Quest. 20. Upon considering the whole circumstances of the case, and agreeable to the resolutions of the Select Committee, as stated at the conclusion of their Third Report, Is it your opinion that an Arch of 600 feet in the span, as expressed in the drawings produced by Messrs. Telford and Douglass, or the same plan, with any improvements you may be so good as to point out, is practicable and adviseable, and capable of being rendered a durable edifice?

Answer. On considering the whole circumstances of the case, It is my opinion, that an Arch of 600 feet in the span, as expressed in the drawings produced by Messrs. Telford and Douglass, especially when combined with the improvements above mentioned, is practicable and adviseable, and capable of being rendered a durable edifice.

Charles Hutton.

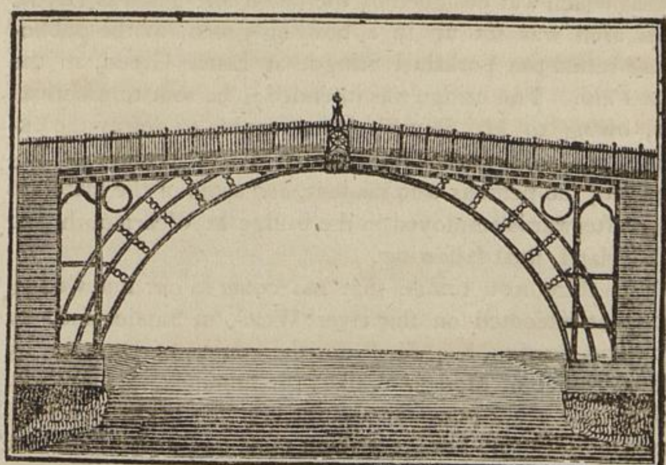
Woolwich, April 21, 1801.

TRACT VI.

HISTORY OF IRON BRIDGES.

A General History of all Arches and Bridges, both ancient and modern, and constituted of either wood, or stone, or iron, would be a very curious and important work. It should contain a particular account of every circumstance relating to them: such as their history, date, place, artificer, form, dimensions, nature, properties, &c. Such a work, in a chronological order, would make a considerable volume, and much too large to form a part of the present work. I confine my views, therefore, in the present Tract, to a short account of the novel invention of Iron Bridges, in several instances that have recently been executed or proposed; some few of which have been lately noticed in the new edition of Dr. Rees's Encyclopedia.

Bridges of cast iron appear to be the exclusive invention of British artists. The first that was executed on a large scale, is that on the river Severn, at Colebrook Dale, which was erected in the year 1779, by Mr. Abr. Darby, iron-master at that place. This bridge is composed of five ribs; and each rib of three concentric rings or circles, which are connected together by radiated pieces. The inner ring, of each rib, forms a complete semicircle: the others only segments, being terminated and cut off at the road-way. These rings pass through an upright frame of iron, which stands on the same plate as the ribs spring from; which not only acts



as a guide to the ribs, but also supports a part of the road-way. Between the inner upright of this frame and the outer ring of the ribs, in the haunches, is a circular ring of iron, of about 7 feet diameter; and between the outer upright of the frame, and the ribs, are two horizontal pieces, which act as abutments between the stonework and the ribs. There are also two diagonal stays, to keep the ribs upright. The roadway is covered with cast iron plates; and it has an iron railing on each side. The inner or under ring, of each rib, is cast in two pieces, each of which is about 78 feet in length, the arch being 100 feet 6 inches span: and the whole of the iron in it weighs 178½ tons.

Whoever judiciously examines the construction of this bridge, will see, that its fame has arisen chiefly from the circumstance of its having been the first of the kind: for the construction is very bad. The cast iron indeed is in the best state of preservation: but the stone-work has cracked in several places. It is probable, therefore, that its duration will not be long; though not from any deficiency in the iron-work.

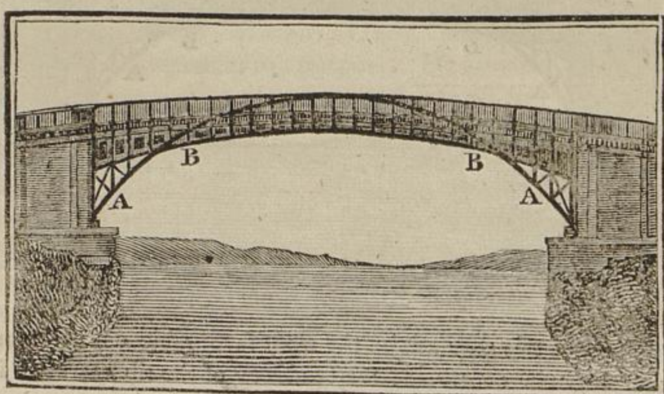
The second iron bridge which has come to my knowledge, is that which was designed by the noted Mr. Thomas Payne. This arch was set up in a bowling-green, at the public-house called the Yorkshire Stingo, at Lisson-Green, in the year 1790. This bridge was intended to be sent to America; but, owing to Mr. Payne's being unable to defray the expense, the arch was taken down by Messrs. Walker of Rotherham, the persons who made it, and some of the materials were afterwards employed in the bridge at Wearmouth and Sunderland, next following.

The third iron bridge that has come to our knowledge, was that executed on the river Wear, at Sunderland, by Rowland Burdon, Esq. M. P. for the county of Durham, by the assistance of Messrs. Walker the founders, Mr. Wilson, and several other persons: and for erecting bridges on similar principles, the first gentleman took out a patent in the year 1794. This bridge was begun in the year 1793, and completed in August 1796. The stone abutments are 70 feet high, above the ordinary surface of the low-water in Sunderland harbour, to the spring of the arch. The iron arch is 236 feet span; and the springing stones project about 2 feet beyond the face of the masonry: so that the whole span, from abutment to abutment, is 240 feet. The versed sine of the arch is 30 feet: its soffit is therefore 100 feet above the surface of low-water in Sunderland harbour.

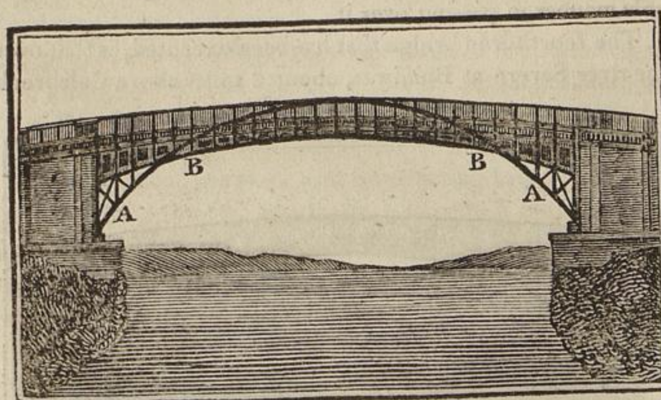
The arch is composed of 6 ribs; and each rib of 3 concentric rings, or segments of circles. Each ring is 5¼ inches deep, by $4\frac{1}{2}$ inches thick ; and these rings are connected by radii, $4\frac{1}{2}$ inches by $2\frac{1}{2}$; the rings being at such a distance from each other, as to make the whole depth of a rib 5 feet. The ribs are composed of pieces of about $2\frac{1}{2}$ feet long ; and worked iron bars are let into grooves in the sides of the rings, and fastened by rivets. These ribs are connected transversely by hollow iron tubes, or pipes, with flanches on their ends, and fastened to the ribs by screw-bolts : there are also diagonal iron bars, to prevent the ribs from twisting. The haunches are filled with circular rings ; and the top is covered with a frame of wood, and planked, to sustain the roadway. It has also an iron railing on each side.

The construction of this bridge is thought to be superior to that at Colebrook Dale ; and its weight is much less, in proportion to the length, the whole being only 250 tons, of which 210 tons are cast iron, and 40 tons of worked iron. Yet it is considered in no small danger of falling, the arch having settled several inches, as well as twisted from a straight direction, and the whole vibrating and shaking in a remarkable manner in passing over it.

The fourth iron bridge that has been executed, is that over the river Severn at Buildwas, about 2 miles above Colebrook



Dale. It was begun in the year 1795, and finished in 1796, the iron work by the Colebrook Dale Company, under the direction of Mr. Thomas Telford. The arch is 130 feet span, with a versed sine or height of only 17 feet; and it is but 18 feet wide to the outside. This bridge seems to have been contructed on the principle of the famous wooden bridge at Schaufhausen. The ribs under the roadway are segments of a large circle, each cast in two pieces: but, on each side of the railing, there is a rib, cast in 3 pieces, which springs from a base, 10 feet lower, then crosses the others, and rises as high as the top of the railing: and from the upper part of these outer side ribs, the other ribs, which bear the covering plates, are suspended by king-posts: the covering plates, which are 46 in number, each extending quite across the bridge, have flanges 4 inches deep, and act as an arch. The outside ribs are 18 inches deep, and $2\frac{1}{3}$ inches thick; the middle ribs 15 inches deep, and $2\frac{1}{2}$ thick; and the whole weight of iron is about 174 tons.



Perhaps this may not be the most favourable construction that might be contrived: the tendency of the rib AA, when it expands, being to raise the ribs BB a little higher than they would by their own expansion, and to depress them lower when it contracts: which is not the case in a wooden bridge, this material not being so affected by heat and cold.

About the same time as the bridge at Buildwas was erected, an iron bridge was thrown over the river Tame in Herefordshire; but its parts were so slender, and so ill disposed, that no sooner was the wooden centring taken from under it, than the whole gave way, and tumbled into the river.

In the same year also as the Buildwas bridge was begun, another was erected by the Colebrook Dale Company, over the river Parret, at Bridgewater. The arch of this bridge is an ellipsis of 75 feet span, with 23 feet rise. The haunches are filled with circular rings of iron, and other fanciful figures: it is composed of ribs connected together by cross ties of iron; and the roadway is supported by plates. This bridge is very neat, and thought to be exceedingly firm and durable.

From the completion of the above bridge, few of any note were executed in this country, till about the year 1800, when the stone bridge erected over the Thames, at Staines, gave way. On this occasion the magistrates of the counties of Middlesex and Surrey came to a resolution to erect an iron bridge there, on the abutments of the stone bridge, the piers of which had failed; and Mr. Wilson, the agent of Mr. Burdon, was employed for this purpose. He accordingly undertook the construction of an iron arch of 181 feet span, with $16\frac{1}{2}$ feet rise or versed sine; the arch being the segment of a circle. In this bridge the ribs were similar to those of Wearmouth: but instead of having the blocks, of which the ribs are composed, kept together by worked iron bars, let into grooves in their sides, the rings of the ribs were cast hollow, and a dowel was let into the hollow ring at each joint; so that the two adjacent blocks were fixed together by this dowel, and by keys passing through the rings. The ribs were also connected transversely by frames, instead of pipes as in the Sunderland bridge. The haunches were filled with iron rings, and the whole was covered with iron plates.

It is to be noted, that an iron arch, in small blocks, is not set up after the manner of a stone one, by beginning at the abutments, and building upwards; but is begun at the top, and continued downwards; it being easier to join the stone to the iron, than to cut the iron at the top, if it should not fit. It is somewhat remarkable, therefore, that when these ribs were put together, and before they joined the masonry, it was so nicely balanced, and its parts were so firmly locked together, that after all the supports were taken out, except those next the abutment, the whole was moved by a man, with a crowbar under the top, and it seemed to have little tendency to push the abutments asunder. This, however, turned out unfortunately not to be the case. The centring was taken away, and the bridge was opened for the use of the public, about the end of the year 1801, or beginning of 1802. At first it seemed to stand firm, and the public were much pleased with its light and elegant appearance. But in a short time it was found that the arch was sinking; and soon after it had gone so much, that it was obliged to be shut up, and the old bridge opened again. The sinking of the arch broke several of the transverse frames, and many of the radii at the haunches; which left no doubt that the abutments had given way. But on examination there appeared no visible sign of such failure: there was not a crack in the masonry, nor had they gone out of the upright.—After much investigation however, it appeared that the whole masonry of the abutments, to the very foundation, had slidden horizontally backwards, still preserving the perpendicular, or upright position. The failure took place in the south abutment, which was supposed to be owing to a cellar, that had been made in it. The inhabitants of Staines therefore, by the advice of an engineer whom they consulted, had this abutment strengthened: but no sooner was this done, than the north one failed: and they had intended to strengthen this also; but their funds being nearly exhausted, they came to the resolution to take the whole down, and erect a wooden bridge in its stead.

Before the completion of the iron bridge at Staines, another was begun of the same dimensions, and on the same principle, over the river Tees at Yarm. This bridge was completed also: but, instead of gradually yielding, as that at Staines had done, the whole suddenly tumbled into the river at once.

From the accidents above described, and from several others of less note, iron bridges have lost a good deal of their celebrity, but probably on no just grounds. Those failures that have happened, have not been through any intrinsic deficiency in the iron material, but from the injudicious manner in which they have been constructed. An opinion has gone forth, not only among the practical builders of iron bridges, but among some men of science, that the lateral pressure of iron bridges, in consequence of their parts being so firmly bound together, is comparatively small, to that of stone arches. But, on a due consideration of their principle, I believe it will be found quite different, and that an iron arch, of the same weight as one of stone, requires much stronger abutments, to resist its lateral pressure or push, than the stone arch does. And this we shall here endeavour to account for.

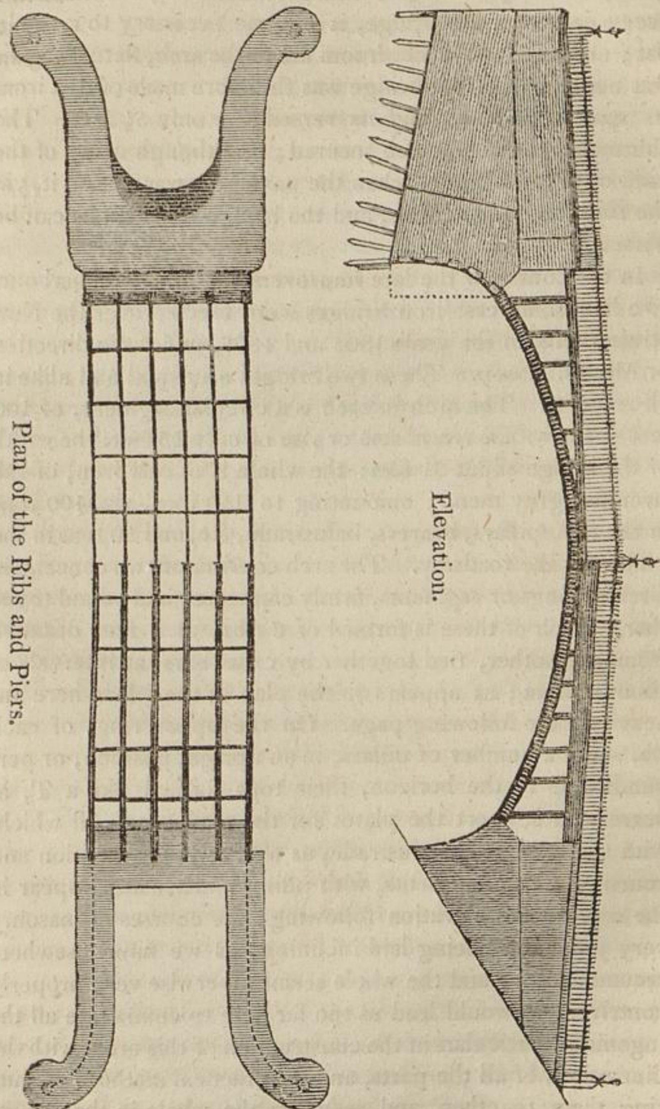
Stone may, in a great measure, be considered as an unelastic substance, being very little subject to expansion or contraction. When, therefore, an arch is composed of this material, and the abutments are sufficiently strong, to support it, when left to itself, there is little probability of its failure. No ordinary load upon it will excite a tremulous motion; nor will it change by heat or cold. The lateral pressure on the piers or abutments is therefore uniform.

But iron is an elastic substance, and is greatly affected by heat or cold, expanding with the one, and contracting by the other. When, therefore, a heavy load acts upon an iron bridge, such as a loaded waggon, the whole is put in motion, and the arch vibrates like the string of a violin, contracting and expanding while its parts are in the act of vibration. Thus at one part of the vibration it pulls the abutments together, and at the other it pushes them asunder, with a force compounded of the quantity of matter in motion, and the velocity with which it moves. When it expands, the whole weight of the arch is raised, and the pressure on the abutments is compounded of the matter and velocity of the weight raised. No such pressure, or rather impulsive momentum, takes place in a stone bridge: therefore the strength of the abutments of an iron bridge should be such, as not only to sustain the weight of the arch, but also the additional push arising from the causes above stated. The abutments of Staines bridge were only 14 feet thick; whereas they ought to have been at least 25 feet. There were also other causes which contributed to the failure of this bridge, such as the improper manner in which the foundations were made.—The abutments of Yarm bridge were made still weaker than those of Staines: no wonder, therefore, that its failure was more sudden.

I am therefore most decidedly of opinion, from what has happened in the bridges above described, and in several others, that no part of the failure is attributable to the iron material, at least respecting its strength.—I do not however mean to say, that iron is generally to be preferred to stone:—on the contrary, I think a stone bridge is preferable to an iron one, when it can be executed with propriety and conveniency. But there are many cases where stone would not answer the purpose; in which cases therefore iron is most valuable.—The cases here chiefly alluded to, are when the foundations cannot be made within the width that a stone arch can with convenience be erected; or when the requisite rise would be very inconvenient for a stone bridge, or in places where stone cannot easily be procured. The bridge at Wearmouth is an example of the former, as stone piers would have very much obstructed the navigation of the river; and of the latter, as the arch is a segment of a circle of about 500 feet diameter.

The bridge at Boston, in Lincolnshire, is another example, though of less extent: the banks of the Witham are very low, and the houses are built close to the river; the rise of tide is great, and barges navigate under it: therefore, to render the access easy over the bridge, it became necessary to make it flat; and to admit of headroom under the arch, flatness again was necessary. This bridge was therefore made of cast iron. Its span is 86 feet, and its versed sine only $5\frac{1}{2}$ feet. The abutments have been well secured; and though many of the radii of the ribs broke, when the pavement was put on it, yet the rings are quite entire, and the bridge is as firm as can be wished.

In the course of the late improvements in Bristol harbour, two handsome cast iron bridges were erected over the New River there, in the years 1805 and 1806, under the direction of Messrs. Jessop. These two bridges are equal and alike in all respects. The arch in each is a circular segment, of 100 feet span, with a versed sine or rise of only 15 feet: the width of the bridge about 31 feet: the whole is of cast iron, of the strongest grey metal; amounting to 150 tons, viz. 100 tons in the ribs, pillars, bearers, balustrade, &c, and 50 tons in the plates for the roadway. The arch consists of two concentric circular rings or segments, firmly connected and bound together. Each of these is formed of 6 ribs, at 6 feet distance from each other, tied together by cross bars, at intervals of about $9\frac{1}{2}$ feet; as appears in the plan of the fabric here annexed on the following page. On the upper ring, of each rib, stand a number of pillars, in an upright position, or perpendicular to the horizon, their tops formed like a T, as bearers to support the plates for the roadway. All which, with the railing, or balustrade, as well as the disposition and coursing of the abutments, with piling underneath, appear in the represented elevation following; the courses of masonry very judiciously being laid inclining, as we have elsewhere recommended; and the whole seems otherwise very properly contrived. It would lead us too far here to enumerate all the ingenious particulars in the construction of this arch, with the dimensions of all the parts, and the practical methods of putting them together, and securing the whole in the firmest manner, as prescribed to the iron masters for their direction.



Plan of the Ribs and Piers.

Elevation.

Suffice it therefore to observe, that, from the mode of putting the bridge together, it is so contrived, that if any part be injured, it can be taken out, and replaced, without disturbing the main body of the bridge.

The cost of one bridge, independent of the digging and earth work, and making the roads to it, was nearly as below.

	£.
Piles - - - - - - - - - - -	250
Masonry, 3200 yards, at 18s. including stone - -	1600
Iron work, 100 tons, at 9l. 18s. and 50 tons, at 9l. -	1440
Covering with gravel, and paving, &c. - - -	292
Expences of erection and painting - - - -	418
	£4000

Thus has been given a short history of such iron bridges as have come to my knowledge: aware however that many others have been built, both for roads and for aqueducts in canals, &c: but none of these, that I have heard of, are remarkable either for their span or construction: so that it appears unnecessary to enter into any particular description of them. The projects also that have been made for bridges of this kind, but not executed, are numerous, and a short account may here be added of some of the more remarkable designs that have come to our notice; though our researches have not enabled us to trace any of them to a period prior to the execution of the bridge at Colebrook Dale.

A design was made in the year 1783, by whom, does not appear, for an arch, chiefly of iron, of 400 French feet in span, and 45 feet in the versed sine; answering to a circle of about 934 feet diameter. This design, with a memorial on the advantages of using iron, in the construction of bridges, was presented by the author to the unfortunate Louis of France, on the 5th of May 1783. It had two large ribs, partly of iron and partly of wood. These ribs were 30 feet deep at the springs, and 15 feet at the midde of the arch. Each rib was composed of 4 rings, drawn from different centres, the inner ring being the strongest; and they were connected together by pieces of iron in various fanciful forms, little adapted to give strength to the arch. Between the ribs were cills, or logs of timber, laid transversely, resting on the interior ring; and a floor of wood was proposed to cover them. So that the road was suspended by the ribs; and the upper part of the ribs was to answer the purpose of a parapet, similar to the wooden bridges in Switzerland.—It appears that this project possessed little merit beyond the boldness of its design; and we have never heard that any bridge has been constructed on this principle.

In the year 1791 a project was made by Mr. John Rennie, Civil Engineer, for an iron bridge, intended for the isle of Nevis. The span of the arch was to be 110 feet, and its versed sine $13\frac{3}{4}$; answering to a circle of 234 feet diameter. It was proposed that this arch was to have 6 ribs; each rib to consist of 3 rings, which were to be connected together by radii. The depth of the rib at the middle was $3\frac{1}{2}$ feet, and at the springs 6 feet. The ribs were to be connected together by transverse frames of iron, placed in the joints of the blocks of which the ribs were composed: the haunches to be filled with circular rings of iron; and the whole was to have been covered with plates of iron, to support the road.

In April 1794, he made another design for the same island of Nevis, in which the span was 80 feet, and the rise or versed sine $9\frac{1}{2}$ feet. This design was formed on the same principles as the former, except that the rib was $11\frac{1}{2}$ deep at the springs, though still only $3\frac{1}{2}$ in the middle. The radii were continued to the roadway; and the whole was to be covered with iron plates, as the former. Neither of these designs however was executed, as the French got possession of the island.

From the above period, no projects for iron bridges, except those above described, have come to my knowledge, till applications were made to parliament, for the purpose of improving the port of London, by means of wet docks. The House of Commons, after having heard a great deal of evidence, on the inadequacy of the Thames to accommodate the shipping, appointed a select committee, to take the whole into their consideration, and to report to the house the best means for giving relief to the extensive commerce of the metropolis. This committee, after having recommended the construction of the West India and London Docks, took up the consideration of the state of the Thames, and of London Bridge, which forms the great obstruction to the influx of tide, and greatly injures the navigation of this very important commercial river; and in the year 1799 they directed plans of London bridge to be made out, with correct descriptions of its construction and state of repair; from which it appeared to them, that a new bridge, of more waterway, was imperiously required: and in consequence encouragement was held out to artists, to bring forward designs, for the construction of a new bridge, instead of the old one. On this occasion many designs were made out, and presented to the committee. Some were for stone bridges, and some for iron. But as the object of this account relates to projects for iron bridges only, we shall here confine our attention to these last alone.

The encouragement held out, by the Select Committee, brought forward four designs of this kind: namely, one by Mr. Wilson, formerly mentioned, of 3 arches; the middle one of which was 240 feet span, having a versed sine of 37 feet; the two side arches of 220 feet span each, and their versed sine 30 feet. The height of the soffit of the middle arch 80 feet above the high-water of an ordinary neap tide. The principles of this design were so nearly the same as those of Sunderland bridge, that it is unnecessary to enter into any minute description of it.

Two other designs were brought forward by Messrs. Telford and Douglass: one to consist of 5 arches across the river, and the other of 3. The middle arch of the former was 180 feet span, with a versed sine of 38 feet; also two arches, each of 140 feet span, and two of 120 feet span each. The other had a middle arch of 240 feet span, with a versed sine of 48 feet; and two side arches, of 220 feet span each: the height of the soffit of the middle arch being 80 feet above the high water of neap tides, the same as that of Mr. Wilson's design.

The arches of both the designs of Messrs. Telford and Douglass were constructed in the same manner; therefore a description of one will serve for both. They were composed of ribs; each rib having an outer and inner ring: the inner ring much stronger than the outer, and they were connected together by radiated bars, which extended quite to the pieces that supported the roadway. In the large arches there were two portions of rings, to stay the radiated bars in the haunches; but in the small arches only one. Of how many pieces the ribs were composed, or in what manner to be joined, was not shown in the designs, nor mentioned in the descriptions. The great height given to these bridges, to admit of vessels passing under them, renders it necessary, particularly on the south side of the river, where the land is under the level of spring tides, that long approaches, or inclined planes, as the designers called them, should be made; and these they proposed to support on iron arches, constructed in a manner similar to those of the bridge. By the section it appears that there will be a rise of about 1 foot in 19, on the main approach from the Borough; so that, taking the height of the roadway on the bridge at 60 feet above the wharf of the Thames, this approach will extend 1140 feet into the Borough, High-street. Now a rise of 1 in 19 is almost double the rise in Ludgate-hill: so that, if it were to be made the same rise as Ludgate-hill, it would extend to a distance not much short of half a mile. The side approach upward, it appears also, would come within about 260 yards of Blackfriars bridge, and that downwards would extend to nearly opposite the Tower. So that a considerable part of the Borough would probably be subjected to great inconveniences and expences by these far extended approaches, which appear unavoidable. The additional labour too that would by this means be occasioned, would probably cost more, to the inhabitants of London and the Borough of Southwark, than all the advantage that might arise by bringing vessels up to Blackfriars bridge. These objections are not applicable to these designs alone, but in an equal degree to Mr. Wilson's also.

There can be no doubt but that both designs could be executed; whatever may have been the opinion of artists on the skill exercised in their mechanical construction. We have before shown, that the true principle on which an arch ought to be constructed, is to increase the depth of the voussoir, as it is called in masonry, towards the spring of the arch, so that the arch, with its load upon it, shall be in equilibrio in all its parts. This being accomplished, it does not appear that any good can result from extending the radii further; for as the roadway presses perpendicularly on the arch, it appears not the strongest mode to support this perpendicular load by inclined pieces; but rather the contrary. It seems proper, therefore, that the roadway should be sustained by upright pillars of iron, instead of inclined radii, though less elegant in appearance to the eye: nay we might even prefer the circular rings or eyes of Mr. Wilson, to this mode: though we are aware that a circle, pressed on four points, is by no means calculated to bear a very great pressure.

The Select Committee of the House of Commons, not being satisfied with any of the three designs, that have been described, directed Messrs. Dance and Jessop to report, whether any, and what advantages, would accrue to the navigation of the Thames, if it were to be considerably contracted. Accordingly these gentlemen reported, that if, instead of the channel of the Thames at London bridge being 740 feet wide, as it was proposed to be when the above designs were made, it were reduced to 600 feet, that great advantages would result to the navigation; since, by diminishing the width, the depth would be much increased.—It might be foreign to the purpose of the present work, to enter into any discussion on the propriety of this measure; for which reason we may leave that discussion to a future opportunity. In consequence of this opinion, Messrs. Telford and Douglass presented to the Committee a very elegant and magnificent design, for an arch of 600 feet span, having its versed sine about 65 feet; so that the circle of which this arch is a segment, must be about 1450 feet diameter.

The arch was composed of seven ribs; and each rib may be said to have 6 rings, the 3 lower concentric, and about 8 feet deep. The dimensions of the iron cannot be correctly taken by measurement from the plan, this being on a small scale. These rings were connected by radii about 18 inches asunder; the outer and inner are the strongest, and that in the middle appears light, and seems intended, it is presumed, chiefly to stiffen the radii, though doubtless it will also add to the strength of the bridge. The ribs are composed of frames of iron, each about 10 feet long, which extend quite to the entablature of the cornice. The other 3 rings are not concentric with those 3 lower, but each drawn from a larger radius than the other. The lowest of these three terminates in the upper ring of the three lower, at about 120 feet from the key, or the middle of the arch. The two above this unite at about the same distance from the middle of the arch, and are thence continued in one ring, till they reach within about 35 feet of the middle or key of the arch, where they join the said upper rib of the lower three. These three upper ribs are united to the third or upper ring, of those first described, by means of radii; but the spaces between these radii include the space of two of the lower radii; and, instead of being stiffened by a light ring, as the lower radii are, that object is effected by Gothic tracery. These seven ribs, above described, are set parallel to each other; and, to brace them horizontally, there are six others, or diagonal ribs, four of which cross the former diagonally, two terminating in the middle rib, and two in the adjoining ribs; and there are two outside ribs, that terminate each on the face of the exterior ones. So that, in fact, two of the seven have no diagonal rib terminating at their top. The whole of these last described ribs are therefore side or diagonal braces, to keep the seven principal ribs in their vertical position, and prevent the arch from racking sideways, as happened at Sunderland or Wearmouth bridge, before mentioned.—All these vertical and diagonal ribs are connected together by transverse frames, at the joints of each of the radiated frames or voussoirs. The top or platform, under the roadway, is covered, in the usual manner, with iron plates; and there is a light iron railing on each side, with Gothic ornaments.—The breadth of the roadway at the top, or middle of the arch, is 45 feet, and at the haunch or extremity of the arch 82 feet wide.—The arch springs from large frames of iron, set in abutments of masonry; and its approaches are similar to those before described for the designs of Messrs. Telford and Douglass.

The principles on which this arch is designed, may be found in a work published at Leyden, in the year 1721, entitled "Recueil de plusieurs machines de nouvelle invention, ouvrage posthume de M. Claude Perrault, &c. &c." and is described in pages 712, 13, 14 of that work, and represented in plates 10 and 11. It is described, "Pont de bois d'une seule arche de trente toises de diametre, pour traverser la Saine visavis le village de Sevre, ou l'on proposoit de la contruire." It may also be seen in the 1st vol. of the Machines approved by the Academy of Sciences, pa. 59, pl. 14. It may appear perhaps doubtful to some persons, whether this design is so proportioned as to be in perfect equilibrio, being remarkably heavy at the haunches; and that, were such an arch as there described to be erected over the Thames, whether it would permanently support itself.—The extension of the radii to the roadway has been before noticed as not well adapted to sustain the perpendicular pressure, with which it would be charged, and that unless its parts were in perfect equilibrio, the joints of the frames might open in such a manner, as to derange the whole fabric, and accelerate its destruction.—That an iron arch of 600 feet span might be constructed in such a manner, as to become a firm and stable fabric, it is not meant to be denied; but, according to the principles we have laid down, it should be rather differently constructed from that we have described. Indeed, if the weight of iron, mentioned in the estimate, be correct, the parts must be very slender indeed; and were the whole to be in equilibrio, this weight of the structure itself might bend the parts in such a manner, as in some measure to endanger its downfall.

We imagine that three distinct objects were proposed to be obtained by the improvements which the public have in view. These are, 1st. The maintaining of deeper water, from the lower part of the Thames to Blackfriars bridge, and upward.—2d. More clear space for the navigation of vessels under the bridge.—3d. Effecting this object with the least rise of road over it.

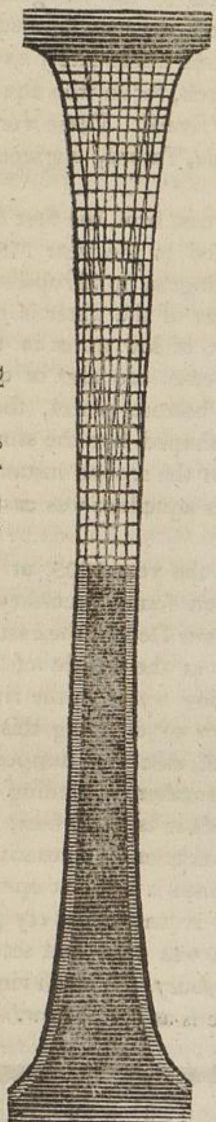
In respect to the first question, I have already declined entering into it; being of opinion it is a discussion rather foreign to the purpose of a book on bridges.—The second appears to come fully under the scope of the principles we have treated on.—The arch here proposed, as we have before seen, is of 600 feet span, with a versed sine or rise of 65 feet. Now, at the distance of 100 feet from the middle, the height is 58 feet; at 150 feet from the middle the height is 49 feet; and at 200 feet it is 37 feet in height. So that, only about 200 feet, or $\frac{1}{3}$ of the width of the river, can be accounted fit for the navigation of coasters: about another third may be fit for the ordinary barges; and the remaining third will be for little other purpose than the lug boats and wherries that ply on the river.

Vessels, therefore, in departing from the wharfs, must be drawn out nearly to the middle of the river, before they can take the advantage of the tide downwards: and those coming to a wharf, must fetch up in the river till they are hauled into it. This might do for vessels that frequent wharfs situated a considerable distance above the bridge: but those for wharfs that might be near it, must experience much trouble and inconvenience; and it is to be feared that they would frequently sustain damage in their masts and rigging, by striking against it, and might probably injure the bridge itself. Mr. Rennie has very properly noticed this, in his answer to one of the queries proposed by the Select Committee of the House of Commons: but he follows up his observations by saying, that, as the strength of the current will be chiefly in the middle of the river, the vessels will generally pass in that track. Now we may admit that, for a vessel sailing up or down the river, and going to some wharf near Blackfriars bridge, or departing from thence downward, that this will be the case: but when going to, or sailing from wharfs near the new bridge, it will be very much otherwise; as may be observed by any one who will attend to the vessels sailing to or from the wharfs below London bridge: and we should fear that, in order to prevent the accidents above noticed, dolphins, or some such contrivance, will be found absolutely necessary, to keep the vessels in the proper track, in passing through this arch.—Now, if we be right in our conjecture, it would probably be better to have two piers, and a bridge of three arches, than a bridge of one only; by which the height or space under the bridge, for vessels to pass, might be very much increased; and those wharfs which lie near the bridge not be subject to the inconveniences, nor the vessels to the risk before mentioned.

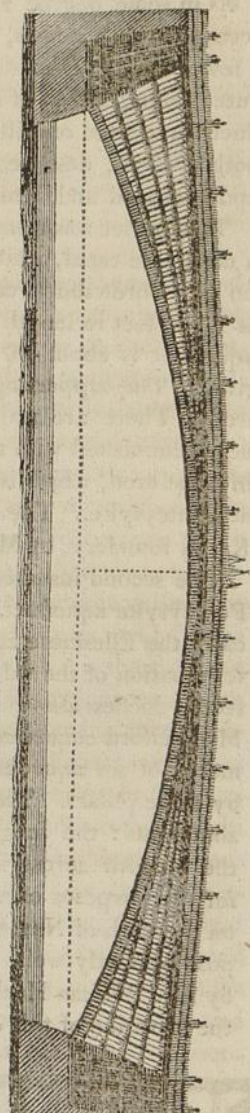
Thirdly, A bridge of three arches will not require the ribs to be so deep at the top, as a bridge of one arch, by at least 3 feet; and therefore so much will be gained in the height of the roadway over it. On the whole therefore it seems, that the design in question is not completely calculated to attain the objects the Select Committee of the House of Commons had in view: but, on the contrary, that it will appear to most thinking men, rather an injudicious idea, to effect by a great work, that which can at least as well, if not better, be accomplished by a work of less expence, and of more probable stability.

Our observations have been hitherto confined to the possibility and propriety of executing an iron arch, of 600 feet span, according to the design given with the report of the House of Commons. We may now add some observations on the practicability of building abutments, in this situation, sufficiently strong to resist the lateral pressure of this arch; which, according to our calculation, made on the supposition that the arch would be similar to one of stone, acting with a regular and uniform pressure upon it, would be of about 9000 tons. But when the effects of the vibration, which must necessarily take place in an arch of this magnitude, are taken into consideration, the lateral pressure, or rather vibrating push, will far exceed that quantity; and for this effort, as has been before noticed, provision must be made in the strength of the abutments: and though the thickness of these in the design, namely 85 feet, seems to be great, yet I am inclined to think it would be found too small, especially at the south end of the bridge, where I am informed the ground is very bad, being moorlog and soft mud to a considerable depth. Indeed I should fear that something of the kind of what happened at Staines would be likely to take place here, namely, the whole mass of masonry be forced back horizontally, by the great lateral push of the arch, in spite of every precaution that could be taken to prevent it. But we must observe, as we have before done in answer to the Queries in the Report of the Committee of the House of Commons, that the foundations of the abutments should be laid inclining towards the centre of the circle to which the arch is drawn, as a more likely mode of preventing them from sliding outwards, than if laid horizontally: but even with this precaution, if the substratum be moorlog or soft mud, it will be likely to give way; and if this ever take place, the abutment and arch must follow it.

The following is a rough sketch, on a very small scale, on the design, at least very elegant, which was given along with the above project.



Plan of the Ribs and the Roadway.



Elevation.

As in some degree and nature related to the foregoing account of iron arches, properly so called, we may here add a few words, just to notice two ingenious works lately executed, being a kind of straight or flat arch, for an iron aqueduct, supported on pillars, carried over rivers. These were, both of them, designed by Mr. Thomas Telord, engineer, and executed under his direction.

The former was a small aqueduct of cast iron, the first for a navigable canal, which was constructed in the year 1795, on the Shrewsbury canal, near Wellington in Shropshire. It is 180 feet in length; and the surface of the water in the aqueduct is about 20 feet above that of low water in the river. The supporting pillars, in this case, are also of cast iron. There are no ribs under the bottom plates, these being connected with the side plates, shaped like the stones in a flat arch, which is also the case in the second instance, at Pontcysylte. The iron work of this aqueduct was cast at Ketley foundery, by Messrs. Reynolds.

The second instance was erected in the year 1805, at the Pontcysylte aqueduct. It having been found necessary to carry the Ellesmere canal across the river Dee, at the eastern termination of the vale of Llangollen, at the height of 126 feet 8 inches above the surface of low water in the river, Mr. Telford conceived the bold design of effecting this by means of an aqueduct constructed of cast iron, supported by stone pillars. These are 20 in number, including the abutments: the length of the aqueduct is 1020 feet, and the breadth across it 12 feet. It has been in constant use for the purposes of navigation ever since it was first opened, on the 26th of November 1805, and it answers every purpose perfectly well. The iron work was cast, and set up, by Mr. William Hazledine, of Shrewsbury. A small view of the elevation of this elegant structure is as here below.