

*THE MENAI BRIDGE*

The most formidable obstacle in the whole of the line of communication between London and Dublin was the strait which separates the Island of Anglesea from the county of Carnarvon. This isle of MONA, the anciently-celebrated resort of the Druids, being wholly projected beyond the general line of coast into the Irish Channel (narrowed by it twenty miles), appears to have been selected for the last retreat of these mysterious bardic legislators. In common with other straits which separate any island from the continent, or from a larger island, this arm of the sea exhibits peculiarities in its tide, which, twice in every twelve hours, runs in different directions, and frequently with great velocity. The rise at ordinary spring-tides is about twenty-two feet, sometimes as much as thirty feet; and being in the vicinity of the Snowdon range of mountains, it is subject to violent gusts of wind, from which liability, and from the ferry passage being frequently made in the night, this part of the journey was rendered a disagreeable object of anticipation, and was sometimes really dangerous.

This ferry, which is about a mile and a half south of the city of Bangor, was leased by Queen Elizabeth to John Williams, at the yearly rent of £3. 6s. 8d.; and from him it descended to Lady Erskine. Being upon the principal road to Ireland, the intercourse had increased so as to produce an annual revenue of £. 878.

To supersede this inconvenient ferry had long been considered an object of great importance, and had accordingly exercised the talents of many ingenious men. Schemes of various kinds had been proposed; bridges of stone and timber, - a stone mound, - and even a tunnel under the bed of the rocky strait, had a

different times been strongly recommended; but it was not until the date of the union with Ireland that the subject was noticed by Government. In that year (1801) the celebrated Mr. John Rennie was employed, and made two designs for bridges of cast-iron; one over the Swillies, another at the rock of Ynys-y-moch (Pig Island). But these plans were laid aside.

In the year 1810, while the North Wales road survey was in progress by public authority, I was directed to include the passage over the Menai strait, also over the Conway estuary; and designs for both these accompanied my Report of 1811, when circumstances occurred which led to the postponement of my two plans; and it was not until the year 1818, when the Holyhead road improvements had made considerable progress, that I was directed to re-survey the Menai Strait, and to make a report as to the most advisable mode of passing it.

It so happened, that in the year 1814 I had been called upon to consider of the best mode of crossing the river Mersey at Runcorn, in Cheshire, with a view of shortening the London road to Liverpool; and under all the circumstances of the case, I recommended a bridge of wrought iron, upon the suspension principle; to prove which, I tried several hundred experiments upon malleable iron, in lengths from 30 to 900 feet, and from one-tenth of an inch to two inches diameter; and having thus obtained a knowledge of elementary facts, I constructed a model 50 feet in length, and ascertained its strength. [The Runcorn Bridge design is represented in Plate 83.] Although the project which gave occasion for the experiments was abandoned, they had authorized me to recommend a bridge upon similar principles over the Menai strait; and this, after much discussion, was adopted by Parliament.

In choosing between the two possible sites for this important edifice, I fixed on that of Ynys-y-moch, where the breadth of the estuary, at high-water, is 306 yards; at low-water, 160 yards. On the Anglesea side, the rocks rise to a height inconvenient for approach to the bridge; on the Carnarvon side, access might be selected at any convenient elevation. The main suspension pier, on the Anglesea side, is placed upon the Ynys-y-moch rock, which rises above high-water mark. On the Carnarvon side, it was necessary to obtain a firm rock foundation, by sinking six feet beneath the level of low-water.

The height of these main piers, from high-water to the roadway, is 100 feet; from thence to their apex is 53 feet. The road platform is occupied by tow parallel carriage-ways, each twelve feet in breadth, and a footpath of four feet between them, thus admitting of four distinct lines of suspension-chains, the distance between the points of suspension being 579 feet.

In the session of 1818, twenty thousand pounds was granted by Parliament in preparation for this work, and the intended road through Anglesea; and on the 8<sup>th</sup> of July carpenters commenced building workshops. The rocks in the immediate vicinity of the bridges were unfit for masonry, but on the Island of Anglesea, at the distance of twelve miles northward from the bridge, is an inexhaustible quantity of hard, grey limestone, of unlimited dimensions; and when the most convenient spot for quarried had been determined, barracks for workmen and shipping-piers were built; and during the remainder of the season, stones were quarried and prepared by the masons.

As the Carnarvon interest (headed by the persevering Mr. Asheton Smith) continued to raise fresh obstacles, by disputing the powers of the Commissioners, it was judged advisable to limit the operations to providing materials, and other preparations, until a new Act could be obtained, explanatory of the disputed powers. The Marquis of Anglesea was always friendly to the measure, and was satisfied that, by removing some of the Swilly rocks, the navigation of the strait would be improved.

In the year 1819, under a new Act of Parliament, the work proceeded with regularity. Vessels were provided for conveying stone and other materials; working drawings, with a specification, were prepared, and a contract was entered into the Messrs. Straphen and Hall, experienced builders, to perform the masonry at fixed prices; and on the 10<sup>th</sup> day of August, the first stone of this great work was laid by W.A. Provis, an intelligent young man, whom I had appointed to act a resident engineer, to superintend not only this, but all the works then in progress in North Wales. This first stone is in the middle of the lowest course of the sea-face of the Ynys-y-moch pier; and during this year, 200 workmen and five vessels were employed.

In the year 1820 several of the smaller piers were founded, also the large pier on the

Carnarvon side. I have already observed, that this latter was founded at six feet under low-water level, and it was carried up with solid square masonry to the first offset before the open compartments were commenced; but in the Ynys-y-moch pier, those compartments were commenced immediately on the rock. I have elsewhere expressed my conviction, that one of the most important improvements which I have been able to introduce into masonry consists in the preference of cross-walls to rubble, in the structure of a pier, or any other edifice requiring strength. Every stone and joint in such walls is open to inspection in the progress of the work, and even afterwards, if necessary; but a solid filling of rubble conceals itself, and may be little better than a heap of rubbish confined by side-walls. The example of the pillars of St. Chad's church (Shrewsbury), when that edifice fell in the year 1788, was ever infixd in my memory. These pillars were built about from impartiality to add, that the piers of Westminster Bridge (no more than eighty years old) now exhibit an almost similar core of imperfect materials and workmanship.

On the 20<sup>th</sup> of March, the value of the ferry was determined by a jury to be £ . 26,954, being thirty years' purchase upon the annual rental. I had valued it a twenty years' purchase, not taking into account the compulsory nature of the sale.

Mr. Straphen being prevented by engagements from giving constant personal attendance, which was indispensable in a work of such magnitude and difficulty, he and Mr. Hall were relieved from their contract, and Mr. John Wilson undertook it at the same rates, and under the same conditions.

At the end of 1820, the state of operations on the Anglesea side was as follows : -The abutment was 14 feet above high water; the small pier, next the abutment, 36 feet; the middle pier, up the level of low-water; the next small pier was 43 feet above high-water mark; and the large pier upon Ynys-y-moch was 51 feet above the level of high-water. On the Carnarvon side, the large pier had reached high-water level; the small pier next to it, 45 feet above high-water; and the other small pier had attained the same height.

After sundry discussions, during the year 1820, respecting the iron-work, all the

patterns and dimensions were finally arranged, and Mr. Hazledine, of Shrewsbury, entered into a contract to furnish the whole at fixed prices. It was to be of the best Shropshire iron, drawn\* at Upton forge, and finished and proved at his establishment near Shrewsbury; every operation to be performed under the inspection of a person (Mr. John Provis) who was appointed by me for that sole service. The iron-work, in this state, was sent, partly by land, direct to the Menai strait, -partly by canal to Chester, and from thence by sea to the bridge, the first cargo being delivered on the 3d of August 1820. The timber centering for the arches on the Carnarvon side was framed and fixed in its position; and during the year 1821, from three to four hundred men, and five to seven vessels, were employed.

At the end of the year 1821, the state of operations on the Anglesea side was thus: --

The abutment and wing-walls were 43 feet above high-water; the small pier next the abutment was 45 feet high, and a course of arch-stones set; the next small piers were 65 feet high, and a course of arch-stones set; the next small piers were 65 feet high, and a course of arch-stones also set. On the Carnarvonshire side of the strait, the masonry was in greater forwardness, all the arches and spandrels having been advanced up to the roadway, except part of the cornice; and preparations were making for the serious task of erecting the pyramid, over which the main-chains were to pass to their somewhat remote point of fixation, in the solid rock.

In January, February and March 1822, on the Anglesea side, all the piers had been carried to the springing-course, and the centerings fixed thereon; the main pier was carried higher, and the main-chainway tunnels in the rock completed, and drains made from them; iron plates were placed in the masonry, for attaching the vertical iron rods, so as to prevent undulation when the bridge came into use.

Regulations were made for proving the bars which constitute the main-chains. The cross section of these was  $3\frac{1}{4}$  square inches in area, and, according to my experiments, they were capable of bearing a strain of  $87\frac{3}{4}$  tons before fracture; but at one-half of this strain, they showed elongation; and to keep within that strain or tension, it was judged advisable to limit the proof to 35 tons, being about 11 tons to every square inch of cross section. A very accurate and

powerful proving machine having been constructed, every piece of iron was submitted to the same proportional strain; and when in that state, it was frequently struck with a hammer; the length was adjusted by an unyielding iron gauge, and after being proved, every separate piece of iron was well cleansed, put into a stove, and when brought to a gentle heat, was immersed in a trough containing linseed oil. After remaining a short time, it was again put into the stove, and, when dried, appeared covered with a varnish. When taken out of the stove the second time, each piece was finished with a coat of linseed-oil paint; and this dry, the iron bar was considered fit to be sent to the bridge. All this process formed the sole employment of Mr. John Provis, who superintended the preparation and proof of the iron-work.

In August, September and October, the arches on the Anglesea side of the bridge were completed, and the main-chain tunnels on the Carnarvon side commenced, the first barge-load of prepared iron-work was delivered, and Mr. Rhodes (a practical mechanic of first-rate ability) was engaged to undertake the junctures and fixture of the iron-work.

The number of workmen employed in the year 1822 was usually 260, and from five to eight vessels for carriage of materials.

At the end of the year 1822, the state of the work on the Anglesea side was thus: --

The abutment and its wing-walls completed; the large pier built to the level of the roadway; the intervening stone arches all finished, and their spandrels up to the cornice; the main-chain tunnels and drainage completed, as also the embanked approach to the bridge. ON the Carnarvon side, all the masonry up to the roadway completed; the pyramid crowning the great eastern pier, above the level of the roadway, commenced, and the main-chain tunnels, with their drainage, about one-half finished; and 2,319 main-chain bars had been proved.

Mr. Rhodes arrived in the beginning of the year 1823, and the first iron-plate in the main-chain tunnel was fixed on the 31<sup>st</sup> of March. The mode of fixing the main-chains in the rock being an important operation, and worthy inspection by every visitor of the bridge, who feels no dread at entering by a side-drain

(on the Anglesea side) into a cavern in the rock, containing gigantic iron-work, and productive of feelings of superhuman agency. No precautions were spared to render every part perfectly true, and therefore secure; for as any variation in the length of the numerous bars would produce unequal bearings, each was subjected to a fresh adjustment by means of a steel model, upon which they were bored when cold, so that a cross-bolt passed through a certain number, in most cases through eight bars, so as to form four chains, thus accurately attached to each other.

The suspension pyramids were, in the year 1823, raised to the height of 30 feet above the level of the roadway, being perforated by carriage-ways of nine feet in width, to give access to the bridge. The masonry in these pyramids was secured by drilling holes through the courses, and by introducing iron bolts, fixed by Parker's cement; moreover iron ties are placed horizontally, at the springing of the arches over the carriage-ways. Powerful blocks, capstans and cranes were provided, also a pair of shears 74 feet in height; and as it was important to know with certainty what power would be required to raise the main suspending-chains to their proper curvature, and experiment was tried, with a real chain, over a small valley adjacent to the bridge, by which it was found that the absolute weight of one of the main-chains, between the point of suspension, was 23 ½ tons, requiring a strain of 39 ½ tons to raise it to its proper curvature; and all the necessary apparatus was prepared accordingly. The reader will keep in mind that the bridge depends on four times four main-chains, of similar and uniform tension or bearing.

In May and June 1824, the masonry of both pyramids was completed, and the cast-iron plates and saddles were fixed upon their tops; the saddles are so constructed, that the chains are movable upon them, and the strain is conveyed to the extremities of each chain, which is fastened in the rock at the end of its tunnel; that upon the pyramid-tops there is only a perpendicular pressure. Every part of these saddles is distinctly delineated, with references and explanations, in Plates 71, 72.

When the pyramids and the roadways over the masonry-arches were completed, temporary timber-framings were constructed between the pyramids and the points where the main-chains entered the tunnels. Upon these

framings a set of four main-chains was laid, the ends being secured under the roadway, and the other ends carried to the top of the eastern and western pyramids respectively. On the Anglesea side, the chains so remained. On the Carnarvon side, the chains were not only carried along the timber-framing to the pyramid-top, but were brought over an down its sea-face to high-water level; the portion of the chain which was to complete the line between the opposite pyramids was laid at length upon a timber float, moored on the Carnarvon side, westward of the great pier. Upon the Anglesea side, at some distance from the pyramid, capstans were placed, to which ropes were attached, of sufficient power for a strain of 50 tons. [Plate 73.]

Every necessary preparation having been made, about the middle of April 1825 I left London for Bangor; and having satisfied myself that every due precaution had been taken, it was resolved to raise the first chain on the 25<sup>th</sup> of that month. Accordingly, on that day, at half-past two o'clock in the afternoon, about an hour before high-water, the raft was cast off, and floated into position between the piers, where being moored, one end of the chain, which lay upon it, was joined to that which hung down the face of the Carnarvon pier; the other end was attached to ropes connected with the Anglesea-side capstans, and the said ropes passed, by means of blocks, over the top of the pyramid of the Anglesea pier. Then the workmen who manned the capstans moved at a steady trot, and, in one hour and thirty-five minutes after they commenced hoisting, the chain was raised to its proper curvature, and fastened to the portion of chain previously placed at the top of the Anglesea pyramid. I then ascended, and satisfied myself that by this juncture had been formed a continuous and safe chain from the Carnarvon fastening in the rock to that in Anglesea. Having announced this fact, a loud and general shout of exultation arose from the workmen and the numerous spectators who had assembled to witness this novel operation. ON Saturday, the 9<sup>th</sup> of June 1825, the last of the sixteen chains was raised to its place in this manner, and the temporary framing removed. In each chain are four adjusting links, but means of which it can be brought to the proper curvature; and, by experiments, it has been ascertained, that nay part of any chain may be taken out and replaced, without endangering the stability of the bridge.

In August the construction of the road-platform was commenced, and in September the trussed bearing-bars were all suspended. The platform of the roadway consists of two thicknesses of fir-plank, both laid longitudinally upon the trussed bearers. The lower planking is three inches, the upper two inches in thickness; between them there is a complete coating of Borrodail's patent felt, saturated with boiled tar. The two layers of planking are spiked together, and both attached to the two trussed bearing-bars by bolts which pass between them. In each carriage-way there is a third layer of planking across the former, also laid on patent felt, which last planking, when worn by carriage-wheels, may be replaced without affecting the essentials of the bridge. Along each side of the carriage-ways are oak-guards (twelve inches by eight) placed seven feet and a half apart.

In the latter end of the year 1825, the side-railings were added, and the toll-houses and gates completed, also the roads of approach; and Henry Fisher, who had assisted in putting up the iron-work, as the foreman of Mr. Rhodes, was appointed bridge-keeper and principal toll-collector; and a carpenter, who had been employed during all the bridge operations, became the other collector and assistant, their practical knowledge being important in watching the effects of heat and cold tempests on the new structure.

Upon my report of the state of the works, the Commissioners determined that the passage over the bridge should be opened on the 30<sup>th</sup> of January 1826. The weather, about this time, proved very stormy; and previously to the opening day, Sir Henry Parnell and myself examined the entire structure, and found all necessary arrangements mail-coach, occupied by W.A. Provis, W. Hazledine, the two junior Wilsons, Thomas Rhodes and the mail-coach superintendent, was the first that passed across the estuary, at the level of 100 feet above that tideway which heretofore had presented a decisive obstruction to travellers. The Chester mail passed at half-past three o'clock and Sir Henry Parnell, with myself, drove repeatedly over; about nine o'clock, and during the whole of the day, was an uninterrupted succession of passing carriages, horsemen and pedestrians, who had assembled to witness and enjoy the novelty; and in the evening all the workmen were regaled with a joyous festival.

Thus was successfully accomplished a complicated and useful bridge of unexampled dimensions, which has now, for the last eight years, converted what was formerly a disagreeable and sometimes dangerous part of the journey to and from Ireland, into an object of national curiosity and delight.

The engraved Plates already referred to, and inserted in the Atlas annexed to this volume, will afford a distinct idea of the general appearance, as well as of the several parts; and Plates 74, 75 show various machinery and tools used in the construction of the Menai Bridge; but for a full and detailed account of the progress of the works, and for a minute narrative of every operation, I must refer to the standard description published by the resident engineer, Mr. W.A. Provis, who faithfully superintended the performance of the whole, from its commencement to completion. I shall therefore only further state, in summary, that in the breadth of the bridge there are 16 chains; each chain is composed of 935 bars; and its total length is 1,710 feet, or nearly one-third of a mile.

The number of suspension-rods affixed to each series of four chains each, is 199; the total number, 796. The total number of trussed bearing-bars is 444, and the total weight of iron-work is 4,373,282 lbs., or above 2,186 tons. The best view of the suspended portion of the iron is from beneath, on the Anglesea side of the Menai estuary. The iron-work is protected externally from the effect of the weather by paint, a coat of which weighs about two tons and a half.