisle Railway	160,000 (second grant 1835)	–	Francis Giles
1834	Ouse Navigation (Yorkshire)	10,000	T. Rhodes	–
1834	Bodmin and Wadebridge Railway	8,000	–	R. Hopkins
[1835]	Hartlepool Dock and Railway	30,000	(T. Rhodes)	–

Note: this list excludes works which were not executed following reports by Telford.

poems in 1802, Telford wrote to Watt, 'Have you any people guilty of a taste for fine poetry in your quarter. If so, I stand ready to whet them in their transgression by adding their names to a list I am trying to procure for this young Scot'. Rickman introduced Telford to Southey. All became his close friends. Telford's earliest-known printed work was an eight-verse poem in Ruddiman's *Weekly Magazine, or Edinburgh Amusement* on 5 May 1779, in traditional early eighteenth century style, which ended:

Lang may ye sing, weel may ye phrase,
Hae routh and plenty a' your days;
And I shall gar a' our green braes
Ken weel your name,
I'm sure ye still sall hae the praise
O' ESKDALE TAM.

This poem was closely followed by *Eskdale*, first published separately at London in 1781, probably for the Pasleys, prefaced by his introduction as a 'stonemason ... a young man of no education but common reading, assisted by some books lent him by neighbouring gentlemen'. It was reprinted several times and was well thought of by Southey. At least twelve poems are known to have been written by Telford during his lifetime, many of which are referred to by Smiles. The last known, in 1831, was a tribute *To Sir John Malcolm on receiving his Miscellaneous Poems* (ed. Paxton, 1971). The most widely circulated was a manuscript poem to Burns, which Dr. Currie considered of 'superior merit' to other poems found among the poet's papers, and he printed 26 verses of it in many editions of Burns's works from 1801. The original version begins:

To Robert Burns

How sweetly flow thy simply strains,
Dear Bard of Scotia's happy plains
Thou pride of a' the cottage swains,
None sings like thee.

Some of Telford's poems were signed with the initials 'TT'. His usual signature in correspondence and reports was reports was 'Thos. Telford' with a flamboyant underlining of his surname, but a small but significant change occurred from *c.* 1806 after which the letters 'o' and 's' were not joined.

Professional societies

In 1820 Telford was invited to become the first president of the Institution of Civil Engineers, an office he held until his death. The Institution, the world's first professional engineering body, had been founded by a group of young engineers, led by Henry Robinson Palmer (q.v.) in 1818, but its youthful leadership lacked the gravitas to attract members; Telford provided the leadership, contacts and prestige to attract members from all over the country and even overseas. Soon after taking office his staff were able to provide continuity in secretarial support to establish firmly the valuable tradition of recording the proceedings and discussions of meetings and the substance of papers read. His diligent and invaluable fostering of the Institution as a forum for engineering knowledge included, encouraging membership, provision of a library of books and drawings, urging members to present papers, and even chasing up and making good the subscriptions of Gotha Canal engineers Lagerheim and Edström. He had considerable influence with the governmental establishment and was the driving force behind the obtaining of the Institution's royal charter in 1828. In his will he left the Institution his largest bequest of over £3,000, and his books, drawings and papers. The money provided financial security, enabling the Institution to find permanent premises and to plan its publications. Telford's contribution to the Institution was fundamental to its early development. His next two largest bequests were to the parish libraries at Westerkirk and Langholm. He was elected to fellowship of the Royal Societies of Edinburgh and London in 1803 and 1827 respectively.

Character and personal

Telford never married and according to John Rickman, 'lived life as a soldier always in active service' (Telford's *Life*, 283). From *c.* 1800 he needed a permanent base in London and lived in rooms at the Salopian coffee house, Charing

Cross, until taking possession of 24 Abingdon Street in 1821, where he lived until his death. This enabled him to change his office organisation. In his earlier career Telford relied largely on personal recommendations and acquaintance for his assistants such as Matthew Davidson. His responsibilities meant he had an office in Shrewsbury from much the same time, administered by Stanton and John Telford. Around 1808 he took on his first pupil, William Provis, but, lacking a permanent home, was unable to develop a formal London base. From 1821, however, he took as pupils the children of trusted deputies such as Mitchell, May, Davidson, Gibb, and others who applied such as Turnbull. To these were added office assistants such as Henry Robinson Palmer and Thomas Casebourne. In addition he continued to rely heavily on largely autonomous deputies in the field like Provis, Stanton and Macneill. There can be little doubt this was much closer to the model of consulting engineering practice that was to follow than that of John Rennie who had no pupils, and kept a strict control of decision making.

Telford's contact with Alison and his family from 1783 to 1834 was probably the nearest approach to home life that he ever enjoyed. Little of Telford's character is to gleaned from his publications, but the opinions of some of his contemporaries are informative. Rickman stated that Telford's most distinguishing character trait was a benevolence which made him accessible to all who came to him for information. His pupil, Joseph Mitchell, recounted his master's 'great delight in his work. The perfect good faith and honour of all his transactions, his clear conscience, and his cheerful temper cast a halo of happiness throughout our establishment' (Mitchell, 102). In 1793 Catherine Plymley wrote after meeting Telford that he was 'an excellent architect and a most intelligent and enlightened man. His knowledge is general, his conversation very animated, his look full of intelligence and vivacity' (Penfold 'Colossus', 2). She also praised the liberality and cheerfulness of his charitable donations.

Southey wrote of Telford, 'there is so much intelligence in his countenance, so much frankness, kindness and hilarity about him flowing from the never-failing well spring of a happy nature, that I was upon cordial terms with him in five minutes' (Southey, 7). Telford was not a lover of concert music. He wrote, 'the melody of sounds is thrown away upon me, one look, one sentence from Mrs. Jordan has more effect upon me than all the fiddlers in England' (Gibb, 294). Sir David Brewster wrote of Telford's apparent sternness of manner which created difficulties at times in his relationships, and belied the genuine benevolence and kindness of his nature. He also referred to Telford's 'quick perception of character, his honesty of purpose, and his contempt for all other acquirements, save that of practical knowledge and experience which was best fitted ... have enabled him to leave behind him works of inestimable value ... which have not been surpassed either in Britain or in Europe' (Sir D. Brewster, 46). Telford died on 2 September 1834 at 24 Abingdon Street, London of a fatal bilious derangement. His remains rest in Westminster Abbey.

Of several portraits of himself Telford preferred that painted by S. Lane *c.* 1822, an engraving of which by W. Raddon was published by E. Turrell in January 1831 and used as the frontispiece to his *Life*. Telford also preferred the engraving to the painting as can been seen from the following letter written by him in February 1831 which was recently discovered on the back of Rickman's copy of the engraving: 'My Dear [Rickman]' he wrote, 'Accept a copy of my portrait made by knowing artists, a masterly performance. It was upwards of two years ago undertaken as a speculation by Mr. Turrell and another engraver, they have only just finished it. I prefer it to the painting. Place it among your friends' (private).

Conclusion

With hindsight, a more theoretical approach would have benefited Telford's structural design practice, but his reliance on experimental and practical procedures was the best available means of achieving the desired result at the time. An essential factor in his immense achievement was his sound judgement in selecting capable and reliable assistants and contractors, many of whom have been mentioned in this article, to whom he was able to devolve responsibility without losing control. Under his direction, they translated his designs into effect often at and even extending the frontiers of engineering technology and knowledge.

Telford's beneficial influence is most alive today through his many surviving works, contract procedures, and the Institution of Civil Engineers as a forum of engineering excellence. Of Telford's surviving works, although leisure interest in his canals is increasing, his roads and bridges, for which he was aptly dubbed by Southey as the 'Colossus of Roads' and 'Pontifex Maximus' (Smiles, 476), now make the greatest contribution to society. A welcome development in 1998 was the designation by the Welsh Office of the Holyhead Road across North Wales as an 'Historic Route' with appropriate information signing. Rolt, who was also the biographer of George Stephenson and Isambard Brunel, believed that Telford's 'achievement was as great as theirs and of equal historical significance' (Rolt, xi). Smiles, Rolt, Penfold and others have all helped to restore his reputation from its low ebb during the 'railway mania' era. Telford was undoubtedly one of the great civil engineers of all time.

ROLAND A. PAXTON

[NB: Original Telford material is to be found in most record offices in the British Isles. The main collections are to be found in the PRO; National Archives Scotland; Telford Collection, Ironbridge;

Telford mss, ICE archives. His large drawings collection, left to ICE on his death, was broken up in 1906, and effectively destroyed. J. Bennett (1830) *The History of Tewkesbury*; Sir H. Parnell (1833) *A Treatise on Roads*; T. Telford (1838) in J. Rickman (ed.), *Life of Thomas Telford*; R. Southey (1839) Review of Life of Thomas Telford, *Quarterly Review*, Jan.–Mar.; Sir D. Brewster (1839) Review of Life of Thomas Telford, *Edinburgh Review*, **LXX**; J. P. Muirhead (1854) *The Origin and Progress of the Mechanical Inventions of James Watt*; S. Smiles (1861) *Lives of the Engineers*, **II**; J. A. Roebling (1867) Report, 1867, *Annual Report of Covington & Cincinatti Bridge Company*; Sir J. Rennie (1875) *Autobiography of ...*; J. Mitchell (1883) *Reminiscences of my Life in the Highlands*; R. Southey (1929) *Journal of a Tour in Scotland in 1819*; Sir A. Gibb (1935) *The Story of Telford*; ICE (1950) *A Collection of Works of Art and Objects of Historical Interest*; ICE (1957) *Thomas Telford Bicentenary Exhibition* (catalogue); L. T. C. Rolt (1958) *Thomas Telford*; N. Pevsner (1958) *Shropshire*; A. R. B. Haldane (1962) *New Ways through the Glens*; T. Telford (1968) in R. A. Paxton (ed.), *Three Letters from Thos. Telford*; T. Telford (1971) in R. A. Paxton (ed.), *To Sir John Malcolm upon Receiving his Miscellaneous Poems—A Poem by Thomas Telford*; J. Dunlop (1978) *The British Fisheries Society 1786–1893*; R. A. Paxton (1975) The influence of Thomas Telford (1757–1834) on the use of improved constructional materials in civil engineering practice, M.Sc. thesis, Heriot–Watt University; T. Ruddock (1979) *Arch Bridges and their Builders 1735–1835*; A. E. Penfold (ed.) (1980) *Thomas Telford: Engineer*; A. Maclean (1989) *Telford's Highland Churches*; A. E. Penfold (1989) *Thomas Telford 'Colossus of Roads'*, exhibition catalogue; C. Hadfield (1993) *Thomas Telford's Temptation*; R. A. Paxton (1993) Review of 'Thomas Telford's Temptation', *The Institution of Civil Engineers Panel for Historical Engineering Works Newsletter*, December No. 60, 6–7; R. Paxton (1998) *Road and Bridge Making on Main Routes in and around Dalkeith*; R. A. Paxton (1999) The early development of the long span suspension bridge in Britain, *Proc International Conference*, Wheeling, West Virginia, USA; Skempton; R. A. Paxton; DNB]

Selected publications

1796. *A Copy of a Letter to the Secretary of the British Society, containing a Course of Experiments on Mr. James Parker's Cement*

1796. Some account of the inland navigation of the county of Salop, in *General View of the Agriculture of Shropshire by Joseph Plymley* (1803)

1800. Plans and estimates for iron bridges of three and five spans over the Thames (with James Douglass), in *Third Report from the Select Committee upon the Improvement of the Port of London*

1800–1802. Plans and an account of a proposed single arch iron bridge of 600 feet span over the Thames (with James Douglass), in *Select Committee on Port of London*, reports and in a tract. Separately published large aquatint view by T. Malton with the bridge engraved by W. Lowry

1801. Mr. Telford's Reports of Cromarty, Aberdeen and Wick, made to the Lords of the Treasury in 1801, in *Third Report from the Committee on the Survey of the Coasts &c. of Scotland: Naval Stations and Fisheries*

1803. Report by Thomas Telford on the Harbour of Aberdeen, in *Reports upon the Harbour of Aberdeen* (1834)

1803. *A Survey and Report of the Coasts and Central Highlands of Scotland, Made by Command of the Treasury, in the Autumn of 1802* (roads and bridges, naval stations, Caledonian Canal, fisheries, emigration, Carlisle & Portpatrick Road)

1803. *A Survey and Report of the proposed Extension of the Union Canal; from Gumley-Wharf, in Leicestershire, to the Grand Junction Canal, near Buckby-Wharf in Northamptonshire* (2nd edn., 1804)

1804–1821. Reports &c., in *Reports of the Commissioners for Highland Roads and Bridges*; reports from 1815–1834 in *Reports ... for maintaining ... roads and bridges in Scotland*

1804–1830. Reports etc. (some with W. Jessop), in *Reports of the Commissioners for the Caledonian Canal*

1804. *Suggestions ... relative to the Canal from Glasgow to the West Coast of the County of Air* [Ardrossan Canal]

1805. *A Report relative to the Proposed Canal from the City of Glasgow to the Harbour of Ardrossan on the West Coast of the County of Ayr, in Scotland*

1805. Report of the general state of the Grand Junction Canal, in *Report of the General Committee of the Grand Junction Canal Company*

1805. Report (with W. Jessop), in *Reports upon the Harbour of Aberdeen* 1834

1805. *A Report respecting supplying the City of Glasgow and its Suburbs, with Water*

1805. Report respecting the River Clyde, in *Reports on the Improvement and Management of the River Clyde* (1854)

1805. Report on improvements to Grangemouth harbour, in *State of Facts and Observations relative to the Affairs of the Forth and Clyde Navigation* (1816)

1806. Report on proposed harbour at Port Gower, in *Report from Committees ... Forfeited Estates*

1806. *Report respecting supplying the City ... of Glasgow with water ...*

1806–1826. Reports etc. in *Reports on the improvement of the River Clyde and Harbour of Glasgow* (1854)

1808. *Mr. Telford's Report on the intended Cumberland Canal*

1808. Report respecting the line of communication between the north of England and Ireland (by the south-west of Scotland, with John McKerlie), in *Report from the Committee Appointed*

to Examine into Mr. Telford's Report and Survey (1809), with sixteen large plans separately bound

1808. Report of the Gotha Canal, being the result of a Survey made in 1808, in *Life of Thomas Telford* (1838)

1809. Report, in *Reports upon the Harbour of Aberdeen* (1834)

1810. *Report relative to the proposed* [cast-iron] *railway from Glasgow to Berwick-upon-Tweed, with Mr. Jessop's opinion thereon*

1810. *Plan and Sections of the Track of a proposed Cast Iron Railway, from the City of Glasgow, to Berwick-upon-Tweed, passing through the Counties of Lanark, Peebles, Selkirk, Roxburgh, Berwick, and Northumberland*

1810. *Report and Estimates relative to a proposed Road in Scotland from Kyle-Rhea in Invernessshire to Killin in Perthshire by Rannoch-Moor*

1810. *Report of Mr. Telford, respecting the Stamford Junction Navigation*

1810. Report by Thomas Telford, Esq., in *Reports on the Means of Improving the Supply of Water for the City of Edinburgh and on the quality of the different Springs* (1813)

1811. Mr. Telford's surveys of New Galloway Bridge: Glenluce Road; and Carlisle and Garistown Road, in *Report from the Committee, upon the Roads between Carlisle and Port Patrick* (1811)

1811. Report to the Treasury, respecting the Great Roads, from Holyhead through North Wales, in *Report from Committee on Holyhead Roads* (1811); includes 'Method of constructing an iron bridge with one arch of extensive span proposed to be carried over the Menai' using iron stays'. Also in W. Nicholson (ed.) *A Journal of Natural Philosophy*, 1813

1812–1821. Contributions to *Edinburgh Encyclopaedia* [see p. 689]

1813. Report on the Crinan Canal (1813), in *Papers relating to the Crinan Canal 1813–1815* (1816); another in *Fourteenth Report of the Commissioners for the Caledonian Canal* (1817)

1814. *Report respecting the Harbour of Dundee in the County of Forfar*

1814. Design for a bridge over the River Mersey at Runcorn and reports, in *Report of the Select Committee appointed to Consider the most Practicable and Expedient Mode of effecting the Proposed Bridge at Runcorn*, Warrington (1817)

1815. *Report on the intended Edinburgh and Glasgow Union Canal*

1815. Report [Grangemouth Harbour], in *State Facts and Observations Relative to the Affairs f the Forth & Clyde Navigation* (1816)

1815–1830. Report respecting the Road from Carlisle to Glasgow, in *Report from Select Committee on Carlisle and Glasgow Road* (1815); later reports made to the Commissioners, ... *for Maintaining and Keeping in Repair certain Roads and Bridges in Scotland*

1815. Reports, estimates, etc., in *Report of the Commissioners for Repairing the Roads between London and Holyhead by Chester and between London and Bangor by Shrewsbury* (1816); numerous later reports in the publications of the Select Committee on the Roads from Holyhead to London, last known 9 August 1834

1815–1817. First (and second) report of Mr. Telford on the intended Edinburgh and Glasgow Union Canal, in *Observations by the Union Canal Committee, on the Objections made by the Inhabitants of Leith to this Undertaking*

1817–1819–1828. Dee Navigation reports, in *Local Acts. Copies of Admiralty Reports under Preliminary Inquiries Act 1850—Dee Conservancy Bill*

1818. *Map of a proposed Line of Navigable Canal from near the Town of Knaresbro' to the River Ouse at Ancaster Sailby with a Line of Rail-Road from Knaresbro' ... to Pately Bridge in the County of York*

1818–1819. [Menai Bridge] Report, plan, and estimate for building a Bridge over the Menai Strait, near Bangor Ferry, in *Papers relating to the Building a Bridge over the Menai Straits near Bangor Ferry*, House of Commons 1819; [and] Design for a bridge over the Menai Straits at Ynys-y-Moch, in *Third Report from the Select Committee on the Road from London to Holyhead &c Menai Bridge*

1819. Report for Glasgow Dock, in *Reports on the Improvement and Management of the River Clyde* (1854)

1819. Some account of the drainages of Holland and short account of the drainage of the fens, in *Second Report for the Select Committees in the State of Disease and Condition of the Labouring Poor in Ireland*, 111–115

1819–1820. *Northern Roads. Copy of a Report and Estimate, of Two proposed Lines of Roads: The one leading from Catterick Bridge, in the County of York, to the Carter Fell, on the Borders of Scotland: The other leading from Catterick Bridge to New Castleton, in the County of Roxburgh; made under the Instructions of the Lords of His Majesty's Treasury*

1820. Report 5 June 1820, in *Holyhead Road. Reports of Mr. Telford*, including 'General Rules for Repairing Roads' (published separately in 8vo 1820; 4th edn., 1823; J. Weale 1837)

1820–1826. Reports on the extension of Broomielaw Quay, in *Reports on the Improvement and Management of the River Clyde and Harbour of Glasgow* (1854)

1821. Report and plan, in *Report by the Committee of Management, relative to the Plans of the New Ferry Harbours at Dundee and the opposite coast of Fife, proposed by Mr. Telford*

1821. *Mr. Telford's Report on the Points referred to him by the Corporation of Wisbech* (Fen drainage)

1821. *Dunmore Harbour. A Copy of the Report of Mr. Thomas Telford*

1822. Edinburgh and Morpeth Road. Report and estimate of a proposed line of road from Morpeth by Wooler, in *Report from Select Committee on Morpeth and Edinburgh Road* (1822)

1822. *Report on the Eau Brink Cut* (with (Sir) John Rennie)

1823. Mr. Telford's Reports [on the foundations of Westminster Bridge], in *Reports by Messrs. Telford, Cubitt, and Swinburne, Civil Engineers, as to the State of the Foundations, &c. of Westminster Bridge* (1836)
1823–1831. *Report of Thomas Telford, Esq. on the Effects which will be Produced on the River Thames by the Rebuilding of London Bridge.* Other reports from 1823 to 1831 in *Report from the Select Committee on Westminster Bridge* (1844)
1823–1824. Report(s) on roads from Glasgow to Port-Patrick, in *Report(s) from the Select Committee on Glasgow and Port-Patrick Roads* (1823–1824)
1824. Report respecting the street pavements &c. of the Parish of St. George, Hanover Square (London), in Parnell (1833) *A Treatise on Roads*
1824. *Report on the Practicability and Advantages of Opening and Improving the Navigation of the River Stour*
1824. Prospectus and Mr. Telford's preliminary report, in *English and Bristol Channels Ship Canal*
1824. *Ship Canal, for the Junction of the English and Bristol Channels. Reports of Mr. Telford and Captain Nicholls* (repr. 1825)
1824–1825. *Berwick and Morpeth Road. Report made by Mr. Telford, to the Lords of the Treasury, respecting the Mail Road between the City of Edinburgh and the Town of Morpeth by the Towns of Berwick and Alnwick*
1825. *Map or Plan & Sections describing the line of an intended Turnpike Road to be made from the Parish of West Wycombe in the County of Buckingham, through Thame to Chilworth in the County of Oxford*
1825–1826. Mr. Telford's report on his Survey of Mail Roads and Steam-boat Stations in South Wales, in *South Wales Roads. A Copy of the Postmaster General's Letter to the Lords Commissioners of His Majesty's Treasury upon the subject of the Roads through South Wales*; other reports on the improvement of communication with Milford Haven across South Wales followed in 1827
1825–1834. Plans and elevations of a church and a manse, in *First Report of the Commissioners for Building Churches in the Highlands and Islands of Scotland. House of Commons*, 1825 (see also 2nd–7th reports)
1826–1829. *Liverpool and London Road. Report(s) on the state of the road from London to Liverpool*
1827. *Report respecting the Mail Road between London and the Town of Morpeth, made under the direction of His Majesty's Postmaster General* (and maps 1826–1827)
1827. *Mr. Telford's Reports, Estimates and Plans for improving the Road from London to Liverpool*
1828. *Report respecting the Lower Ferry between the Counties of Mid-Lothian and Fife*
1828. *Plan of the St. Katharine Docks*
1828. Report on the Queensferry Passage (across R. Forth), in *Report of the Committee*, Edinburgh
1828. Reports with R. Stevenson and A. Nimmo on the intended ship canal between the Rivers Dee and Mersey, in D. Stevenson (1878) *Life of Robert Stevenson*
1828. Report with P. Roget and W. T. Brand, in *Report of the Commissioners appointed by His Majesty to inquire into the State of the Supply of Water in the Metropolis*
1829. *Liverpool and Manchester Rail-way. Mr. Telford's Report to the Commissioners for the Loan of Exchequer Bills*
1829. Report on the improvement of Swansea Harbour, in *Reports on the Harbour of Swansea*
1829. Report of the proposed new mail road, from Carlisle to Edinburgh (by Langholm) (and map), in *Report from the Select Committee on the state of the Northern Roads* (1830)
1830. [Report on] *Glasgow Railway* [to connect the Forth & Clyde Canal with Broomielaw Harbour]
1830. Report respecting the port and harbour of Belfast, in *Admiralty–Harbour Department—History of the Harbours of the United Kingdom* (1852)
1830. Report, in *Report from the Committee on Birmingham and London Junction Canal Petition*
1830. Report on state on the Holyhead and Liverpool Roads with report from Mr. Macneill on the labour of horses in drawing carriages on roads of different construction, in *Seventh Report of the Commissioners for the further Improvement of the Road from London to Holyhead and from London to Liverpool*
1830. Collected edition of articles on architecture, bridges, inland navigation and Jessop. First published *c.* 1810–1821, in *The Edinburgh Encyclopaedia* (see p. 689)
1830. Plan for improving the harbour of Aberdeen, in *Reports upon the Harbour of Aberdeen*
1833. Report, in *Report of the Committee of Management on the Glasgow Bridges; relative to the Building of Jamaica St. Bridge*
1833. Report, with others, of the result of an experimental journey ... in Sir Charles Dance's steam carriage, in A. Gordon (1836) *A Treatise on Elemental Locomotion*
1834. *Metropolis Water Supply. Report of Thomas Telford, Civil Engineer, on the Means of Supplying the Metropolis with Pure Water*
1834. Report, in *Report from the Select Committee on Dover Harbour*
1834. *Report on the Present State of the New London Bridge* (with James Walker)
1834. Report on Firth of Forth Ferries (Newhaven–Burntisland), in *Forth Ferries*, House of Commons (1838)
1838. *Life of Thomas Telford, Civil Engineer, written by himself*, John Rickman (ed.)

Works
See table on pp. 696–697

THATCHER, Thomas (fl. 1799–1834), contractor, presumably had experience of canal construction when he applied for the post of Agent on the Kennet and Avon Canal in 1795. In the event

Thomas Telford: works

Date	Work	Cost (£)	Resident Engineer
1782–1793	Shrewsbury Gaol	–	–
1790–1792	Montford Bridge	6,000	Matthew Davidson
1792–1794	St. Mary's Church, Bridgnorth	7,000	–
1794–1796	St. Michael's Church, Madeley	–	–
1794–1805	Ellesmere Canal*	460,000	John Duncombe, 1794–1803
	1795–1805: Pontcysyllte	47,000	Thomas Denson, 1803–1805
	1790–1701, Chirk Aqueduct	21,000	
1795–1796	Buildwas Bridge	6,500	–
1795–1796	Longdon Aqueduct	–	–
1795–1799	Bewdley Bridge	9,000	Matthew Davidson
1803–1821	Highland roads and bridges	430,000	James Donaldson,
	1806–1808: Dunkeld Bridge	30,000	1803–1806
	1811–1812: Bonar Bridge	14,000	John Duncombe, 1806–1809
	1812–1814: Craigellachie Bridge	8,000	John Mitchell, 1809–1823
1803–1822	Caledonian Canal†	900,000	Matthew Davidson, 1804–1819 James Davidson, 1820–1822 John Telford, 1804–1807 Alexander Easton, 1807–1822
1805–1806	Tongland Bridge	7,710	Adam Blane
1806–1811	Glasgow–Paisley Canal and Ardrossan Harbour	130,000	David Henry
1806–1824	Highland harbours	100,000	
	1808–1811: Fraserburgh‡	11,000	William Stuart
	1814–1817: Fortrose	4,000	John Mitchell
	1816–1821: Banff	16,000	John Gibb
	1818–1823: Peterhead	23,000	John Gibb
1807–1812	Loch Spynie Canal	12,740	William Hughes
1807–1810	Weston Canal, Weaver Navigation	50,000	Samuel Fowls
1809–1833	Gotha Canal, Sweden	–	John Wilson and others
1810–1815	Aberdeen Harbour II	100,000	John Gibb
1815–1825	Dundee Harbour	120,000	David Logan, 1816–1821 Peter Logan, 1821–1825
1815–1830	Holyhead Road	495,000	William Provis, 1815–1826
	1815–1830: Shrewsbury-Bangor	117,000	John Provis, 1826–1830
	1818–1826: Menai Bridge	185,000	William Provis
	1819–1829: Anglesey Road	61,000	William Dargan, 1820–1822
	1820–1830: London-Shrewsbury	132,000	John Provis, 1822–1829 John Easton, 1820–1826 John Macneill, 1826–1830
1816–1817	Crinan Canal, repairs	–	William Thomson
1815–1823	Glasgow–Carlisle Road	50,000	William Provis John Pollock
1818–1827	Gloucester–Berkeley Canal	330,000	Thomas Fletcher
1819–1823	Edinburgh Water Supply	145,000	James Jardine
1819–1826	Dee (Chester) Navigation improvements	26,000	Thomas Wedge
1820	Glasgow Old Bridge, widening with cast iron cantilevered walkways	–	–
1820–1821	Loose and Linton Hill Road, Kent, improvements	–	Henry Robinson Palmer
1820–1823	Lanarkshire Roads	19,000	John Pollock
	1821–1822: Cartland Crags Bridge	5,000	Henry Welch
1822–1826	Conway Bridge	51,000	William Provis
1822–1825	Dublin Docks completion	40,000	John Aird
1823–1828	Holyhead Harbour II	43,000	James Brown(e)
1824–1826	Mythe Bridge, Tewkesbury	35,000	William Mackenzie
1824–1827	Harecastle Tunnel	112,000	James Potter
1825–1827	Knypersley Dam	16,000	James Potter
1825–1830	Birmingham Canal III	24,000	William Mackenzie
	1825–1828: Rotton Park Dam		
	1829: Galton Bridge		

Thomas Telford: works (contd.)

Date	Work	Cost (£)	Resident Engineer
1826–1828	Over Bridge, Gloucester	43,000	Thomas Fletcher
1826–1828	Holt Fleet Bridge	–	William Mackenzie
1826–1829	Eau Brink Cut, widening‡	33,000	Charles Burcham
1826–1830	St. Katharine's Docks, London	250,000	Peter Logan, 1825–1828 John Hall, 1828 Thomas Rhodes, 1828–1830
1826–1835	Birmingham and Liverpool Junction Canal‖	800,000	Alexander Easton
1827–1830	Chester–Bangor Road	14,000	John Provis
1827–1830	Nene Outfall Channel†	200,000	William Swansborough
1827–1834	Highland churches	54,000	Joseph Mitchell and others
1827–1830	Bridge of Don, Aberdeenshire	25,000	John Smith
1827–1830	Pathhead Road	6,500	Henry Welch
	Lothian Bridge	–	John Cargill
1829–1831	Morpeth Bridge	19,000	Charles Atherton
1829–1831	Dean Bridge, Edinburgh	60,000	John and Alexander Gibb
1829–1832	Aberdeen Harbour III	150,000	James Leslie
1830–1834	Dundee Docks	150,000	William Swansborough and Thomas Pear
1830–1834	North Level Drainage of Fens	34,000	Charles Atherton
1833–1836	Broomielaw Bridge, Glasgow		

*William Jessop, principal engineer
†William Jessop, consultant 1803–1812
‡Sir John Rennie, joint engineer
§John Rennie, principal designer
‖Completed by William Cubitt

he was not appointed, but with John Clark was awarded three lots west of Devizes. These contracts were for earthworks only, the bridges in two of them being awarded to James Hollinsworth (q.v.). Thatcher, again with Clark was next awarded the first excavation contract on the City Canal in London's Isle of Dogs on 24 October 1799. This related to the top 6 ft. of earth, and was carried out January to July 1800. John Dyson (q.v.) completed the excavation. The engineer for the work was William Jessop (q.v.) and he was again engineer for the next contract for which we have information, that for the soil excavation at Bristol Dock in April 1804. Thatcher's initial (business) partner was James Sharp, who left in June 1805. Thatcher obtained further contracts in the docks for excavating the eastern half of the New Cut, and the Rownham and Bathurst contracts in 1804. Later in 1805, with a new partner, Richards, he obtained the excavation contracts for the western end of the New Cut, and the Cumberland entrance locks. In June 1806 they followed this with a contract for walling the basin. Work generally progressed smoothly, although in June 1808 a high tide broke over the cofferdam and through the bank at Rownham, necessitating £15,000 of additional expenditure. By dint of extraordinary exertions, Thatcher was able to complete the basin and locks on schedule. More than one thousand men were employed on the construction of the docks, although other contractors were involved, such as Hodge and Langman. Richards was a mason who brought additional expertise to Thatcher's enterprise, and built the Prince Bridge. The whole scheme was completed in May 1809.

Thatcher's subsequent career is unknown, until he reappears in the fens in 1825, undertaking work again involving cofferdams for Samuel Bower (q.v.). In the 1830s Richard Parr cited Thomas Thatcher as his surety when tendering for a contract on the London–Birmingham Railway.

P. S. M. CROSS-RUDKIN AND MIKE CHRIMES

[Frank Smith Files and Jessop papers, ICE archives; Kennet and Avon Canal papers, RAIL 842, PRO; R59/31/6a/1, Cambs CRO]

Works

1796. Kennet and Avon Canal, contractor for lots 11, 13 and 14, worth £641, £1148, £1500, respectively
1799–1800. City Canal, excavation, contractor
1804–1809. Bristol docks, excavation and masonry work, contractor
1825. Welmore Lake Sluice, Denver, contractor, over £9,000

THOM, Robert (1774–1847), civil engineer, was born in Tarbolton, Ayrshire, and spent his early years on his father's farm. In the winter months, and whenever he could be spared from agricultural employment, he attended school or pursued his studies on his own. He then, under the instruction of an elder brother, became an expert joiner or 'wright', at which trade he worked when he moved to Glasgow in the hope of advancing in