If, when travelling north into Scotland, you leave the A7 at Langholm and follow the B709 towards Eskdalemuir, you will pass through Bentpath. When you take a left-hand bend, your eyes are tempted to look straight ahead, up a pleasant verdant valley in which Thomas Telford was born (1757 – 1834). If you are not careful, you will miss a stone seat on the left-hand side. The inscription on it reads:-

This seat was erected in 1928 to perpetuate the memory of Thomas Telford, son of the unblameable shepherd, and to record his fame as an engineer and his untiring benevolence. Apprenticed to a stonemason in Langholm, his creative genius gave the nation many works of inestimable benefit. He was the first “President of the Institution of Civil Engineers”.

I am very honoured to have been invited to present this paper on Thomas Telford and pay tribute to a most remarkable man who rose from humble origins to become first President of the Institution of Civil Engineers. To do justice to the whole range of his achievements would take far longer than the time available to us this evening so I will examine only a few highlights of his civil engineering achievements, particularly because I want to compare Telford with two other contemporaries – James Watt (1736 – 1819) and John Rennie (1761 – 1821)

Telford was born on 9 August 1757 at Westerkirk, Eskdale. His father, the unblameable shepherd died in the following November, leaving his mother to bring up their only son. His uncle Jackson paid the fees which enabled Telford to attend the parish school at Westerkirk. He was then apprenticed to a stonemason in Langholm where he helped in
the rebuilding of the main bridge. His marks can be found on some of the stones. His later achievements in stone, cast and wrought iron must be set against this minimal education and contrasts with both Watt and Rennie.

Watt’s father, also James, was a comparatively well-off shipping merchant in the port of Greenock. His son, our Watt, was a rather sickly lad, who attended the local school and had the run of his father’s ship chandling business, including tools and scientific navigation instruments. He was particularly attracted to such instruments which took him first to Glasgow and then to London for training as a scientific instrument maker. On his return to Glasgow, he set up a shop in the University where he made the acquaintance of professors such as Joseph Black. It was Prof. Anderson who asked him to repair a model of a Newcomen atmospheric steam engine which would lead to his important invention of the separate condenser. The point I wish to make is that the young Watt had a youth with a better social background and better contacts with the scientific world of his day than did our Telford.

The same can be said of Rennie. He was born in 1761 in his parent’s farm at Phantassie, Haddington, East Lothian. His father died in 1766. Samuel Smiles recounts the usual tale about young Rennie setting off to school but never arriving because he had to pass the workshop of the famous millwright, Andrew Meikle. Rennie also acquired some mathematical knowledge from Mr. Gibson, a master at Dunbar High School, where his talents in that subject as well as in natural and experimental philosophy were recognised. Rennie matriculated at Edinburgh University in 1779 where he could have attended Prof. Robison’s courses on Natural Philosophy. Somewhere Rennie trained as a millwright and built his first bridge at the age of 23 and a flour mill at the same age. In 1783, Robison introduced him to Matthew Boulton. Rennie set out for Birmingham in 1784 to receive a couple of month’s training in erecting Boulton and Watt engines before leaving for London to be in charge of erecting the steam engines at the Albion Mill. When these were finished, Rennie established his own millwrighting business at Blackfriars, repairing waterwheels in paper mills and the like. But the on the second of January 1792, Boulton wrote to him,
I am sorry to perceive that you are turning all your attention and all your force from Mills to Canals, particularly as I want a very large and capital mill to be built for one of my friends. (National Library of Scotland, Rennie Papers, Ms. 19824.41, Matthew Boulton to John Rennie, 2 January 1792)

The mechanical engineer, with a very different background to Telford, had become a civil engineer.

What had been happening to our Telford in the meantime? Our stone-mason worked at first in Edinburgh but, in 1782 aged 24, he set out for London with a letter of introduction and so met Sir William Chambers, one of the best architects of his day. In London, Telford began to study mathematics, architecture, philosophy and languages. He also worked for Sir William Pultney who probably obtained his appointment to supervise works at Portsmouth dockyard.

Telford’s real break-through in his career came in 1786 when Pultney brought him to Shrewsbury to work on the castle there. In the following year, he became Surveyor of Public Works for the County Salop. In an architectural role, he became involved with the renovation of Shrewsbury prison, St. Mary Magdalene Church in Bridgnorth and St. Michael’s Church in Madeley. His reputation was further enhanced when he was employed as consultant over the leaking roof of St. Chad’s Church in Shrewsbury. At first he was derided when he predicted that the building was so unsafe that it was in imminent danger of collapse, which indeed it did three days later. Soon after this, he began to switch from domestic architecture into public works such as roads bridges and canals.

Let us look first at the work of Thomas Telford, stonemason, and see a couple of his masterpieces. One of his last great road bridges must be the Dean Bridge in Edinburgh constructed in 1831. My Aunt’s flat overlooked it which gave quite a good view of its dramatic setting, towering over the Water of Leith. Its height above the river is 106 ft. and each of its four arches has 90 ft. span. Notice the clean lines and economy in its construction with the lighter side arches supporting the foot-
paths, one of Telford’s characteristic features. Notice also the tasteful inclusion of different types of variously coloured stone.

A bridge that has always impressed me is the one Telford designed in 1826 to cross the River Severn at Over, the lowest on that river. But first we will take a quick look at what must be considered Rennie’s masterpiece, London Bridge, designed by him in 1821 but only completed by his son, Sir John Rennie and opened by William IV and Queen Adelaide on 1 August 1831. It had five spans, the two at either end being 130 ft., the next two 140 ft. and the centre 150 ft. That 150 ft. span is the same as the single one of Over Bridge. While Rennie’s London Bridge had to be replaced and the stonework re-erected over Lake Havasu in Arizona, Telford’s bridge remains on its original site although recently by-passed and bereft of traffic.

We saw on the Dean Bridge Telford’s use of two arches of differing curvature. It was a feature used on some of his earliest designs such as the cast iron bridge at Buildwas and which he used to good effect at Over. It has been suggested that the sloping stonework at either end might have been designed to assist the passage of floodwater. While Rennie’s central span was buttressed by those on either side, Telford’s had to supported by massive earth abutments. It is remarkable how little the arch has sunk, especially when we consider that, until recently, it was successfully carrying modern monster lorries, far heavier than the horses and carts of Telford’s day.

I will be returning to Telford’s contributions to the development of our road network at various times in this talk for he was engineer to roads in England, Wales and Scotland, including the Snake Pass from Glossop and the Cat and Fiddle from Macclesfield. But I am going to turn to his capacity as Engineer to many canals. Starting with the Ellesmere Canal in 1793 and Shrewsbury Canal in 1795. Telford was involved with the second era of canal construction after the pioneers like James Brindley had shown how successful and profitable canals might be. Telford was able to plan on a much larger scale. This is shown dramatically at Harecastle where between 1822 and 1827 Telford constructed a second much larger tunnel beside Brindley’s original one in a much shorter
Telford’s had the addition of a towpath, hence cutting out the agony of legging through. He had used this feature in the 1790s at Chirk on the Ellesmere Canal where the canal passes into the tunnel after crossing the Chirk aqueduct – as an aside, I recommend anyone walking on the towpath through that tunnel to take a torch because the towpath has collapsed in places.

Chirk aqueduct was opened in 1801 and is worthy of closer study. It is 600 ft. long and 70 ft. high. Each of the ten arches had a 40 ft. span. To reinforce the point I wish to make, let us look at Rennie’s contemporary aqueduct on the Lancaster Canal, that over the River Lune. Notice the depth of the stone work over the arches because the arches had to support not only the depth of the water in the canal but also the clay puddling to make certain the canal did not leak. Telford solved this in an original way. He lined the bottom of the canal on the aqueduct with cast iron plates. Notice how thin is the bottom compared with the side walls. Notice also another Telford feature, his hollow piers supporting the arches, resulting in a much lighter structure. This he used again at Pont Cysyllte, Menai and doubtless elsewhere. The result at Chirk is a light, elegant structure, rather sadly overshadowed by the much later railway viaduct of Henry Robertson. It is said that some Oxford undergraduates taking a punt to Llangollen had great difficulty crossing Chirk aqueduct because the punting pole could not grip on the cast iron plates.

Rennie, the mechanical engineer, did not build has first cast iron bridge until 1803 at Boston in Lincolnshire. Telford, the stonemason, enthusiastically took up this new material much earlier. He had already used it in 1795 for an aqueduct on the Shrewsbury Canal at Longdon on Tern. It would have been a daring design at any period but even more so as it was one of the earliest cast iron aqueducts in the world. The enormous weight of water in the trough is supported on cast iron pillars that are so slender. Modern analysis has shown that the sections are well within the structural limits of the material. Later William Hazeldine carried out many tests on behalf of Telford at Ruabon ironworks. Notice the shapes of the side plates, the centre one of which formed, as it were, a keystone at the top of an arch. But Telford made a mistake in the design. He put the towpath level with the bottom of the trough and made
the trough very little broader than the width of the boats passing through. The horses pulling the boats had to force the water ahead of them, so it spilt over the sides. It is still preserved on its original site although the embankments that carried the canal on either side to it have been carted away.

Telford corrected this on another masterpiece, Pont Cysyllte. There is much dispute about who should take the credit for this design, William Jessop, the engineer in charge of the whole of the Ellesmere Canal, or Telford, the General Agent and Engineer. It does seem that the final plans were those of Telford and that the plates were cast at Hazeldine’s foundry conveniently situated close to one end of the aqueduct. The resulting structure was truly dramatic, 1,007 ft. long, 126 ft. high, 11 ft. 10 ins. wide with 19 arches at 53 ft. span. The stone piers were constructed on Telford’s hollow principle with cast iron ribs supporting the trough across the top of them. The outside ribs were filled in to give the aqueduct a more solid appearance. The mistake at Longdon on Tern was corrected here because the trough was much wider than the boats and the towpath was constructed projecting over the water. Pont Cysyllte was opened amid much ceremony on 26 November 1805, a proud moment for Telford. It still carries boats on their trip to Llangollen but it needs a good head for heights to walk across.

Telford always favoured canals in preference to railways such as the Liverpool and Manchester that were being promoted and indeed constructed towards the end of his life. So he sought to improve and extend the canal network. Here I would like to make a comparison with Watt. Watt’s civil engineering career lay between roughly 1768 and 1774, entirely in Scotland, then a poor country. He developed the idea of a narrow level canal that could be constructed without expensive locks. Sections at different levels would be linked probably with wheeled trucks running up and down inclined planes but precisely how is not explained. He also realised that as a boat is constructed as a trough to keep water out, so a wooden aqueduct could be constructed to keep water in, a solution much cheaper than masonry. Both Watt and Telford tried to design canals that should be as economical and efficient as possible. Let us take the Macclesfield Canal for an example, running
north from Harecastle tunnel to Marple. It has long, level stretches with a single major grouping of locks at Bosley. The locks have side pounds to conserve water. Or take Telford’s realignment of the Birmingham Canal at Smethwick. Telford lowered the main line of Brindley’s 1769 canal by something like forty feet through the Galton cutting, avoiding six locks up and down each side to the original summit. This speed up the canal traffic enormously as well as saving water.

Regarding canals, Telford’s masterpiece in this country must be the Caledonian Canal through the Great Glen in Scotland. Watt had surveyed a line for this canal in 1773 and was able to send Telford some of his results in 1802. Telford replied, I found the whole of your statements particularly correct except in the fall from Loch Oich to Lochness where we differ a few feet, but the states of the water in the Lochs make some difference – and the only bad weather I experienced was during this part of the Survey, so that I am not positive that I am right. (James Watt Papers, 4/27.77, T. Telford to J. Watt, 3 May 1802)

At the northern end, Watt would have ended his canal at the town of Inverness while Telford extended his into a massive sea lock extending out into the Beauly Firth. Watt had to leave his assistant James Morrison to complete the southern end of the survey and return to Glasgow where his wife lay dying. He would not have carried his canal down to Loch Linneh in that dramatic flight of locks, Neptune’s Staircase. I have mentioned Telford’s dislike of railways. The little swing bridge at Moy shows that he would use railways occasionally in his construction projects because the counterbalance weight in this bridge consist of tram plates or rails.

The construction of such a major civil engineering project through a region with only the barest of communication and other facilities presented Telford with major logistical problems. The Highlands were in a woeful state with primitive agriculture and sheep supplanting people. The Caledonian Canal was seen as part of a much broader scheme to rehabilitate the region. The objective was to employ local people but they had little skills and had to be trained as stonemasons and so on. The Napoleonic War caused difficulty in obtaining labourers as well as
materials and also caused the costs to rise steeply. Steam engines were needed to pump dry lock foundations, steam dredgers to clear channels through the lochs, tramways to move building materials, while food, etc. for the workforce had to be shipped in, particularly to the southern end at Corpach. Telford organised a system of managerial command with John Mitchell as chief assistant over six superintendents who were responsible for supervising the contractors. So we see in Telford not only a deep understanding of his construction materials such as stone, cast and wrought iron, but also the ability to develop an organisation able to carry out his multitudinous and very varied civil engineering projects.

I will mention only briefly the Gotha Canal in Sweden with which Telford was involved from 1809 to 1833. It was another massive engineering project, aimed to secure a safe passage for ships across the centre of Sweden, giving the east of Sweden an inland route to the North Sea. It must have been the largest canal of its day. While its original purpose was soon outmoded through the spread of the steam ship, the Gotha Canal still carries commercial traffic and also is extensively used for pleasure boating and passenger steamers.

Telford was involved with the Caledonian Canal from 1803 to 1822 during which time he was also commissioned by the Government to improve the roads and open up the Highlands. This was pioneering work and even today I would hesitate to follow in some of his tracks through very rough country, where he had to sleep in hovels with mud floors and heather thatch. His first Scottish survey was carried out in 1801 and from 1802 until about 1822 he regularly visited Scotland twice a year to inspect the works under his charge. In Scotland alone he built 892 miles of new roads and improved 308 miles of the old military roads. Over 1,000 bridges had to be constructed. In addition there were another 104 miles of roads in the lowlands connecting England and Scotland. He tried to use local labour where possible but this was often unreliable. Climatic conditions were little understood. One contractor asked Telford if he could reuse some wooden centring to support a bridge he was building with the result that it would be larger than
Telford’s plans. Telford consented. Even though this gave the bridge a larger opening, it was still swept away by floods the next winter.

This nearly happened also at Craigellachie where Telford planned to build a bridge with a series of low arches. He was discussing the plans on site and asked a local about the height of the floods. This person pointed to a bough lodged in a tree high above them and said it was deposited there by a flood the previous winter. Telford quickly revised his plans, resulting in the bridge that still survives. Craigellachie bridge was built in 1812 to 1815 as one of a series of similar cast iron bridges starting with one at Bonar a couple of years previously. I have mentioned the centring needed to support a stone span while it was being constructed. But centring would block the river in time of floods and the River Spey not only was prone to flash floods but was also used to transport large tree trunks to the sea which acted as battering rams. By using large cast iron sections for the ribs which were cast by Hazeldine, Craigellachie Bridge and similar ones could be constructed quickly as well as having longer spans. That at Craigallachie is 150 ft. The structure has an air of lightness about it. Telford planned a similar one for London with a span of 600 ft. which probably was fortunate not to have been built.

Another remarkable design of cast iron bridge is that on the road from London to Holyhead at Bettws-y-Coed. Lettering around the span proudly proclaims that ‘This Bridge was Constructed in the Same Year the Battle of Waterloo was Fought’. In fact it was not finished until the following year, 1816. It is another piece of magnificent iron founding by Hazeldine, featuring a rose for England, a thistle for Scotland, the shamrock for Ireland and a leek for Wales. I have often wondered how much of this ornamentation contributes to the structural strength. When the bridge had to be rebuilt and strengthened to carry modern traffic, the two ornamental side plates were retained.

This Waterloo Bridge brings us neatly to the subject of roads, particularly that of the one between London and Holyhead. Improvements to this road were prompted by the Act of Union in 1801 which required Irish parliamentarians to go from Dublin to London and, if need arose,
for British soldiers to make the return trip. This, like his other major roads, had a ruling gradient of 1 in 30 wherever possible. The surface was built up on Telford’s principle of laying a firm foundation of large stones and forming the running surface with a layer of fine binding stones. He took care to provide adequate drainage channels alongside. Even today, driving along his major roads such as the A5 through the mountainous regions of North Wales, shows how well he laid out the courses of his roads. The Nant Francon pass is a revelation to see how Telford maintained a steady gradient for his coaches and horses. This little tollhouse near Llangollen has since been swept away by modern improvements. However the drawback for traffic today is the sudden sharp bends, safe for the speed of a coach and four at 10 miles an hour but too often a death trap for modern vehicles.

The route across Anglesey was merely a rough track, catering really only for post boys on horseback and even for them it was extremely hazardous, with frequent accidents. The harbour of Holyhead itself was on an island so Telford had to construct a massive embankment and causeway to link the island to Anglesey. Since this was a turnpike road, Telford had to design tollhouses and gates. An unusual two-storey one on Holyhead Island itself has been turned into a café staffed by mentally handicapped people. Its typical Telford tollgate also survives. From London to Shrewsbury, Telford improved a route of around 217 miles. It was at least a further 110 miles on to Holyhead through much more difficult country. His first survey of the route in North Wales was carried out in 1810 while he supervised the majority of the actual construction between 1815 to 1829.

I have mentioned harbours, so before turning to the third of Telford’s building materials, wrought iron, we will have a quick look at one of his dock projects, St. Katharine’s Dock next to the Tower of London. Shipping in the Thames was chaotic. Ocean going ships had to moor mid-stream and be unloaded into lighters which conveyed their cargoes ashore. There was much pilferage and loss. The Warehousing Act of 1823, which allowed goods to be stored in bond duty free, brought to a head the movement in favour of the building of a new ‘free’ dock to provide badly needed accommodation in the overcrowded port. The
site of the ancient St. Katharine’s hospital was selected as being close to the City so the St. Katharine’s Dock Company was formed in 1824. The site was cleared of 1,250 houses and construction began in May 1826. It was to be a floating dock with lock access to the Thames at high tide. Round the perimeter Telford constructed warehouses, alongside which ships could be moored to discharge their cargoes directly. For added security, the warehouses had no doors onto the perimeter roads. I took these photos in 1967 when the buildings were semi-abandoned. I asked the policeman at the gates if I could go inside to take more photos. ‘O no, Sir’, came the reply, ‘Wartime regulations’.

We must move on quickly to look at Telford the stonemason turning to another new material, wrought iron. Around 1814, he drew up plans for crossing the River Mersey at Runcorn with a new type of bridge, a suspension bridge. He carried out 200 experiments upon malleable iron at Brunton’s cable manufactory to make continuous wires or rods for the suspension cables. Not only were the figures he used within modern limits but his method of using a continuous cable is similar to that used today. The bridge was never built, certainly the angles of the suspension cable of catenary seem far too low.

In the meantime, William Brown had used a system of chain links on his Union Bridge near Berwick on Tweed. The bridge survives with its original type of wooden decking. It is fascinating to watch how this deflects through the weight of a car passing over it. It would be this principle that Telford followed for his own suspension bridges over the River Conwy at Conwy and, more spectacularly, over the Menai Straits to complete the London to Holyhead road. That at Conwy retains more of its original features than its larger neighbour and is now under the guardianship of the National Trust. Owing to its proximity to Conwy Castle, Telford departed from his severely functional style for most of his bridges and designed the suspension towers in the form of castellated medieval gateways. This bridge has a span of 327 ft. between the towers. To erect the suspension chains, cables were stretched between the two towers at the correct curvature and a platform built on top of them. The links were assembled on the platform. Conwy suspension bridge was opened on 1 July 1826.
In 1818, Telford was asked again by the Holyhead Road Commissioners to submit plans for a bridge across the Menai Straits. The Navy demanded that the Straits be kept clear at all times for shipping and that naval ships should be able to pass under any bridge. A cast iron arch had been proposed in 1811 which could be assembled with supporting cables from the shore abutments. However in 1818, Telford turned to the suspension principle. The scheme passed through many designs, such as one with cast iron towers. Telford was helped by David Gilbert, President of the Royal Society, to calculate the best form for the suspension catenary.

In the final design, the road was carried at the southern end on three masonry arches before reaching the masonry suspension tower. The piers were built with Telford’s usual hollow construction. On the Anglesey side, the suspension tower was constructed on Pig Island and linked to the shore by a four arch viaduct. Suitable stone was found at Penmon, the eastern tip of Anglesey. The links for the chains were forged by Hazeldine. Once again tests were carried out to ascertain the best size. A special machine was designed for boring the eyes to take the pins and each link was also proof tested. To protect them from the corrosive effect of the salt atmosphere, the links were heated, plunged into a bath of linseed oil and then stove dried.

Telford was faced once more with the problem of how to sling his chains across from tower to tower for he could not block the channel for any length of time. There were 16 chains in four groups of four and the suspended portion of each weighed 23 ½ tons. He had a raft built 450 ft. long by 6 ft. wide on which the central portion of the chain was laid. Further links hung down from the tower on the mainland side. On 26 April 1825, the raft was manoeuvred into position and one end of the chain on the raft linked to that hanging down that tower. The raft was hauled across to the Anglesey tower where the end of the chain was attached to ropes and winched up. All went well and the chains were united at the top of the 150 ft. tower. The span is 580 ft, the longest in the world at that time. The Menai Bridge was opened at the end of January 1826 without any fuss. It still stands, although the original deck-
ing was replaced in the 1930s with a much stronger steel structure so that the central pairs of chains were removed. Yet the bridge retains much of its original character and is a fine memorial to a quite remarkable civil engineer.

I would like to finish with a few comments about those three Scotsmen, Watt, Rennie and Telford. Watt left the realms of civil engineering for his partnership with Matthew Boulton and his steam engine. It is said that the dues they received from Watt’s patent for his separate condenser between 1769 and 1800 were the greatest of any patent up to that date. Watt was always something of a hypochondriac and retired into his home on Handsworth Heath. With very few exception such as Rennie, there was never any school of mechanical engineering connected with the firm of Boulton and Watt in contrast with Henry Maudslay. Watt worked for himself and not the general public.

Much the same can be said of Rennie, although in his case he worked himself to death with all his civil engineering projects. He had his own engineering works at Blackfriars but I do not know of his carrying out any testing of the materials he was using. He seems to have preferred to rely on the solidity of traditional stone rather than the new cast and wrought iron, perhaps through experience from his mechanical engineering background. While his canals and fen drainage schemes benefited the public, there does not seem to have been any broad philanthropic motive underlying them. Like Watt and James Watt junior, Rennie’s sons carried on their father’s work but there is no claim to founding any school of civil engineering.

With Telford, we have a quite different personality, one who was able to overcome the disadvantages of his being orphaned very early in life and who received only a meagre primary education. He was able to move away from his apprenticeship as stonemason and produce quite remarkable bridge designs in the new materials of both cast and wrought iron. But such achievements would have been impossible, particularly when we include his work on roads, harbours and canals, without a team of devoted people under him whom he was able to inspire for implementing his designs. His contracts in Scotland were major
Example of his philanthropic work trying to improve the lot of the people in his native land. In addition, he looked to the future of his own profession by training and nurturing those who worked under him. Therefore we should not be surprised to find that in 1820 this remarkable man was chosen to be the first President of The Institution of Civil Engineers.