XXIII. *An Account of the new or Grosvenor Bridge over the River Dee at Chester.*

[THE drawings from which the engravings of this bridge (plates nos XXI and XXII) have been made were furnished by Mr John B. Hartley, son of the engineer under whose direction the edifice was built, and the following account has been derived from a letter from him to the President, accompanying the plans, and other original communications in the possession of the Institution, and partly from the minutes of conversation at several meetings when Mr Trubshaw, the contractor for the work, was present*, while such other trustworthy sources of information as were accessible have also been referred to. The statements, so far as they go, rest therefore on good authority, but the Council cannot help regretting that they are unable on this occasion to present a connected account of the work worthy of its magnitude, directly from the pen of some one of the gentlemen engaged in its construction.

Though the site of the new bridge is quite apart from that of the old one, and the latter exists as before with the exception of being no longer the leading thoroughfare, a short notice of the ancient structure, as supplied by antiquarian writers, has not been considered altogether out of place.]

THE old bridge over the Dee at Chester extends from the city to a suburb on the opposite side of the river named Handbridge. The first notice of a bridge in this place occurs in the thirteenth century, during which it is recorded to have fallen down or been carried away twice. Those structures were most probably of timber, but on the second accident alluded to a stone erection seems to have been substituted at the cost of the citizens: this was in 1280, and it does not appear that the bridge has been entirely rebuilt since, though it is mentioned that part next Handbridge was "made new" in the year 1500. The two arches on this side are plainly of later build than the rest; one of them is

* *Orig. Commun.* Vol. IV. No. 9, and Vol. V. No. 16; *Min. of Convers.* Vol. V. Nos. 8, 9, and 13.

in form a segment of a circle, the other is very slightly pointed, while the remaining arches are pointed Gothic. The whole has been repaired and widened within the last few years.

As usual in former days, Chester Bridge was provided with its gates, which remained until towards the end of last century. Each extremity of the bridge was guarded in this manner, and over the gate next the city stood a tower, named "Tyrer's Tower," for raising water from the wheels under some of the arches for the supply of the town: the tower no longer exists, and there is now only one gate, a modern edifice, on the English side of the river, but the waterworks and the weir still remain.

The bridge, thus irregular alike in workmanship, form and dimension, consists of seven arches supported on huge piers or buttresses, and has been aptly and pithily described as "a long fabric of red stone, extremely dangerous and unsightly, and approached by avenues on the Chester as well as the Hand-bridge side, to which the same epithet may be safely applied."* The inconvenience of a steep and twisting passage of this kind on the main communication between Wales and the centre and north of England, became more felt every day amid the rapidly growing intercourse arising from the improvement of the roads in the principality, particularly that to Bangor and Holyhead, and at length brought about a conviction of the necessity of a new bridge. It was many years, however, before any active measures were taken to carry so desirable an object into effect, nearly a quarter of a century having elapsed between the period when the late Mr Harrison of Chester projected the structure on the site it now occupies, and the beginning of the work; and by this time, from advanced age and declining health, the superintendence of its execution required too much exertion for the strength of that most respectable practitioner, whose works have added so much to the architectural embellishment of his picturesque native city. Under these circumstances Mr Hartley of Liverpool was applied to by the commissioners to undertake the management, which he consented to do on the condition that no alteration should be made from Mr Harrison's external design, but that the interior and all practical points should be left entirely to him. It may be proper to add that Mr Harrison had given two elevations, one having the abutments ornamented with Grecian Doric

* Ormerod's Cheshire, Vol. I. p. 285.

columns, the other having a plain niche with a pannel over it, and that the latter was adopted by Mr Hartley's advice.

The new bridge is situated about a quarter of a mile to the west of or lower down the river than the old one, stretching from the rock below Chester Castle towards the village of Overlegh, with a boldness that appears still more striking if the view be from the low ancient bridge. The valley of the Dee here skirts close round the city, the ground next which rises rapidly, and the road is carried with a slight fall from the castle gate on an embankment, which, after ascending gently over the bridge, is continued across the broader plain on the other side of the river, until it falls into the Flintshire road from the old bridge. The harbour is below the site, but vessels occasionally pass above the bridge, which from its great height offers no obstruction to navigation. The flow of the tide so far up the river is not more than twelve feet in ordinary springs.

The abutments are founded on the solid rock, except the back part of that on the north or city side, where, a fault occurring from the rock dipping down almost vertically as shown on the section, piling became necessary; and so soft was the material with which the fissure was filled, (a kind of quagmire or quicksand,) that the piles went down five or six feet at a blow for a considerable part of their depth. On the head of the piling a floor of stone was laid and the abutment built upon it. In consequence of the defect in the foundation just mentioned it was considered prudent, with a view to keep the lateral thrust of the arch within the limit of the rock, to make the springing a foot lower and the crown as much higher than was at first intended, and this was the only deviation from the original design that took place in the work.

The arch is a segment of a circle of 140 feet radius, the span or chord being 200 feet, and the rise or versed sine 42 feet. The archstones are 4 feet deep at the crown, and increase to 6 feet at the springing, but from the mode followed in laying the masonry, it will be seen that the principle of the arch is carried through the abutments, even down to the foundations, the radiating joints giving place to horizontal ones only in what is comparatively superstructure.

To prevent flushing near the haunches and rectify any tendency to

change of form in the arch on the removal of the centre, the first course above the springers was laid upon a wedge of lead $1\frac{1}{2}$ inch thick on the face and running out to nothing at the extremity of the bed, and strips of sheet lead eight or nine inches wide were also introduced in the joints on each side, up to where the point of pressure was considered to change its position from the front to the back of the archstones, or in fact in the present case over about two-thirds of the whole soffit. This disposition remained unaltered until the easing of the centre let the whole of the arch settle on the lead, which from its yielding nature then caused the pressure to be spread evenly over the whole of the bed of each course, and thereby prevented drafts or openings at the back of the archstone joints; the wedge-piece at the springing also acting by way of adjustment, and counteracting the inclination of the arch in coming to its bearing when the centre is struck to throw an undue weight on the intrados of the springing course. Judging from the soundness of the archstones throughout, this plan seems to have answered fully the end sought, the weight having been received so uniformly and gradually on all points, that not the slightest appearance of *spaulching* or cracking is perceptible in the work of the great arch.

In setting the keystones three thin strips of lead were first hung down on each of the stones between which they were to be inserted, and the keystone being then besmeared with a thin greasy putty made of white lead and oil, was driven down with a small pile-engine, the lead acting as a slide and preventing grating until the stone was quite home.

The mode in which the spandrils were made up internally, by tiers of pointed arches with flag-stones or landings at top to carry the road material, will be seen by a glance at the cross section on plate no. XXI; and indeed beyond what has been already stated, and the materials used, which are now to be described, with the mode of dressing them, there does not seem much of importance as regards the construction of the permanent part of the work which an inspection of the plans will not readily supply.

The river face of the abutments up to the springing, and the first two courses of archstones above, are of granite; the key-course with one on each side of it and the quoins all through the arch are of the limestone known as Anglesea marble, and the rest of the work, including all the other archstones, almost entirely of the sandstone of the country. The granite was

brought from Craignair near Castle-Douglas in Kirkcudbrightshire, the limestone partly from Anglesea and partly from the similar quarries of Wagbur near Burton in Kendale, and the other stone for the outside works from Manley near Northwich and Peckforton near Nantwich in Cheshire, the quarries of both which places produce a superior kind of the new red sandstone. The principal part of the backing is of a similar sandstone, found adjacent to the site of the bridge. The mortar used was made from the lime found in the neighbourhood, mixed with twice its bulk of sand.

The external faces of the bridge and abutments, with the cornices, parapets and dressings, are neatly tooled; the land-arches and wings slightly chamfered in the joints and then scappled off, so as to have a rougher and more rustic appearance. The archstones of the main arch are also chamfered in the soffit joints, two inches on each arris.

The centre on which the stupendous arch of Chester new bridge was raised, and which is stated by Mr Hartley to have been exclusively designed by Mr Trubshaw, claims a detailed notice, from the novelty of the principle it was formed on, the efficiency with which it did its work, and the economy that attended its use. The centre consisted of six ribs in width, and the span of the arch was divided into four spaces by means of three nearly equidistant piers of stone built in the river, from which the timbers spread *fan-like* towards the soffit, so as to take their load *endwise*. The lower extremities of these radiating beams rested in cast iron shoe-plates on the tops of the piers, and the upper ends were bound together by two thicknesses of 4 inch planking bending round, as nearly as they could be made, in the true curve of the arch. On the rim thus formed the *lagging* or covering, which was $4\frac{1}{2}$ inches thick, was supported over each rib by a pair of folding wedges, 15 or 16 inches long by 10 or 12 inches broad and tapering about $1\frac{1}{2}$ inch;—for every course of archstones in the bridge there were therefore six pairs of striking wedges. The horizontal timber of the centre was only 13 inches deep, and the six ribs were tied together transversely near the top by thorough bolts of inch iron, but with a view not to weaken and injure the timber more than was absolutely necessary, the least possible of iron was used.

From this description and an examination of the drawing it will be observed, that the centre differs essentially from those that have been used else-

where. At first sight it reminds one of that employed by Smeaton in building Banff bridge, but the likeness is only apparent. Each rib of the latter is a complete connected frame from pier to pier, though supported intermediately, and is capable of being eased only as one mass by the folding wedges which are placed under and carry it; whereas in the Chester centre each rib is composed of four distinct and independent parts, and carries the wedges on its outer rim instead of being borne by them, so that it can be struck gradually, being made tight at one place and slackened at another, according to the symptoms shown by the arch as its support is removed and the stonework comes to its bearing. Mr Trubshaw's principle is, therefore, in a few words, to arrange the timber so as to have the strain all in a vertical direction, doing away with the necessity of much horizontal tying, which from its sinking he considers apt to derange the framing, and to ease immediately under the covering instead of under the sill of the centre; and with this construction he would strike a centre soon after the arch was finished, while the mortar was yet as it were a paste, easing a little at first and then giving some time for the joints to accommodate themselves, and so proceeding. His method of striking is to keep up the crown and let the haunches down, and though this has a tendency to press the keystone up, he states that he has found a greater and more usual difficulty to be in managing an arch after the key was lowered, as it must be at once and beyond recall with centres of the usual make.

The centre was of fir, and with the exception of the parts already mentioned as otherwise, was composed entirely of whole and half timbers;—pieces from 22 to 36 feet long were not bored with more than one hole, and it of small size, so that, the material being sound when taken out, the whole cost to the contractor was only about £500, an amount which, even allowing for the advantage derived from the accidental circumstance of a quantity of seasoned wood being opportunely required for a public work in the neighbourhood, must still be considered a very low price for a structure requiring 10,000 cubic feet of timber. That the expectations of the projector were fulfilled in other respects also, is proved by the circumstance of half the arch being turned before the centre was finished, while the fact that on its removal the crown sank only from $2\frac{1}{2}$ to $2\frac{5}{8}$ inches, the joints remaining perfectly close and no derangement of form being perceptible, attests the skill and care at once of the carpenter and the mason.

In reference to the temporary works, it seems necessary only further to mention that the archstones were carried to their places by the traversing machine now usually adopted for such purposes, which, though old in principle, it is believed assumed its present form in the hands of the late Mr Rennie, as a means of working the diving bell in his operations at Plymouth. Of the contrivance, though it scarcely requires description in the present day, it may be shortly said, that it consists in suspending the body to be moved to a carriage travelling on a railway fixed on a frame of timber, which frame is itself moved in like manner on a similar railway under and at right angles to it, so that the carriage has a double motion and can be brought over any point within the range of the frames to deposit its load. In the present case the *inferior* railway extended from abutment to abutment, resting on the intermediate piers, and on it travelled two transverse frames of from 45 to 50 feet span, so as to embrace the whole width of the arch; and there being thus a carriage at each end of the bridge, the setting of the archstones did not consume much time.

The Act of Parliament under which this bridge has been built was obtained in the session of 1825; the works were contracted for by Mr James Trubshaw, of Haywood in Staffordshire, early in 1827, and immediately commenced, the son of the contractor being resident throughout; the first stone was laid by the present Marquess of Westminster (then Earl Grosvenor) on the 1st of October in the same year; and the bridge was formally opened on the 17th of October, 1832, by the Princess Victoria, on the occasion of Her Royal Highness's visit to Eaton Hall, and named, at the request of the Commissioners, Grosvenor Bridge, but it was not thrown open to the public generally until New-Year-Day, 1834.

The total cost of the work was £49,900, in which is included a sum of £7500 for the heavy embankments required in the approaches. The money was partly raised by bonds, and partly advanced by the Commissioners for the Loan of Exchequer Bills, and is secured on tolls charged both on the new and the old bridge, the revenue yielded by which is about £3000 a-year.

The following table*, containing the leading dimensions of the largest stone arches that have been built (from 150 feet span upwards), will enable a comparison to be made between the bridge it has been the purpose of this paper to describe, and others approaching but not equalling it in magnitude of arch.

Name.	River.	Form.	Span.	Rise.	Keystone.	Date.	Engineer.
			Feet.	Feet.	Ft. In.		
Claix (Grenoble)	Drac	Circular	150	54	3 1	1611	
Gloucester . .	Severn	Elliptical	150	35	4 6	1827	Telford.
London . . .	Thames	Elliptical	152	37 $\frac{1}{2}$	4 9	1831	Rennie.
Tournon . .	Doux	Circular	157	65		1545	
Verona . . .	Adige	Elliptical	160	53		1354	
Lavaur . . .	Agout	Elliptical	160	65	10 9	1775	Saget.
Gignac . . .	Erault	Elliptical	160	44	6 5	1793	Garipuy.
Vieille-Brioude	Allier	Circular	178	69	5 3	1454	Grenier and Estone.
Chester . . .	Dee	Circular	200	42	4 0	1833	Hartley.

* The dimensions of the continental bridges have been gathered from M. Perronet's *Description des Projets et de la Construction des Ponts*, M. Gauthey's *Traité de la Construction des Ponts*, and Von Wiebeking's *Theoretisch-Practische Wasserbaukunst*; and in the cases of the discrepancies that sometimes occur, (particularly as to the span of the ancient bridge of Vieille Brioude, which is stated to be 183 feet by Perronet, in his bold project for the bridge of Melun, and also as to the rises of some of the other arches,) Gauthey's Work has been preferred, as it seems entitled to be from the character of its talented editor, the late M. Navier, in whose death the Institution has too soon to lament the loss of a valued honorary member.

CHESTER BRIDGE.

10 5 0 10 20 30 40 50 60 70 80 90 100 Feet.

CHESTER BRIDGE.

CROSS SECTION
THROUGH THE LINE A.B.

CROSS SECTION
THROUGH THE CROWN.

HALF SECTION SHEWING THE CENTRING.

HALF PLAN OF ARCH ABOVE THE SPRINGING.

PLAN OF ROADWAY.

HALF PLAN OF ARCH BELOW THE SPRINGING.

20 5 0 10 20 30 40 50 60 70 80 90 100 Feet