## Mr. SMEATON'S Memorial concerning Hexham Bridge.

WHEN Mr. Smeaton was applied to by Mr. Errington, for the building of Hexham Bridge, it was not till after the total deſtruction of a bridge at the weſt end of Tyne Green, near that place, built under the patronage of Sir Walter Blackett; which, about twelve or fourteen months after it was finiſhed, was totally deſtroyed by an extraordinary flood, that has ever ſince been diſtinguiſhed by the name of the Great Inundation, which happened in November 1771; but as this bridge was ſtanding at dark in the evening, and totally demoliſhed the next morning, no other information could be drawn from this very fatal and alarming accident, but that this river was capable at times, from a certain combination of cauſes, of being ſwelled to a degree of violence far exceeding any thing that had before this been experienced, handed down by tradition, or imagined.

As an evidence of this, amongſt many others that might be given, the water roſe ſeven or eight feet, or thereabout, upon the main ground floor of Mr. Fenwick's new-built apartments at Bywell; which being erected from the deſigns of that eminent architect Mr. Payne, it is not likely that he would direct the main floor to be laid within flood-mark, as it had, at that time, been known, or then thought likely to happen; and yet, Bywell being many miles below the junction of the two Tynes (that is of the North and South Tyne, about a mile above Hexham) and after it had had much room to ſpread over the wide haughs that laid between Hexham and Corbridge, and alſo in the ſpace between Corbridge and Bywell, we muſt conclude, that the riſe of the water was leſs at Bywell than in the neighbourhood of Hexham.

Under this degree of information, and experience of the utility of a bridge at Hexham, (Sir Walter Blackett having choſen rather to forfeit the penalty of a bond of three thouſand pounds, that he had laid himſelf under for the upholding thereof, than attempt to rebuild or re-eſtabliſh the bridge), the erection was taken up by the county; and, for this purpoſe, conſulted that eminent engineer Mr. Wooler, then engaged for the town of Newcaſtle, in the re-eſtabliſhment of Tyne Bridge there, ſo far as the magiſtrates of that town were concerned therewith, and (which through the Fan down the river, and in the tides-way, ſuffered alſo an almoſt total demolition) Mr. Wooler, on faith of borings made by a ſurveyor, a perſon employed by the magiſtrates of the county for that purpoſe, who reported, that a bed of clay laid at no more than four feet under the bed of the river, at a place about fifty yards above, or weſtward of the bridge built by Sir Walter Blackett, formed a proper

deſign for building a bridge upon the foundation deſcribed, upon the principles of piling and planking under the piers, and which was begun accordingly in the year 1774; and, after building the north land-breaſt, Mr. Pickernell was recommended in the beginning of the year 1775 to the county, by Mr. Wooler, and employed as ſurveyor under him for the erection of this bridge; who having ſunk the foundation pit for the firſt pier from the north abutment, as directed, to the depth of four feet below the bed of the river, to find the bed of clay; inſtead thereof, came to a ſtratum of a very different nature, which, after examining, he reported to Mr. Wooler, then at Hull, viz. "A quickſand full of "bubbly ſprings, and of ſo looſe a texture, that by hand only, a bar of iron entered "into it forty-ſix feet without meeting any reſiſtance; and that a trial pile of whole timber "entered twenty-ſix feet, at two inches and a half per ſtroke of the ram without ſloping; "and that the gentlemen concerned were eye-witneſſes to the facts."

Upon the above report Mr. Wooler declared his opinion, that the attempting to ſet a bridge upon ſuch an enormous depth of quickſand, over a river ſo ſubject to great floods as the Tyne, may be deemed ſo hazardous, as to be next to imprudence itſelf — and again, that this wretched quickſand, rendered the attempting a bridge on ſuch principles (that is piling and planking under the piers) little better than folly — a quickſand, which, from its reſiſtance to the iron bar, cannot be deemed much better than a heap of chaff. For, ſays he, "let it again be ſuppoſed, that a flood like that which overturned the late bridge "ſhould happen, it cannot be doubted, that when the looſe gravel under the bed of "the river (only four feet thick) ſhall be ſwept away between any of the piers, the "quickſand under it will preſently follow like water itſelf; and an excavation may be "made in a few hours, as deep or deeper than any of the piles that guard the piers; "when a downfall muſt be the immediate conſequence. On theſe principles therefore, "the bridge ought not to be attempted in this ſpot; and, if no better can be found in "any other ſituation, there is but one method of dealing with ſuch ground, which has "ſucceeded where expenſe was not regarded: that is, by carrying a ſolid wall quite "through the river, from ſide to ſide, about ſix feet high; and in this caſe it muſt be "forty-two feet broad." The preceding extracts are made from a copy of Mr. Wooler's letter of the 19th of July, 1775, to Mr. Pickernell; the peruſal of which will more amply ſet forth the grounds and reaſons of Mr. Wooler's opinion; that no bridge under ſuch circumſtance, is likely to be accompliſhed at any limited expenſe; he concludes with ſaying, "I had the honour to mention this method (that is of the ſolid wall) "to Mr. Aynſley, when there was a doubt about the nature of the ground, ſometime "before their ſurveyor found out the ſtratum of the clay; but he then looked upon the "expenſe to exceed their abilities; but however, after all, if ever a ſtable bridge be

"made

" made there, I do not know any other means to effect it — You will lay this before the " gentlemen for their conſideration."

After this, Mr. Pickernell proceeded to ſink a well or ſhaft in the ſolid ſoil of Tyne Green, near the place where the ſouth abutment of the intended bridge was to be; when paſſing through the ſtratum of gravel, found the quickſand at nearly the ſame depth, (that is to ſay, four feet below the bed of the river) as in the foundation pit for the pier on the other ſide, into which he thruſt his iron bar as before, and covered up the ſhaft, till Mr. Wooler ſhould come and examine the premiſes.

He alſo proceeded to try the river, by boring in other places; and particularly in the pool below the eaſt boat; that is, a little above the place where Mr. Smeaton afterwards pitched upon, to build a bridge for Mr. Errington; an account of which boaring being tranſmitted by Mr. Pickernell to the clerk of the peace, reference being thereto had, will more fully appear; but which went to prove, that whenever Mr. Pickernell had penetrated the bed of gravel, univerſally a ſtratum of quickſand was found.

Under theſe circumſtances Mr. Wooler attended at Hexham, to ſurvey the premiſes; and in the preſence of ſome of the magiſtrates aſſembled on the occaſion, repeated the trial of the bar, both in the foundation pit near the north, and in the ſhaft near the ſouth-end of the intended bridge, and which ſucceeded as before mentioned. The exiſtence of a ſtratum of quickſand under a bed of gravel in this place, then, does not depend upon the ſimple teſtimony of Mr. Pickernell, but is alike witneſſed by very reſpectable, as well as competent judges.

The reſult of which view and ſurvey was, that no other place appearing more eligible and likely, than where the beginning had been made, and being unwilling to go on upon the principle intended and began, of piling and planking under the piers; and the magiſtrates not giving ear to the ſolid wall propoſed by Mr. Wooler (acroſs and under the whole bed of the river, from ſide to ſide, as an artificial foundation whereon a bridge was to be erected), on account of the expenſe thereof, which was not likely to be uncertain, but ſo great as to be very imprudent for even the county to enter upon, the whole undertaking was at that time given up or ſuſpended: and Mr. Wooler having been urged, as too eaſily deſiſting from his original plan, on going away, he very ſagaciouſly and prophetically ſaid, whoever meddled with a bridge there, would burn their fingers. After this the gentlemen of the county, unwilling to loſe ſight of a bridge at Hexham, an advertiſement ſoon after appeared in all the Newcaſtle newſpapers, as from the bench of magiſtrates of the

county

county, importing an invitation to all adventurers to undertake the erection of a bridge, taking the riſque of making a foundation upon themſelves, and taking their own method of doing it, but to build the ſuperſtructure according to a certain deſign to be produced to them, and ſecurity for the permanency of the whole for the term of ſeven years. This advertiſement was continued till the latter end of the year 1776, in which interval ſeveral adventurers had in ſucceſſion offered, but all of them on a cloſer view, before the completion of a contract, ſtarted off; ſeveral expenſive preparations having been made at the expenſe of the county, and the materials lying upon their hands: this work being therefore, as will appear from what is preceding, generally conſidered as a derelict ſcheme, or at leaſt a forlorn hope; ſome time in the latter end of the year 1776, Mr. Donkin, agent of Mr. Errington, came to Mr. Smeaton in Mr. Errington's name, to know if he would undertake the direction of building a bridge over the Tyne, ſomewhere between the Lowford, and the Eaſtboat at Hexham, for Mr. Errington, provided he (Mr. Smeaton) could find a place for the founding thereof which he thought ſo ſufficient, as that he would riſque his credit upon it as an artiſt: in which caſe, if it could be done upon a moderate eſtimate, he (Mr. Errington) would make a propoſal for building it to the county; urging, that as the county had been ſo long baffled in the attempt, as it would be an advantage to his eſtate, if it could be done there, it was probable that if it could be done at a moderate expenſe, the county might accept of a bridge there, rather than none, and if he (Mr. Errington) was two or three hundred pounds out of pocket on the above account, he would think it worth his while.

Mr. Smeaton, being ſomewhat ſurprized at the uncommonneſs and newneſs of the propoſal, deſired time to conſider of it, as previouſly to that time, he had ſtudiouſly avoided having any thing to do with it; though he had been frequently in that neighbourhood for a courſe of years, comprehending, and even preceding, the time of firſt undertaking thereof by Sir Walter Blackett; but conſidering it on this occaſion as a great advantage to the public, that if that could be done which they then ſeemed unlikely to get done; he began to conſider the cauſes of failure in thoſe that preceded, and in thinking ſeriouſly of the ſubject, there occurred to him a mode of conſtruction, that could not only be executed for a very moderate expenſe, conſidering the extent of the ſubject; but the only mode in which a bridge could be executed, on ſuch a kind of foundation as was then generally ſuppoſed, at any moderate expenſe and with a reaſonable proſpect of ſafety.

This conſidered, Mr. Smeaton acquainted Mr. Donkin, that he was willing to examine the ſituation; and if he found it competent, ſo that he could hazard his credit as an artiſt upon

upon it, he would be willing to give Mr. Errington an eſtimate. The trial was made, aſſiſted by Mr. Pickernell, who on this occaſion recounted the principal part of what is above ſtated, ſo far as he was concerned; the eſtimate was made, preſented and accepted, the bridge undertaken, built, and ſuffered the fatal overthrow that has occaſioned the preſent litigation.

The preceding narrative will ſufficiently ſhow, that none of the parties preſſed themſelves into this unfortunate, this ill-fated buſineſs, or proceeded in it from any intereſted motives.

Reſpecting Mr. Errington, he neither profeſſed nor could ever have any view of profit from the undertaking, the contingent benefit that it might in that ſituation be to his eſtate, being the ſole motive of the pains and trouble that muſt neceſſarily attend it.

Reſpecting Mr. Smeaton, he neither aſked, expected, ſought, nor received more than his accuſtomed daily hire, and he truſts, that it will not be ſuppoſed, that he could wiſh to undertake this buſineſs for want of employ; and in reſpect of Mr. Pickernell, if he wanted employ, he would have been much more likely to have met with it, by the bridge being proceeded with, if he had reported a good gravel to an unfathomable depth, knowing or believing there was a quickſand at nine or ten feet under it, than he could expect from reporting a quickſand, at nine or ten feet under the ſurface of the gravel, knowing or believing it was gravel unfathomable; becauſe being then not at all acquainted with Mr. Smeaton's ideas of the proper method of treating ſuch a ſubject, he muſt ſuppoſe it more likely for a bridge to be undertaken and proceeded with, if the foundation was a gravel unfathomable, than if it was a gravel with a quickſand under it.

What remain, therefore, as queſtions material to the county and to all the parties, ſeem to be the following, and what they who undertake to judge of the whole matter, ſhould be acquainted with.

1ſt, Whether Mr. Smeaton from the whole matter before him, at the time of forming his project, did it with that deliberate judgment and reaſonable probability of ſucceſs, that have characterized him in other things?

2dly, Whether

2dly, Whether Mr. Errington was ſparing of any thing neceſſary to give ſucceſs to that mode of building which Mr. Smeaton had adopted?

3dly, Whether Mr. Pickernell did to the beſt of his power and abilities execute, to a reaſonable and poſſible extent, what he was directed by Mr. Smeaton?

4thly, Whether under all the experience and knowledge of the ſubject, as it now ſtands, the preſent bridge ſhould be attempted to be re-inſtated, or a new one built at Hexham?

With reſpect to Mr. Smeaton's ſcheme for the bridge, the following matters are worthy of obſervation:

1ſt, That from the failure of Sir Walter's bridge in the night, no eſtimate could be formed, of the fall or velocity that the water had in paſſing that bridge, at the extreme of the flood, before its failure: for though the marks of the flood were left very viſible, which ſhewed it to have riſen many feet higher than any former flood, in point of height; yet this gives no light into the ſtreſs laid upon the bridge by the velocity of the water, for no bridge, even tolerably built, ought to ſuffer from the water's riſing any height upon it whatever, if ſtagnant or riſing very ſlowly, by the counteracting of a riſing tide oppoſing the natural current.

2dly, That it is aſcertained beyond a doubt, that at the place where Mr. Wooler began, there in reality exiſted a quickſand of an unfathomable depth, covered with a bed of gravel, of a very moderate thickneſs and conſiſtence, and intermixed with large tumbling white ſtones.

3dly, That not only from the faith of Mr. Pickernell's ſubſequent borings, but from the proximity of the two ſituations (not one-third of the breadth of the river aſunder), it appeared in the higheſt degree probable, that the ſame, or ſome ſuch a ſtratum of looſe matter, lay under the foundation of the bridge built by Sir Walter Blackett, and was the cauſe of its deſtruction; otherwiſe, its ſudden and total deſtruction, in ſo ſhort a ſpace of time, was to Mr. Smeaton totally unaccountable; who in the way of curioſity (as other buſineſs often carried him to Hexham) had ſometimes viewed the operations of that bridge while it was building: that bridge having been in his judgment at that time competently well founded to guard againſt accidents, conſidering in what manner it

it was done, when compared with the manner of founding on gravel uſed by our fore-fathers; and which, for Sir Walter Blackett, was deſigned and undertaken at the riſque of that ingenious and well experienced builder Mr. John Gott, of Woodhall, in the Weſt-Riding of the County of York, who for ſeveral years previous to that, had been undertaker of the building and repairs of the county bridges in the ſaid Weſt-Riding, and alſo ſurveyor of the rebuilding and repairs of the navigation works upon the rivers Aire and Calder; a man rendered truly reſpectable to all who knew him, from a long ſeries of ſucceſsful experience in this kind of arduous undertakings; and who, moreover, previouſly to this undertaking at Hexham, had with great ſucceſs and credit to himſelf, then undertaken and completed the new bridge at Ferrybridge, in Yorkſhire, which was done upon the ſelf ſame principles that he afterwards put in practice upon the Tyne, and which bridge ſtill ſtands unhurt upon the river Aire (there alſo united with the large river Calder) to the praiſe of the ſkill of the worthy builder thereof.

This perſon, Mr. Gott, being perſonally known to Sir Walter Blackett, as well as his works, Sir Walter pitched upon him as a proper perſon to enſure ſucceſs to his favourite project; and ſtill the more effectually to do it, he joined with Mr. Gott, Mr. Brown, a very worthy and experienced maſon of the neighbourhood; a perſon that had acquitted himſelf by many works done for Sir Walter and others, and ſome in the bridge way, and was alſo at that time ſurveyor for the bridges of the county of Northumberland: and ſtill the further to ſecure their care and induſtry in this undertaking, he had them bound to him as undertakers for the ſum for which they contracted with him, to uphold their works for the term in which he ſtood engaged to the county; but as a demonſtration, that ſhews how well he was ſatisfied, that the care and ſkill of the undertakers were fully and properly exerted, he, after the accident and a full examination, gave them up the bond they had entered into with him, contenting himſelf to pay the penalty in which he ſtood engaged to the county.

And now, as it will throw a conſiderable light upon what I have to ſay further upon the ſubject, it will not be loſt time to explain the mode of founding, adopted and put in practice by Mr. Gott, as it appeared to Mr. Smeaton by ocular inſpection, and who at the time was acquainted with the undertakers, but more particularly and previouſly with Mr. Gott.

Having conſtructed large and broad coffer dams of earth to fence off the water, by the help of chain pumps, they ſank the foundation pit about three feet into the gravel, then they drove piles over the whole area of the intended foundation of each pillar, from ten to twelve feet long, and from ten to twelve inches diameter in the heads, and tapering according to the natural taper of the timber, proper for driving into gravel of conſiderable reſiſtance. The heads being cut to a level, the whole was covered by a platform, made of whole (that is twelve inches) Riga balks, rabbetted or halved into each other, ſo that each could not ſubſide without its neighbour going with it, and upon this platform the pillars were reſpectively built.

Mr. Smeaton has reaſon to believe (though he never happened to be there when any piles were driving), that the undertakers finding their piles go into the ground more eaſily than they expected, and the upper part the hardeſt, did not in all the pillars make the excavation of the foundation pit quite ſo deep as above mentioned, but yet all were founded below the bed of the river: and, in a converſation with Sir Walter Blackett, after the founding the bridge was done, Sir Walter obſerving to Mr. Smeaton, that a rumour had gone forth, that the founding of the bridge had not been made ſufficiently ſtrong, Mr. Smeaton ſaid, that had they encreaſed the circumference with plank or ſheet piling, as he had done in all the gravel foundations of the kind, that he had had the ordering of, it was all he ſhould have done more than was done; but as the laying a ſolid platform, and even the piling itſelf, were things that our forefathers had not generally practiſed in ſuch caſes, and yet we found many of their bridges ſtanding after many years trial; it muſt be ſomething very extraordinary that could hurt a foundation ſo laid, far beyond any thing wherewith we were then acquainted.

This ſerves to ſhew what the opinion of Mr. Smeaton was at that time, before any derangement had happened, ſo that it was a matter to him of very great ſurprize, that notwithſtanding the extraordinary height of the water, a bridge ſo founded ſhould be ſo entirely demoliſhed in ſo ſmall a ſpace of time; but when the operations of Mr. Wooler were known, his ſurprize ceaſed: looking upon it as a certainty, that the violence of the water having taken off the cruſt of gravel, wounded alſo by the excavation for the piers, ſo as to let looſe the quickſand, he no longer wondered at the ſudden demolition of the bridge.

The third matter to be obſerved is, that Mr. Smeaton had at that time, (that is, at Mr. Donkin's application) finiſhed with ſucceſs two capital bridges in Scotland, over

two of the reputed moſt rapid rivers of their magnitude in that part of Great Britain; that is, over the Tweed at Coldſtream, which was finiſhed about the year 1767, and the Tay at Perth, which was finiſhed in or about the year 1770, and which in the interim before Mr. Donkin's application, had ſuſtained many ſevere attacks from floods, but without any injury, except (in ſome ſlight degree) to the rough rubble ſtone depoſited round the piers by way of defence, and which being occaſionally replaced, the whole remained and does ſtill remain unhurt.

Theſe bridges, the firſt being in part, and the latter wholly upon gravel of unfathomable depth, were founded on bearing piles, encaſed with ſheet or plank piles, below the bed of the river, the ſpace being filled up, and the foundation farther defended by the depoſition of rough quarry rubble ſtones: and Mr. Smeaton having experienced the great dependence and power of reſiſtance of ſtones ſo depoſited, not only in the caſes of building the bridges above mentioned, but in a great variety of caſes, preceding thoſe undertakings as well as after, wherein he found them the moſt effectual means, not only of controuling the violence of rapid rivers, but of the ſea itſelf, he was naturally led to place very great confidence in that ſpecies of defence.

4thly, That partly from the report of Mr. Pickernell's borings, partly from the ſimilarity of ſituation of the place propoſed by Mr. Errington, to that where Sir Walter Blackett and Mr. Wooler had worked, being both of them near the bottom of an extenſive pool, wherein the water is kept up by a bed of gravel juſt below them, and forming as it were a natural dam, whereby the motion of the water in the pool above, in the low ſtate of the river, was ſcarcely perceptible; I ſay, from ſimilarity of ſituations, Mr. Pickernell's report of the ground, juſt above the place pitched upon by Mr. Smeaton, and the trials that he (Mr. Smeaton) made himſelf, by driving a ſharpened iron bar from nine to ten feet into the bed of the river in ſeveral places, which was very conſiderably leſs reſiſted, and particularly in the main current, after it was driven down ſome feet, than it was in entering the upper cruſt of the gravel bed, which was apparent to him, by his aſſiſting perſonally in the operation; from all theſe conſiderations he thought himſelf well juſtified in concluding, that at ſome depth, exceeding nine or ten feet, at this place, there either actually exiſted a ſtratum of quickſand, ſimilar to that at the weſt end of Tyne Green, or at leaſt matter ſo little compact or capable of bearing weight, that to drive piles into it would only weaken the ſtratum. The queſtion therefore, that he had to decide for his own guidance was, Whether there was a bed of gravel of ſufficient thickneſs and compactneſs to bear the weight of a bridge, in caſe it was unwounded and unbroken? And the experiment of the bar abovementioned

(which was tried in ſeveral places acroſs the river), determined his judgment, that what he had felt and experienced was ſufficient.

It may here naturally be enquired, why Mr. Smeaton did not bore the bed of the river, inſtead of driving the bar in the manner deſcribed? and he anſwers, becauſe former experience had taught him to have very little faith in boring in gravel, for the purpoſe of founding bridges; for the colliery borers, though exceedingly expert in boring for the purpoſes to which they are to apply them, yet are no competent judges of the compactneſs of the ſtratum for the purpoſe of building a bridge; and in the trials formerly made by Mr. Smeaton himſelf, from the continual falling in of the ſmaller parts of the gravel itſelf, while the ſhank of the inſtrument is turning round, thereby occaſioning a continual grinding; and if the inſtrument is attempted to be withdrawn, the holes immediately filling, made it never appear to him in the light of a ſatisfactory operation, convincing to his mind of any certain concluſion: he has therefore, for many years paſt, contented himſelf with trials by the bar, which being driven by a hammer, he judges of the compactneſs of the gravel, by the number and ſtrength of the blows that it takes to go down; and on the faith of trials of this kind, where the bar went down with a competent reſiſtance and a near equality, he built the bridge of Perth upon piles encaſed with ſheeting.

From a mature conſideration of the above particulars and circumſtances, Mr. Smeaton found himſelf led to the following concluſions, viz.

That to build a ſolid wall acroſs the river as a foundation for the whole bridge, in the manner propoſed by Mr. Wooler, would not only be attended with an enormous expenſe, but, in the place where he propoſed it, likely to be in itſelf impracticable: for it did not, nor does it occur to Mr. Smeaton, how this is to be done without draining off the water from the bottom of the very large excavation that would be neceſſary to be laid open at once; which muſt not only go down to the quickſand, but in reality conſiderably into it, to lay the propoſed foundation of the wall; that in caſe the quickſands ſhould break up and run, as it was moſt likely to do, the drainage of this liquid matter would be endleſs; and if any part of it was attended with ſo much ſucceſs as to get founded, yet the part ſo founded would be ſapped, when the ſand is ſo broken up in any ſucceeding part.

That though in the place pitched upon by Mr. Smeaton, the bed of gravel appeared both thicker and firmer than where Mr. Wooler had begun; yet, as it appears evi-

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dently to him, was likely to partake of the ſame quality, the execution of the ſcheme of the ſolid wall, or of penning as propoſed by others (to make which effectual muſt amount to the ſame thing) could not be done upon any limited eſtimate; and at any rate, would exceed all bounds of expenſe, that it appeared to him likely or indeed prudent to be gone into by the county.

That to attempt the building of the bridge upon the principles of that of Perth; that is, to ſink an excavation pit conſiderably into the bed of the river, and in this to pile and encaſe, would be, in effect, firſt to deſtroy the very beſt and firmeſt part of the ſtratum, and then by driving piles into what was likely to be incapable of bearing the weight, would be in reality to repeat the errors, that, as it ſeemed to him, had been committed in Mr. Gott's erection; and as, laſt of all, the ſecurity of the bridge in any of theſe methods, muſt ultimately depend upon the defences to be made by the judicious and proper depoſition of rough quarry rubble; it appeared to him a folly, firſt to deſtroy the firm upper cruſt of gravel that he reported verbally on his trial thereof to be comparatively hard, like the pavement of Hexham ſtreets, and then, at a great expenſe, ſubſtitute ſomething not ſo much to be depended on, and this ſtill want defending by quarry rubble, which in every caſe could be applied: and he muſt here beg leave to remark, that a quarry, ſituated moſt commodiouſly to this ſituation of the bridge in the eſtate of Mr. Errington, offered the greateſt plenty of this kind of material, and of the moſt excellent quality for the purpoſe that he has any where had the experience of.

From the whole of the premiſes he concluded, that the ſafeſt way would be to preſerve the upper cruſt of the bed of gravel inviolably unbroken even by a pile; and particularly in the main channel of the river, where the diminution of the hardneſs of the upper cruſt principally to him appeared; ſo that, concluding to build the two land-breaſts upon piles, with caſting, and alſo the two pillars next thereto, in the ſame method, with coffer dams to drain out the water (he having found that within that compaſs the bed of gravel appeared equally hard and compact) the method that naturally offered itſelf was to found the reſt of the piers by caiſſon; a method the moſt eaſy and ready, and attended with the leaſt coſt of any. So that having before abundantly experienced that good quarry rubble would reſiſt the action of a current to a greater degree than any kind of gravel, it appeared that the pillars ſo ſunk, being defended from accidental flood till they could be ſurrounded by a ſlope of rubble (which the depth of the water naturally admitted in this place) hence would ariſe every degree of ſecurity that the nature of the ſubject would admit of.

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He concluded therefore to build a bridge of nine arches inſtead of ſeven, that it might have more legs to ſtand upon, in conſequence of the natural weakneſs of the ſtratum; and by way of ſecurity to the piers, before they could be properly and ſufficiently ſurrounded by way of the propoſed ſlope of rubble, as well as after, in caſe of any derangement to the rubble defence, a girdle of ſtones in blocks of a ton weight and upwards, was propoſed to be let down, and ſurround the baſe of each pier, to be fitted to each other, and to the pier they ſurrounded, and to be cramped together.

Upon this idea of conſtruction Mr. Smeaton formed his original eſtimate; and which, from the ſimple mode of it, could be executed for a very moderate ſum of money, in proportion to the largeneſs of the river and extent of the work; and which, in conſequence, was bargained for by Mr. Errington, and the work proceeded with accordingly.

The north land-breaſt and the adjoining pier were ſucceſsfully built upon piles encaſed as propoſed; and the gravel being there very ſufficiently compact (ſo as to afford only a moderate quantity of water) Mr. Smeaton determined to try to go on as far as he could upon that principle, and therefore ordered the ſecond pier from the north abutment to be tried with a coffer dam, to encavate and found like the firſt; but when the pit was ſunk but two feet under the level of the water outſide, and not much more than half as much under the natural bed of the river, the water boiled up between the interſtices of the gravel ſtones, bringing ſand along with it, that it required forty men continually at the pumps to keep it down; and it was not without the utmoſt difficulty that the pier was founded on that principle at that depth.

The ſouth abutment and contiguous pillar were alſo ſucceſsfully founded, according to the original intentions; but at the ſecond pier from the ſouth, the water being much deeper (being in the main channel, and the gravel bottom clean waſhed, like the ſecond from the north) Mr. Smeaton judged it in vain to attempt any more pillars by coffer dams, becauſe it would be an uſeleſs expenſe to conſtruct a coffer dam without the leaſt probability of maſtering the water.

Early in the ſummer of 1778, the remaining five pillars were begun to be executed by caiſſons, and Mr. Smeaton attended the execution of the firſt that was laid, which was the fourth pier from the north ſide of the center arch; and which was done with ſo much expedition, eaſe, and convenience, that the ſeaſon and weather turning out remarkable fine, the whole body of agents and workmen preſſed forward to get as many

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