TRACT V.

ANSWERS TO QUESTIONS, PROPOSED BY THE SELECT COMMITTEE OF PARLIAMENT, RELATIVE TO A PROPOSAL FOR ERECTING A NEW IRON BRIDGE, OF A SINGLE ARCH ONLY, OVER THE RIVER THAMES, AT LONDON, INSTEAD OF THE OLD LONDON BRIDGE.

AMONG the various means of improving the port of London, which have lately been devised, was one by removing the old inconvenient London bridge, and erecting another in its stead, which might be more commodious, and better according with the improved state of the port. Several projects were given in to the Committee of Parliament, appointed to consider those improvements, among which was one proposed by Messrs. Telford and Douglass, to be of a single arch, made of cast iron, which the Committee so far noticed, as to order engravings to be made of the design, and, for more safety, to issue a set of questions, concerning this extraordinary project, to be sent to several ingenious professional and literary men, requesting their answers to all or any of them, within a limited time.

The present tract contains my answers, which were delivered in, to those questions, and for which I was honoured with the thanks of the Committee; which answers are here given as a proper appendix, among other articles, to the essay on bridges in the first Tract.

The situation proposed for this new bridge, is about 200 yards above the old bridge, which brings it to run nearly in a line with the Royal Exchange, and with the wide part of the main street of the Borough of Southwark. This is the narrowest part of the river, being here but 900 feet over. It was also proposed to narrow the river still more in this

part, by building strong abutments of masonry, running 150 feet into the river on each side, against which to abut the proposed arch of cast iron, which consequently was to be of 600 feet span, extending across the river at one stretch. The height of the arch at the crown or key piece, was to be 65 feet above high-water, to allow ships of considerable burden, with their top masts only struck, to sail through beneath it, up to Blackfriars bridge; to load or unload by the side of new wharfs, to be built into the river, on both sides of it, all the way up to Blackfriars. The width of the bridge, to be 45 feet in the middle, and from thence widening all the way, in a curved form, till it should become enlarged to 90 feet at the extremities.

The letter of the Committee is here given first, with the set of questions, followed by the answers as delivered in consequence of that requisition.

THE ORDER OF THE COMMITTEE.

" Lunæ 23 die Martii 1801,

" At the Committee for the further improvement of the Port of London;

" Charles Abbot, Esq. in the Chair:

" Ordered, That the Print, Drawings, and Estimates of an Iron Bridge, of a single arch, 600 feet in the Span, together with the annexed Queries, be sent to Dr. Hutton, requesting that he will, on or before the 25th of April next, transmit to Mr. Samuel Gunnell, the Clerk to this Committee, his opinion upon all of these queries, or such of them as he may be disposed to consider.

" Charles Abbot, Chairman.

" *To Dr. Hutton,*

" *Military Academy, Woolwich.*"

" *Estimate.*

	£.
" Getting out and securing the foundation of the two abutments - - - - -	20,000
432,000 cubic feet of granite or other hard stone	86,400
20,029 cubic yards of brickwork, at 20s. - -	20,029
19,200 cubic feet of timber in tyes, at 3s. 6d.	3,360
6,500 tons of cast iron, including scaffolding and putting up, at 20l. - - -	130,000
Making roadways and footpaths - - - - -	2,500
	£262,289"

" *Questions respecting the Construction of the annexed Plate and Drawings of a Cast Iron Bridge of a Single Arch,* 600 *feet in the Span, and* 65 *feet Rise.*

" 1. What parts of the bridge should be considered as wedges, which act on each other by gravity and pressure, and what parts as weight, acting by gravity only, similar to the walls and other loading, usually erected upon the arches of stone bridges.—Or, does the whole act as one frame of iron, which can only be destroyed by crushing its parts?

" 2. Whether the strength of the arch is affected, and in what manner, by the proposed increase of its width towards the two extremities, or abutments; when considered vertically and horizontally. And if so, what form should the bridge gradually acquire?

" 3. In what proportions should the width be distributed from the centre to the abutments, to make the arch uniformly strong?

" 4. What pressure will each part of the bridge receive, supposing it divided into any given number of equal sections, the weight of the middle section being given. And on what parts, and with what force will the whole act upon the abutments?

" 5. What additional weight will the bridge sustain; and what will be the effect of a given weight placed upon any of the before mentioned sections?

" 6. Supposing the bridge executed in the best manner, what horizontal force will it require, when applied to any particular part, to overturn it, or press it out of the vertical plane?

" 7. Supposing the span of the arch to remain the same, and to spring ten feet lower, what additional strength would it give to the bridge.—Or, making the strength the same, what saving may be made in the materials.—Or, if instead of a circular arch, as in the plate and drawings, the bridge should be made in the form of an elliptical arch, what would be the difference in effect, as to strength, duration, convenience, and expences?

" 8. Is it necessary or adviseable, to have a model made of the proposed bridge, or any part of it, in cast iron. If so, what are the objects to which the experiments should be directed; to the equilibration only, or to the cohesion of the several parts, or to both united, as they will occur in the intended bridge?

" 9. Of what size ought the model to be made, and what relative proportions will experiments, made on the model, bear to the bridge, when executed?

" 10. By what means may ships be best directed in the middle stream, or prevented from driving to the side, and striking the arch, and what would be the consequence of such a stroke?

" 11. The weight and lateral pressure of the bridge being given, can abutments be made in the proposed situation for London bridge, to resist that pressure?

" 12. The weight and lateral pressure of the bridge being given, can a centre or scaffolding be erected over the river, sufficient to carry the arch, without obstructing the vessels which at present navigate that part?

" 13. Whether it would be most adviseable to make the bridge of cast and wrought iron combined, or of cast iron

only. And if of the latter, whether of the hard white metal, or of the soft grey metal, or of gun metal?

" 14. Of what dimensions ought the several members of the iron work to be, to give the bridge sufficient strength?

" 15. Can frames of cast iron be made sufficiently correct, to compose an arch of the form and dimensions as shown in the drawings No. 1 and 2, so as to take an equal bearing as one frame; the several parts being connected by diagonal braces, and joined by an iron cement, or other substance?

N. B. The plate is considered as No. 1.

" 16. Instead of casting the ribs in frames, of considerable length and breadth, as shown in the drawing, No. 1 and 2, would it be more adviseable to cast each member of the ribs in separate pieces of considerable lengths, connecting them together by diagonal braces, both horizontally and vertically, as in No. 3?

" 17. Can an iron cement be made, which shall become hard and durable. Or can liquid iron be poured into the joints?

" 18. Would lead be better to use in the whole or any part of the joints?

" 19. Can any improvement be made in the plan, so as to render it more substantial and durable, and less expensive. And, if so, what are those improvements?

" 20. Upon considering the whole circumstances of the case, and agreeable to the resolutions of the 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 made a durable edifice?

" 21. Does the estimate communicated herewith, according to your judgment, greatly exceed or fall short of the probable expence of executing the plan proposed, specifying the general grounds of your opinion?

" The Resolutions referred in No. 20, are as follow.

" 1st. That it is the opinion of this Committee, that it is essential to the improvement and accommodation of the port of London, that London Bridge should be rebuilt, upon such a construction, as to permit a free passage at all times of the tide, for ships of such a tonnage, at least, as the depth of the river would admit of, at present, between London Bridge and Blackfriars Bridge.

" 2d. That it is the opinion of this Committee, that an Iron Bridge, having its centre arch not less than 65 feet high in the clear, above high-water mark, will answer the intended purpose, and at the least expence.

" 3d. That it is the opinion of this Committee, that the most convenient situation for the new bridge, will be immediately above St. Saviour's Church, and upon a line from thence to the Royal Exchange.

" Charles Abbot.

" *To Dr. Hutton, Woolwich.*"

The Answers to the foregoing Queries, were as follow; where each question is repeated immediately before its answer, to preserve the connection more close and immediate.

Answers to the Questions concerning the proposed New Iron Bridge, of one arch, 600 *feet in the span, and* 65 *feet high.*

QUEST. 1. What parts of the bridge should be considered as wedges, which act on each other by gravity and pressure, and what parts as weight, acting by gravity only, similar to the walls and other loading usually erected upon the arches of stone bridges. Or, does the whole act as one frame of iron, which can only be destroyed by crushing its parts?

Answer. It is my opinion, that all the small frames or parts ought to be so connected together, at least vertically, as that the whole may act as one frame of iron, which can only be destroyed by crushing its parts.—For, by this means, the pressure and strain will be taken off from every particular

arch or course of voussoirs, and from every single voussoir or frame, and distributed uniformly throughout the whole mass. Hence it will happen, that any particular part which may by chance be damaged, or be weaker than the rest, will be relieved, and prevented from a fracture, or, if broken, prevented from dropping out and drawing other parts after it, which may be next to it, either above or on the sides of it. By this means also, the effect of any partial or local pressure, or stroke, or shock, whether vertical or horizontal, will be distributed over or among a great number of the adjacent parts, and so the effect be broken and diverted from the immediate place of action. By this means also will be obviated, any dangerous effects arising from the continual expansion or contraction of the metal, by the varying temperature of the atmosphere, in consequence of which the bridge will, all together, in one mass, in a small and insensible degree, keep perpetually and silently rising or sinking, as the arch lengthens by the expansion, or shortens by the contraction of the metal.—This unity of mass will be accomplished, by connecting the several courses of arch pieces together vertically, or the lower courses to the next above them, and also by placing the pieces together in such a way as to break joint, after the manner of common or wall masonry, and that perhaps in the longitudinal and transverse joints, as well as the vertical ones.

Quest. 2. Whether the strength of the arch is affected, and in what manner, by the proposed increase of its width towards the two extremities, or abutments; when considered vertically, and horizontally; and if so, what form should the bridge gradually acquire?

Answer. There can be no doubt but the bridge will be greatly strengthened by an increase of its width towards the two extremities, or abutments, especially if the courses or parts be connected together in the manner above mentioned, in the answer to the first question. For thus, the extent of the base of the arch at the impost being enlarged, the strength or resistance of the abutment will be increased in a much higher degree than the weight and thrust of the arch, and

consequently will resist and support it more firmly. The arch itself will thus also acquire a great increase of strength and stability, both from the quantity and disposition of the materials, as well vertically as horizontally, by which, in the latter direction in particular, the arch will be better enabled to preserve its true vertical position, and to resist the force or shock of any thing striking against it in the horizontal direction. And, for the better security in these particulars, considering the immense stretch of the arch, it will perhaps be adviseable to enlarge the width in the middle to 50 feet, instead of 45, and at the extremities to 100 feet, instead of 90, as proposed in the design.—As to the form of this width or enlargement, the side of the arch might be bounded either by a circular arch, or by any curve that will look most graceful: perhaps a very excentric ellipse will answer as well as any other curve, or better.

QUEST. 3. In what proportions should the weight be distributed from the centre to the abutments, to make the arch uniformly strong?

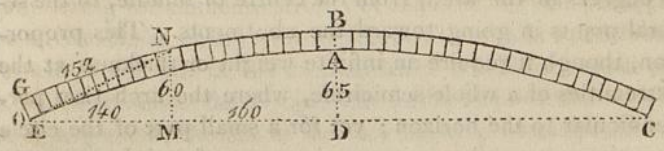
Answer. To make the arch uniformly strong throughout, it ought to be made an arch of equilibration, or so as to be equally balanced in every part of its extent.—When the materials of the arch are uniform and solid, then, to find the weight over every part of the curve, so as to put the arch in equilibrio, is the same thing as to find the vertical thickness of the arch in every part, or the height of the extrados, or back of the arch, over every point of the intrados or soffit of the under curve of the arch: the rule for determining and proportioning of which, is described at large in my Treatise on Bridges, particularly in prop. 4*, and the examples there given to the same. But in the case of the present proposed design for a bridge, a strict mathematical precision is not to be expected or attained by mere calculation, on account of the open frame work of iron, in parts of various shapes and sizes. We must therefore be content with a near approach to that point of perfection; which can be accomplished in a degree

* The same as prop. 10, tract 1, of this volume.

sufficient to answer all the purposes of safety and convenience. Now this can be conveniently done, by a comparison of the present design of a bridge, with the example of a similar intrados curve in the book above mentioned, and which is the case of the first example to the said 4th prop., being that with a circular soffit. By that example it appears, that the weight above every point in the soffit curve, should increase exactly in proportion as the cube of the secant of the number of degrees in the arch, from the centre or middle, to the several points in going toward the abutments. This proportion, though it require an infinite weight or thickness at the extremities of a whole semicircle, where the arch rises perpendicular to the horizon; yet for a small part of the circle near the vertex, the necessary increase of weight or thickness, toward the extremities, is in a degree very consistent with the convenient use and structure of such a bridge; as will be evident by a glance of the figure and curve to that example. For, as the whole extent of the soffit arch, in the present design for an iron bridge, is but about 48° 54′, or 24° 27′ on each side, from the middle point to the abutments, that is, little more than the fourth part of the arch in that example; therefore, by cutting out the fourth part of that arch, it will give us a tolerable idea of the requisite shape of the whole structure, and increase in the thickness where the materials are solid, or at least the increase in weight over every point in the soffit; that is, the figure exhibits a curve for the scale of such increase. Or, if we compute the numeral values of the weights or thickness, by the rule in that example, in the proportion of the cube of the secants, they will be as in the annexed tablet; which is computed for every degree in the arch,

Deg.	Wt. or height	Deg.	Wt. or height
0	10·000	13	10·810
1	10·000	14	10·947
2	10·018	15	11·096
3	10·041	16	11·258
4	10·073	17	11·434
5	10·115	18	11·625
6	10·166	19	11·831
7	10·227	20	12·052
8	10·298	21	12·290
9	10·379	22	12·546
10	10·470	23	12·821
11	10·572	24	13·116
12	10·685	24½	13·272

from the middle, supposing the middle thickness or weight to be 10. And the true representation of the figure, as constructed from these numbers, or the extrados curve determining the true scale of weight or thickness, over every such point in the soffit curve, is as is here exhibited below. Where the thickness or height in the middle being supposed 10, the vertical thickness or height of the outer curve, above the inner, at the extremities, is 13·272, or nearly $13\frac{1}{4}$, and the



other intermediate thicknesses, at every degree from the vertex, are as denoted by the numbers in the latter column of the table. If the thickness at top be supposed 7, or 8, or 12, or any other number, instead of 10, all the other numbers must be changed in the same proportion. Now the upper curve in this figure is constructed from these computed tabular numbers, and exhibits an exact scale of the increase of weight or thickness, so as to make the whole an arch of equilibration, or of uniform strength throughout, when the materials are of uniform shape and weight. And in this case the upper curve does not sensibly differ from a circular arc in any part of it. But, as the convenient passage over the bridge requires that the height or thickness at the extremities, or imposts, should be a great deal more than in proportion to these numbers denoting the equilibrium of weight, it therefore follows, that the frame work of the pieces above the arch, in the filling up of the flanks, ought to be lighter and lighter, or cast of a form more and more light and open, as in the engraved design, so as to bring the loading in those parts as near to the equilibrium weight, as the strength and stability of the iron frames will permit.

QUEST. 4. What pressure will each part of the bridge receive, supposing it divided into any given number of equal sections, the weight of the middle section being given; and

on what part, and with what force, will the whole act upon the abutments?

Answer. By the equal sections, mentioned in this question, may be understood, either vertical sections of equal weight, or those perpendicular to the curve of equal weight, or of equal length; and whichever of these is intended, their thrust or pressure in direction of the curve may be easily computed, if wanted for the purpose of making experiments on the strength of the frames, to know whether they will bear those pressures, or what degree of pressure they *will* bear, without being crushed in pieces. But as it is evident that the frames next the abutments will suffer the greatest pressure of any, I shall here give a computation of the actual pressure there, which may be sufficient, since if the frames at the abutments are capable of sustaining that greatest pressure, we may safely conclude, that all the others, from thence to the vertex, will be more than capable of sustaining the lesser loads or pressures to which they are subject; and this computation will answer the latter and most essential part of the question, viz. "on what part, and with what force, will the whole act on the abutments." Now, from the nature of an arch, it appears that the whole pressure on the abutments, will be chiefly on the lower part of the impost, where the lower frame rests on it, and where we shall therefore, in our computation, suppose it to act. And in the calculation, the whole weight of the half arch AO must be supposed united in its centre of gravity N. Then, if a vertical line MN be drawn through the centre of gravity N, by computation it is found that DM is nearly equal to 160 feet, and consequently ME equal to 140 feet: also, if NO be perpendicular to the impost, or in the direction of the arch at OE; we shall have this proportion, viz, as MN (60), is to the weight of the half arch (3250 tons), so is NO (152), to the pressure on the impost in the direction of the arch at O, and so is ME (140), to the horizontal thrust or pressure in the direction ME; this gives 8233 tons for the pressure on the impost at O in direction of the arch, and 7583 tons for the horizontal thrust in direction ME; being

the pressures at each end of the bridge. We may therefore estimate the greatest pressure on the last or abutment frame, at about 8 or 9 thousand tons.

QUEST. 5. What additional weight will the bridge sustain, and what will be the effect of a given weight placed upon any of the before mentioned sections?

Answer. It is perhaps not possible to pronounce exactly what additional weight the bridge will sustain, without breaking, as it depends on so many circumstances, some of which are not known. But, considering the great dimensions and strength of the arch frames, and of the whole fabric, we are authorized to conclude, that there is no possible weight which can pass over any part of the bridge, even heavy loaded waggons, whose pressure can be great enough to cause any danger to such strong and massy materials, and especially when it is considered that, by connecting all the frames together, by proper bond and otherwise, as mentioned in the answer to the first question, the local additional pressure will soon be distributed through the whole series of the iron framing.

QUEST. 6. Supposing the bridge executed in the best manner, what horizontal force will it require, when applied to any particular part, to overturn it, or press it out of the vertical plane?

Answer. This question will be much better answered by means of experiments, made on a proper model, than by theoretical calculations *a priori*. But when the bridge is executed in the best manner, with the frames properly bonded and connected together, it seems more likely that any violent horizontal shock, such as a ship driving against it, would break any particular frame, rather than overturn such a mass of bonded materials, or even move it sensibly out of the vertical position.

QUEST. 7. Supposing the span of the arch to remain the same, and to spring ten feet lower, what additional strength would it give to the bridge.—Or, making the strength the same, what saving may be made in the materials.—Or, if instead of a circular arch, as in the plate and drawings, the

bridge should be made in the form of an elliptical arch, what would be the difference in effect, as to strength, duration, convenience and expence?

Answer. Should the arch spring ten feet lower than in the design, the bridge would be more stable, because the thrust or pressure on the abutments would be directed lower down, and more into the solid earth: and in general, the lower the springing of the arch, the more firm the abutments and stable the bridge, if the height of the crown above the springing of the bridge be the same.—But the greatest advantage would be, by making the bridge in the form of an elliptical arch, instead of the circular one, in all the articles of strength, duration, convenience, and expence. For, as the elliptical flanks require less filling up than the circular, this will produce a great saving in the iron frame work: and this same reduction of materials in the flanks, toward the abutments, is the very cause of greater strength, by reducing the weight there nearer to the case of equilibration; since that very extraordinary mass employed in the flanks of the circular arch destroys the equilibrium of the whole, by an overload in that part. The elliptical arch will be also much more convenient, as it will allow of a greater height of navigation way between the water and the soffit of the arch. The elliptical arch is also a much more graceful and beautiful form than the circular arch.

QUEST. 8. Is it necessary or adviseable, to have a model made of the proposed bridge, or any part of it, in cast iron. If so, what are the objects to which the experiments should be directed; to the equilibration only, or to the cohesion of the several parts, or to both united, as they will occur in the intended bridge?

Answer. It appears to be very adviseable, to have a model made of the whole of the proposed bridge, in cast iron, as well for the greater safety and satisfaction, as for the benefits and improvements to be derived from the experiments to be made with it, and from the experience and knowledge de-

rived from the casting and making it.—The objects to which the experiments should be directed, might be, the equilibrium of the whole, the cohesion and fitting of the several parts, the effects of a vertical load on every part separately, and the effects of a horizontal blow or shock against every part in the side of the arch. Also what weight would be requisite to break or to crush the model frames.

QUEST. 9. Of what size ought the model to be made, and what relative proportions will experiments, made upon the model, bear to the bridge, when executed?

Answer. The greater the size of the model, the more satisfactory the experiments and conclusions will be. For this purpose, it seems adviseable, that the model be not less than the 20th part or dimensions of the bridge, that is, of 30 feet in length. Now, as the solid contents of similar bodies are in the same proportion as the cubes of their linear dimensions, such a model would require only the 8 thousandth part of the weight or metal in the bridge, because the cube of 20 is 8000. So that, as it is estimated the bridge will require 6500 tons of metal, it follows, that about 3 quarters of a ton weight of metal will suffice for the model of 30 feet in length. As to the relative proportions of experiments made with the model: those relating to the equilibrium, will be in the same direct proportion with the masses of the model and bridge, as well as those relating to loads or shocks. But the strength of any particular bar or frame will be only as the square of the scantling, while the stress upon it will be barely in the same proportion as the length.

QUEST. 10. By what means may ships be best directed in the middle stream, or prevented from driving to the side, and striking the arch; and what would be the consequence of such a stroke?

Answer. Some kind of fences might be placed in the river, to direct the navigation to the proper opening in the middle. The effect of the stroke or shock of a vessel, striking the side of the bridge, if very heavy, might endanger the breaking

of the particular frame or bar so struck. But, the whole being well bonded and connected together, none of the others would probably be displaced.

QUEST. 11. The weight and lateral pressure of the bridge being given, can abutments be made in the proposed situation for London bridge, to resist that pressure?

Answer. No doubt of it; and especially if the courses of masonry have the joints directed towards the centre of the arch.

QUEST. 12. The weight and lateral pressure of the bridge being given, can a centre or scaffolding be erected over the river, sufficient to carry the arch, without obstructing the vessels which at present navigate that part?

Answer. I doubt not that the requisite centring or scaffolding can be erected, without obstructing the present navigation.

QUEST. 13. Whether it would be most adviseable to make the bridge of cast iron and wrought iron combined, or of cast iron only; and if of the latter, whether of the hard white metal, or of the soft grey metal, or of gun metal?

Answer. It appears most adviseable to make the bridge of cast iron only, and that of the soft grey metal, the bars and frames of which will be less liable to fracture by a blow or shock, than the hard metal.

The mixture of wrought iron with the cast metal, would be very improper, as the sorts are of unequal expansion and contraction by heat and cold, and as the several arch frames should not be tied or bolted together, but suffered to have a little play lengthways, in their butting grooves, so as that no one part be more confined than another.

QUEST. 14. Of what dimensions ought the several members of the iron work to be, to give the bridge sufficient strength?

Answer. This question will be best answered by experiments made on the metal.

QUEST. 15. Can frames of cast iron be made sufficiently correct, to compose an arch of the form and dimensions as

shown in the drawings No. 1 and 2, so as to take an equal bearing as one frame, the several parts being connected by diagonal braces, and joined by an iron cement, or other substance?

N. B. The plate is considered as No. 1.

Answer. There can be no doubt that cast iron frames may be made sufficiently correct to compose an arch of any form whatever, and give them an equal bearing; because the wooden moulds, from which the metal is cast, can be made or cut to any shape desired.

QUEST. 16. Instead of casting the ribs in frames, of considerable length and breadth, as shown in the drawing No. 1 and 2, would it be more adviseable to cast each member of the ribs in separate pieces of considerable lengths, connecting them together by diagonal braces, both horizontally and vertically, as in No. 3?

Answer. It is, in my opinion, better to cast the ribs in frames, of considerable length and breadth.

QUEST. 17. Can an iron cement be made, which will become hard and durable, or can liquid iron be poured into the joints?

QUEST. 18. Would lead be better to use in the whole, or any part of the joints?

Answers to Questions 17 *and* 18. The joints might either be filled with an iron cement; or liquid iron might be poured into the joints, having a furnace near at hand for that purpose; or, melted lead may be run in, which will be best of all; because, being a soft metal, it will yield to, and accommodate itself to the inequalities of pressure or of shape, forming a sound and soft bond or bearing between frame and frame; and preventing their fracturing each other by a too hard and unequal bearing; in some respect performing the same office as the cartilages between the joints of the bones in the animal frame.

QUEST. 19. Can any improvement be made in the plan, so as to render it more substantial and durable, and less expensive. And if so, what are those improvements?

Answer. Although the plan appears to possess a very extraordinary degree of excellence, I am of opinion, that it is not incapable of some further improvements, so as to render it more substantial and durable, as well as less expensive. The circumstances which, it appears to me, would be improvements, are as follow:

1st. To make the vertical arch or curve of the bridge elliptical, instead of circular; which will be an improvement in stability, in convenience, in beauty, and in saving expence.

2d. To make the width of the bridge 50 feet in the middle, and 100 feet at the extremities: which will add greatly to its stability and security.

3d. To make the thickness of the arch at the crown, or the height of the middle or key frame there, to be not less than 10 or 12 feet, instead of 6 or 7 as proposed; because, in so extended and massy a fabric, *that* seems to be the least thickness that can afford a rational ground for security and stability.

4th. I would tie or connect every course of frames to those next above them, so as that the whole bridge may rise or settle together as one mass, by expansion or contraction. Yet I would not tie or bolt the frames together lengthways, but would simply make the edge, or the tenons, of the side of each frame, fit into the groove or the mortice holes of the next, going into each other two or three inches; by which means the arch frames will always sit or fit close together, in every degree of temperature, without straining or tearing asunder at the ties.

5thly. I would place the frames of the whole fabric so together, as to make a proper bond, in the manner of good masonry, by making them all to break joint both longitudinally and transversly: by which means, every shock or pressure on any part, would be broken and divided, or shared, among a great many, and any openings be prevented, which might arise from the manner of placing the frames with straight joints continued quite through.

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.