THE PRINCIPLES OF STONE BRIDGES.

SECTION I.

Of the Projects of Bridges, with the Design, Eſtimate, &c.

WHEN a bridge is deemed neceſſary to be built over a river, the firſt conſideration is the place of it; or what particular ſituation will contain a maximum of the advantages over the diſadvantages.

In agitating this moſt important queſtion, every circumſtance, certain and probable, attending or likely to attend the bridge, ſhould be ſeparately, minutely, and impartially ſtated and examined; and the advantage or diſadvantage of it rated at a value proportioned to it: then the difference between the whole advantages and

diſadvantages, will be the neat value of that particular ſituation for which the calculation is made. And by doing the ſame for any other ſituations, all their neat values will be found, and of conſequence the moſt preferable ſituation among them.——Or, in a competition between two places, if each one's advantage over the other be eſtimated or valued in every circumſtance attending them, the ſums of their advantages will ſhew whether of them is the better. And the ſame being done for this and a third, and ſo on, the beſt ſituation of all will be obtained.

In this eſtimation, a great number of particulars muſt be included; and nothing omitted that can be found to make a part of the conſideration.

Among theſe, the ſituation of the town or place for the convenience of which the bridge is chiefly to be made, will naturally produce a particular of the firſt conſequence; and a great many others ought to be ſacrificed to it. If poſſible, the bridge ſhould be placed where there can conveniently be opened and made paſſages or ſtreets from the ends of it in every direction, and eſpecially one as nearly in the direction of the bridge itſelf as poſſible, tending towards the body of the town, without narrows or crooked windings, and eaſily communicating with the chief ſtreets, thoroughfares, &c.——And here every

every perſon, in judging of this, ſhould diveſt himſelf of all partial regards or attachments whatever; think and determine for the good of the whole only, and for poſterity as well as the preſent.

The banks or declivities towards the river are alſo of particular concern, as they affect the conveniency of the paſſage to and from the bridge, or determine the height of it, upon which in a great meaſure depends the expence.

The breadth of the river, the navigation upon it, and the quantity of water to be paſſed, or the velocity and depth of the ſtream, form alſo conſiderations of great moment; as they determine the bridge to be higher or lower, longer or ſhorter. However, in moſt caſes, a wide part of the river ought rather to be choſen than a narrow one, eſpecially if it is ſubject to great tides or floods; for, the increaſed velocity of the ſtream in the narrow part, being again augmented by the farther contraction of the breadth, by the piers of the bridge, will both incommode the navigation through the arches, and undermine the piers and endanger the whole bridge.

The nature of the bed of the river is alſo of great concern, it having a great influence on the expence; as upon it, and the depth and velocity

of the ſtream, depend the manner of laying the foundations, and building the piers.

Theſe are the chief and capital articles of conſideration, and which will branch themſelves out into other dependent ones, and ſo lead to the required eſtimate of the whole.

HAVING reſolved on the place, the next conſiderations are the form, the eſtimate of the expence, and the manner of execution.

With reſpect to the form; ſtrength, utility, and beauty ought to be regarded and united; the chief part of which lies in the arches. The form of the arches will depend on their height and ſpan; and the height on that of the water, the navigation, and the adjacent banks. They ought to be made ſo high, as that they may eaſily tranſmit the water at its greateſt height either from tides or floods; and their height and figure ought alſo to be ſuch as will eaſily allow of a convenient paſſage of the craft through them. This and the diſpoſition of it above, ſo as to render the paſſage over it alſo convenient, make up its utility.—Having fixed the heights of the arches, their ſpans are ſtill neceſſary for determining their figure. Their ſpans will be known by dividing the whole breadth of the river into a convenient number of arches and piers, allowing at leaſt the neceſſary thickneſs of the

the piers out of the whole. In fixing on the number of arches, take always an odd number, and rather take few and large ones than many and ſmaller, if convenient: For thus you will have not only fewer foundations and piers to make, with fewer arches and centers, which will produce great ſavings in the expence, but the arches themſelves will alſo require much leſs materials and workmanſhip, and allow of more and better paſſage for the water and craft through them; and will appear at the ſame time more noble and beautiful, eſpecially if conſtructed in elliptical, or in cycloidal forms: for the truth of which it may be ſufficient to refer to that noble and elegant bridge lately built at Blackfriars, London, by Mr. Mylne. And here I can't help remarking that the Gentleman who, a few years ſince in a pamphlet on the Principles of Bridges, cenſured Mr. Mylne and Mr. Muller concerning elliptic arches, has very much expoſed himſelf, and abſurdly criticiſes them through his own want of mathematical knowledge, which he ſomewhere in the ſame pamphlet affects to deſpiſe. He brings to my mind an expreſſion of (I think) Mr. Henry Fielding ſomewhere in his works, That a perſon does not ſpeak the worſe on a ſubject for knowing ſomething about it. I do not however make this remark through any particular diſreſpect for this Gentleman, concerning whom I know nothing farther, any more than I do about the other two Gentlemen, but only to prevent

prevent others from being prejudiced and miſled by the authority of his *ipſe dixit*.—If the top of the bridge be a ſtreight horizontal line, let the arches be made all of a ſize; if it be a little lower at the ends than the middle, the arches muſt proportionally decreaſe from the middle towards the ends; but if higher at the ends than the middle, let them increaſe towards the ends. A choice of the moſt convenient arches is to be made from the 4th and 5th propoſitions, where their ſeveral properties, &c. are demonſtrated and pointed out: Among them, the elliptic, cycloidal, and equilibrial arch in prop. 5, will generally claim the preference, both on account of their ſtrength, beauty, and cheapneſs or ſaving in materials and labour: Other particulars alſo concerning them may be ſeen under the word ARCH in the Dictionary in the laſt ſection. And as the choice of the arch is of ſo great moment, let no perſon, either through ignorance or indolence, prefer a worſe arch becauſe it may ſeem to him eaſier to conſtruct; for he would very ill deſerve the name or employment of an Architect, who is incapable of rendering the exact conſtruction of theſe curves eaſy and familiar to himſelf; but if, by chance, a Bridge-builder ſhould be employed who is incapable of doing that, he ought at leaſt to be endowed with ſuch a ſhare of honeſty as to procure ſome perſon to go through the calculations which he cannot make for himſelf.

Next

Next find what thickneſs at the keyſtone or top will be neceſſary for the arches. For which ſee the word KEYSTONE in the Dictionary in the laſt ſection.

Having thus obtained all the parts of the arches, with the height of the piers, the neceſſary thickneſs of the piers themſelves are next to be computed by prop. 10.

This done, the chief and material requiſites are found; the elevation and plans of the deſign can then be drawn, and the calculations of the expence from thence made, including the foundations, with ſuch ornamental or accidental appendages as ſhall be thought fit; which I ſhall leave to the diſcretion of the Practical Architect, as being no part of the plan of my undertaking, together with the practical methods of carrying the deſign into execution. I ſhall however, in the Dictionary in the laſt ſection, not only deſcribe the terms, parts, machines, &c. but alſo ſpeak of their dimenſions, properties, and any thing elſe material belonging to them; and to which therefore I from hence refer for more explicit information in each particular article, as well as to theſe immediately following propoſitions, in which the theory of the arches, piers, &c. are fully and ſtrictly demonſtrated.

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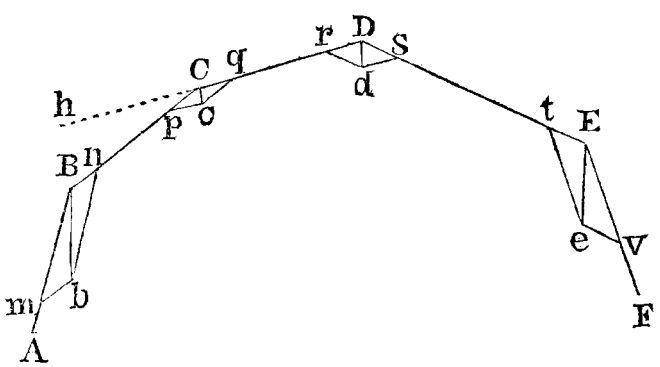
SECTION II.

Of the Arches.

PROPOSITION I.

LET there be any number of lines AB, BC, CD, DE, *&c. all in the ſame vertical plane, connected together and moveable about the joints or angles* A, B, C, D, E, F; *the two extreme points* A *and* F *being fixed: It is required to find the proportions of the weights to be laid upon the angles* B, C, D, *&c. ſo that the whole may remain in equilibrium.*



Solution.

FROM the ſeveral angles having drawn the lines Bb, Cc, Dd, &c. perpendicular to the horizon; about them, as diagonals, conſtitute paral-

parallelograms ſuch, that thoſe ſides of each two that are upon the ſame one of the given lines, may be equal to each other; viz. having made one parallelogram m n, take C p = B n, and form the parallelogram p q; then take D r = C q, and make the parallelogram r s; and take E t = D s, and form the parallelogram t v; and ſo on: Then the ſaid vertical diagonals B b, C c, D d, E e, &c. of thoſe parallelograms, will be proportional to the weights, as required.

Demonſtration.

By the reſolution of forces, each of the weights or forces B b, C c, D d, &c. in the diagonals of the parallelograms, is equal to, and may be reſolved into two forces expreſſed by two adjacent ſides of the parallelograms; viz. the force B b will be reſolved into the two forces B m, B n, and in thoſe directions; the force C c into the two forces C p, C q, and in thoſe directions; the force D d into the two forces D r, D s, and in thoſe directions; and ſo on: Then, ſince two forces that are equal, and in oppoſite directions, do mutually balance each other; therefore the ſeveral pairs of forces B n and C p, C q and D r, D s and E t, &c. being equal and oppoſite, by the conſtruction, do mutually deſtroy or balance each other; and the extreme forces B m, E v, are balanced by the oppoſite reſiſtances of the fixed points A, F. Wherefore there is no force

to change the position of any one of the lines, and consequently they will all remain in equilibrium. *Q.E.D.*

Corollary.

HENCE, if one of the weights and the positions of all the lines be given, all the other weights may be found.

PROPOSITION II.

IF any number of lines, that are connected together and moveable about the points of connection, be kept in equilibrium by weights laid upon the angles, as in the last proposition: Then will the weight on any angle C *be universally as* $\frac{\text{sine of the } \angle \text{BCD}}{s.\angle \text{BCc} \times s.\angle \text{cCD}}$; *that is, directly as the sine of that angle, and reciprocally as the sines of the two parts or angles into which that angle is divided by a line drawn through it perpendicular to the horizon.*

Demonstration.

BY the last proposition the weights are as Bb, Cc, Dd, &c. when Bn = pC, Cq = rD, Ds = tE, &c. But, since the angle ABb is = the angle Bbn,