of them done as poſſible while that favourable ſeaſon laſted; but a number of blocks for the girdle courſe not immediately ariſing out of the quarries of a ſufficient ſize for the purpoſe, about the latter end of July four out of the five caiſſon piers were grounded upon the bottom of the river, and brought above water, when only one of them had any of the girdle ſtones brought and depoſited, and this only in part around it; beginning from the weſtern or up ſtream ſalient point, and extending from thence about half way round the pier on each ſide: in this ſtate of things, after a remarkably dry ſeaſon of ſome months, there came a violent rapid flood, not indeed a very high one, but the river being previouſly empty of water, and the rain which occaſioned it falling very ſuddenly, it came down (being alſo urged by a violent wind at weſt) with uncommon rapidity; the conſequence of which was, that the four caiſſon piers, totally unguarded except as above-mentioned, were all underwaſhed at the weſt end, to the depth of about 15 inches at a medium, at the borders, and ſome to a greater breadth and ſome leſs; but the pier that had the half girdle courſe round the weſt point having been found to ſuffer along with the reſt, though not in ſo great a degree, this induced Mr. Smeaton to think of a mode of defence not merely terminating upon the upper cruſt of the gravel as the girdle ſtones (which this event ſhewed was not ſufficient to reſiſt the increaſed velocity of the current, when paſſing by a new object), but inſtead of the girdle ſtones, to go ſome depth into the gravel; which it appeared practicable to do, by driving a caſing of plank piles to ſurround every caiſſon pier at the diſtance of three feet, which would alſo enable him ſafely to underpin the parts underwaſhed.

To this propoſition (though attended with an addition of expenſe unthought of before, of between five and ſix hundred pounds) Mr. Donkin very readily conſented on the part of Mr. Errington. This was therefore immediately put in hand before further proceedings were gone upon.

Hitherto I have been particular, as it ſeemed abſolutely neceſſary to give an adequate idea of the natural difficulties attending this work, and what a very ſmall portion of them were known before it was originally enterpriſed by Mr. Gott; how gradually they unfolded themſelves in conſequence of the ſteps that from time to time had been taken; and how very far all were from being aware of the whole, when the work was begun by Mr. Errington under the direction of Mr. Smeaton. Suffice it therefore to ſay, that the caſing of the damaged piers, and the underſetting of three of them, was proceeded upon with the greateſt alacrity, and completed that ſeaſon; nor did any other adverſe accident happen to the completion of the bridge.

It

It may be proper to mention that when the firſt caſing was completed, which was about the fifth pier from the north ſide, Mr. Smeaton ordered a trial to be made to pump out the water, which, if practicable, would have afforded the moſt eaſy way of underſetting the under-waſhed parts; but this being attempted, Mr. Pickernell reported, that with four double pumps and two ſingle ones they had not been able to ſink the ſurface of the water within the caſe above an inch below the ſurface on the outſide. In this method, however, the coffer-dam caſes uſed at Perth Bridge were driven ſo as to keep the water out of the foundation pits, when the ſurface of the river (when the tide was in) was from ſix to ſeven feet deep upon the bed of the river, and conſequently againſt the ſides of the caſing, it would therefore have ſeemed that there had been ſome very palpable defect in driving theſe caſes, had not the operations at the ſecond pier from the north ſide ſufficiently ſhewn how extremely open the bed of gravel is to the paſſage of water, and how impracticable every method was likely to prove that depended upon the drainage of the water, for the piers to be placed in the main channel of the river.

Several very rapid and much larger floods than that which did the miſchief happened in the courſe of the ſucceeding winter, particularly one upon the 12th of December, when the water was within nine inches of the top of the inpoſt; when Mr. Pickernell marked a fall of two feet three inches, but without any material damage to any thing, which naturally induced all thoſe concerned to proceed in the way they were then going on.

The ſeaſon of 1779 was begun by new founding the weſtern half of the pier, that the weather prevented from being completed the year before, which was the fifth from the north, and was done without caiſſon or draining the water, by means of an air cheſt or diving machine, that had been very ſucceſsfully and conveniently employed in underſetting the other five damaged piers; and the pier before unbegun (being the ſixth from the north) was the next in courſe founded by caiſſon; but with this difference, that the caſe was firſt drove all except the down ſtream ſalient pointing, before the caiſſon was floated into its place through this opening.

It would cauſe too great a prolixity to deſcribe the particular operations of what followed the diſaſter of Auguſt 1778; nor can they be done without reference to figures; I ſhall therefore proceed to ſay that in the beginning of the year 1779, and alſo afterwards while the arches were throwing, the whole of the caſes were guarded all round by a depoſition of rubble; and to render it the more effectual againſt the torrents that this river then appeared ſubject to, the up ſtream points of the rubble bulwarks were extended to the length of 30 feet above the ſalient point of the caſes reſpectively.

That

That the underſetting of the three piers ſo treated, was done ſo as to be as ſolid and effectual as the gravel ſtratum which the whole ſtood upon, as alſo the new founding of half of the fifth pier, and the original founding of the ſixth, which was the laſt founded; and that the whole ſtood upon one bottom equally capable of ſupporting the weight of the ſuperſtructure built upon it, appears from this, that in the whole of the maſonry, from the time of the accident in 1778 to the time of its total overthrow in the year 1782, there never appeared the leaſt crack or ſet in any part of the work, not even in the parapets, which to thoſe who are well experienced in bridge-building, will appear a remarkable inſtance of the ſoundneſs of the work; and furthermore, that the whole was ſufficiently guarded againſt every accident that could be foreſeen or expected appears from this; that in the year 1779 a remarkably rapid flood happened: which Mr. Pickernell obſerved, from marks upon the bridge, above and below, ſhewed a fall of three feet nine inches, occaſioning a velocity of above 900 feet per minute, which not only paſſed without any material derangement; but, on the contrary, ſuch changes as had been made in the bed of the river had been for the better, as it had acquired a more equal depth from ſide to ſide; the ſhallow parts becoming deeper, and even the deeper parts, by the depoſiting of gravel, had become ſhallower, and every flood that happened after, occaſioned reports of the ſame kind till the laſt. In this manner, and with theſe ideas, every thing was ſatisfactorily finiſhed, and the rubbling completed, according to Mr. Smeaton's directions, at or about Chriſtmas 1780; and in the beginning of January 1781, Mr. Smeaton viewed the whole, in the preſence of the magiſtrates of the county, who attended for that purpoſe, and found every thing done to his great ſatisfaction as well as theirs; and as ſuch reported it to the county, as being completed according to Mr. Errington's agreement.

After all ſucceeding floods, every account was of the moſt flattering kind; ſo that previouſly to the laſt flood, every perſon concerned therein or therewith ſeemed perfectly eaſy as to the ſecurity of Hexham Bridge.

On Sunday evening the 10th of March 1782, there happened in that country a great downfall of ſnow, ſo great as to be a foot thick upon the plain ground; which was immediately ſucceeded by a violent hurricane: and as the nature of ſnow is to drink up the rain like a ſponge, till it becomes perfectly ſaturated with water, it then burſts at once like a ſnow-ball in the fire, and may be fitly compared to an immenſe reſervoir, extending over the whole country, and breaking looſe altogether; and as the hills, and whole face of this country, are ſteep, comparatively like the roof of a houſe, the water is capable of coming down very ſuddenly; it then meets altogether, by the junction of the two Tynes, a little above Hexham, without having any conſiderable flat ground to ſpread itſelf upon. The next morning, viz.

viz. Monday, March 11th, Mr. Donkin perceiving an extraordinary high flood in the river (which runs from weſt to eaſt) attended with a very high weſterly wind, he was led to go down to the bridge, to obſerve the effects of the water upon it; but without thel eaſt ſuppoſition of any damage happening thereto; when he obſerved, that the water was up to the top of the dooming (as there called), that is, the tops of the caps of the ſalient points upon the piers of the up ſtream ſide of the bridge, when it ſcarcely touched the down ſtream ſide, which makes a difference in level in paſſing the bridge of no leſs than between four and five feet, and which, according to the known rules of hydraulicks, will occaſion a velocity of one thouſand feet in a minute; but yet he was ſo far from apprehending any danger to the bridge, that he had juſt ſent his ſon over it, to the ſouth end, with two or three maſons, to examine the ſtate of the land-arches there, who reported all ſafe, but they had not returned above five minutes, before he began to obſerve ſymptoms of failure, when to his great ſurprize, " he perceived ſome particles of lime fall from the fourth arch, about " the ſize of chaff, and the lime coming from thence and no where elſe, he pointed his " obſervations to that part only. That the falling of the lime continued to encreaſe in " ſize and quantity, for the ſpace of a minute; that ſoon after he obſerved a crack acroſs " the bend of the arch towards the upper ſide of the bridge, which crack gradually " widened, and in about a minute more, the ſplinters from the ſtones in the plain part of " the ſpandrel, between the third and fourth arch, which he could perceive ſhake, gave " way, and the two arches and a pier fell together; that the whole bridge was deſtroyed " in half an hour," only two arches remaining whole, and one fell in part in the evening. Such was the ſudden cataſtrophe of this much commended unfortunate bridge.

The ſecond queſtion is, Whether Mr. Errington was ſparing of any thing neceſſary to give ſucceſs to that mode of building, which Mr. Smeaton had adopted?

To this Mr. Smeaton can only bear his teſtimony, that he was not; nor did he ever hear him find fault with any expenſe, thought neceſſary by Mr. Smeaton; on the contrary, he always expreſſed his wiſhes to have the bridge completed in the moſt ſubſtantial and effectual manner. Nor did he ever appear diſquieted by the diſaſter of 1778, or at the expenſe of what Mr. Smeaton had propoſed as a neceſſary addition, though at ſo conſiderable an increaſe as five or ſix hundred pounds, as has been already ſtated.

Thirdly, reſpecting Mr. Pickernell, whether he did to the beſt of his power and knowledge, execute to a reaſonable and poſſible extent, what was directed by Mr. Smeaton? And to this Mr. Smeaton thinks it but juſt to ſay as a witneſs, that he always looked on Mr. Pickernell throughout the whole proceeding, as a perſon particularly attentive to execute

execute orders and directions given by him, and upon whoſe capacity for that purpoſe, he could ſafely rely, after having ſhewn him the mode of going about any new operation, and upon whoſe reports of theſe operations, he could alſo ſafely rely; and as the general workmanſhip of the bridge has been applauded by many, and diſcommended by none, it ſeems there is only one point in which Mr. Pickernell's execution of Mr. Smeaton's orders can be called in queſtion, and that is reſpecting the driving down of the caſes of piles, round the caiſſon piers, to a proper depth; it is therefore neceſſary to ſtate this matter particularly.

Mr. Smeaton's written inſtructions were as follow; "The length of the piles ſhould "conform to the depth of the water; I would not wiſh the ſheeting piles round the weſt "end, and the firſt bay of the return on each ſide, to go into the ground more than "about ten feet, and if they do not drive kindly, muſt be contented with leſs; from "thence, each bay may be gradually leſs depth into the ground, ſo that round the down "ſtream pointing ſeven feet will be ſufficient. If the gage piles drive kindly, they may "be longer by eighteen inches or two feet than the ſheeting, but if not, they need not "be above one foot longer."

To the above, in the courſe of the work, Mr. Pickernell reported, that having driven the piles of the fifth pier from the north, which was the firſt to which the caſing was applied, the gage piles went down very well and entered two or three inches at a ſtroke, but when he came to drive the plank piles, they could not be got into the ground more than from five to ſeven feet.

He further reported in the courſe of this buſineſs, in regard to the ſheet piling of the ſeventh pier from the north (or ſecond from the ſouth ſide) which was the laſt caſing driven of the four damaged piers; that the bed of the river at the ſouth ſide, is entirely full of large flat ſtones, ſuch as they got out of Oakwood bank quarry, which have been the ruins of the boats' landings, taken away by floods and ice from time to time, and thoſe ſtones had obſtructed their ſheet piling round that foundation, and had occaſioned many of them to go out of their places at bottom, ſo that ſundry cavities were occaſioned thereby, more than in the laſt.

Theſe were the repreſentations of Mr. Pickernell, concerning his execution of Mr. Smeaton's orders, reſpecting the piling; ſo that if they were driven to a leſs depth, or in any manner leſs effectual than as above repreſented, Mr. Pickernell muſt anſwer to it, as Mr. Smeaton was totally unacquainted therewith, nor was any inſufficiency in this part of the

the work ever ſuggeſted to him by any perſon whatſoever during the courſe of the work, or ſince, till he heard of an oppoſition to Mr. Errington's bill for relief from his obligation.

But whether in reality Mr. Pickernell did this part of the work equal to the above repreſentation of it or not, that the ſtanding or falling of the bridge may not be wholly left to reſt at Mr. Pickernell's door, Mr. Smeaton, in juſtice to Mr. Pickernell as well as himſelf, thinks it neceſſary to declare, that for the reaſons already aſſigned, (as well as the verification thereof during the courſe of the work, by every flood that happened) ſo great and abſolute was his dependence upon the application of Oakwood bank quarry rubble, as an ultimate defence to controul the violence of the Tyne's floods (no part of it laid round the coffer dam foundations, having ever been moved); that provided the piles of the caſings were but driven into the ground, ſo far as to fix faſt therein, and ſo cloſe together, that though the caſes might not hold water, they might retain the gravel from being waſhed out through the chinks from under the piers; he had not the leaſt doubt of preventing any material damage ever being done to the pile work, by the application of the ſaid rubble to ſurround them. This ſentiment, however, though it dictated that part of his inſtructions, " get the bays of ſheet-piling at the weſt end of the piers down to " ten feet if you can, if you cannot, we muſt be contented with leſs;" and alſo made Mr. Smeaton contented with what was above reported to him, as the moſt imperfect part of the performance; yet he never communicated this opinion to Mr. Pickernell, or any other perſon; leſt the workmen from hearing thereof, might be induced to ſatisfy themſelves with doing leſs than otherwiſe they might be capable of, in the way of getting them down as far as they could.

Whether Mr. Smeaton's opinion, concerning the ſecurity of Oakwood bank quarry rubble, was well or ill-founded, will be further examined in the ſequel; but this is certain, that the driving of the caſes not being completed before the middle of September, and being then very deſirous to take advantage of the ſecurity they afforded, to get the piers underſet, if poſſible, or otherwiſe ſecured before the heavy winter floods came on, he concluded, that if the experience of theſe floods ſhould ſhew a need of greater ſtrength and defence, it might be added in the courſe of the next ſeaſon.

This autumn of 1778, in reality, afforded the experience of a conſiderable number of floods, amongſt which, the laſt, which was of December 12, was a capital one, and the higheſt that had been ſince the great inundation of 1771; and the water on the weſt or up ſtream ſide of the bridge, was within nine inches of the top of the impoſt of the ſecond

pier

pier from the north, when at the eaſt end it was one foot three inches below it, ſo that the fall was then no leſs than two feet three inches, and which would produce a velocity of above ſeven hundred feet per minute.

After the water was ſubſided ſo as to afford a full examination, Mr. Pickernell reported the effect; viz. that there were but very few of the rubble ſtones removed from where they were thrown in round the foundation; what were moved, were from the weſt ſhoulders; but that from the third pier to the north, round which no ſtones had been depoſited, it had torn up the gravel from the ſalient point and weſt ſhoulders, to the depth of three feet; and that from thence to the ſtones that were laid round the ſecond pier, it had deepened the bed of the river full eighteen inches, (which before was too ſhallow); but as to all the other part of the river's bed, he could not perceive it altered in the leaſt.

The experience therefore of theſe floods, and particularly that of the 12th December, all concurred in proving, that the Oakwood bank quarry rubble was a ſufficient defence againſt every violence of the Tyne: ſo that it did not appear neceſſary to introduce any new mode of defence, but only to apply the rubble in the moſt effectual manner; and as the weſt ſhoulders appeared to be the parts that the greateſt ſtreſs came upon, Mr. Smeaton ordered that the water might not meet with ſo ſudden an oppoſition there, but be more evenly, ſlopingly, and gradually brought thereupon, that the weſt ſalient points of the rubble ſhould be extended weſtward of the ſalient points of the caſes reſpectively, to the length of at leaſt thirty feet; which was accordingly executed by Mr. Pickernell upon all the caiſſon piers.

4thly, We come now to the fourth and laſt queſtion, viz. Whether under all the experience and knowledge of the ſubject as it now ſtands, the preſent bridge ſhould be attempted to be reinſtated, or a new one built at Hexham?

This queſtion is indeed of far the moſt material import; for it is of little conſequence to the public, in the preſent ſtate of things, whether Mr. Smeaton misjudged of the ſubject? Whether he was deceived himſelf, or was deceived by others? Or, whether Mr. Pickernell did or did not do his beſt, towards a full execution of Mr. Smeaton's orders, in regard to the driving the caſing piles? Nor is it of any conſequence to know, that in point of art, but without any regard to, or limitation of expenſe, a bridge is poſſible to be built: the true queſtion is, Is it fitting for the county to undertake it? Suppoſing the Treaſurer in poſſeſſion of whatever ſum can be recovered from Mr. Errington, in conſequence of his obligation, will it not (like Sir Walter Blackett's three thouſand pounds)

pounds) be a temptation to the county to ſpend ſtill much larger ſums upon an unfruitful project; and it may reaſonably be ſuppoſed, that the whole county ſtock is not an unlimited ſum; nor can it be properly expended in the erection of a bridge at one ſingle paſſage.

It is now known for a certainty, what was not, and could not have been known before the erection of this bridge, that there is a poſſibility of natural cauſes being ſo combined, as to produce a flood ſo large, and of ſo ſudden a nature, as to produce a velocity of the water exceeding one thouſand feet in a minute; and whether even this may, or may not, be the uttermoſt limit of Nature, is not in the power of any man to calculate:—

That the velocity of ſeven hundred and twenty feet per minute, ariſing from a difference of two feet three inches, as per flood of December 1778, was ſufficient to tear up and remove the natural bed of gravel, which forms the bed of the river in this place, wherever there was a particular ſet upon it, but was not cabable of moving or materially deranging the defences compoſed of Oakwood quarry rubble.

That the velocity of nine hundred and thirty feet, reſulting from a difference of three feet nine inches, in a flood of the 1ſt of December 1779, ſtill made not the leaſt alteration in the defences, nor to any part of the bed of the river, ſave that the rubble ſtones depoſited at the third pier where the current had torn up the natural gravel in the flood of December 1778, were now wrecked full and covered with gravel, and reduced to the level of the adjacent parts. Another flood ſucceeded this in the compaſs of ten days, that roſe within eight inches as high as the former, but in this nothing happened of any kind; in ſhort, the bridge being now erected, as far as it was concerned with the water, all the arches cleared, and the defences completed, after a conſiderable number of great floods, and nothing happening in conſequence, every one ſeemed ſo entirely ſatisfied of the ſtability of the bridge, that even the Gilligate people, Mr. Pickernell obſerved, ceaſed their viſits, who before had conſtantly, after every flood, come to inſpect, in hopes of finding ſomething correſpondent to their prayers and wiſhes for the downfall of the bridge.

Mr. Smeaton was, however, agreeably ſurpriſed on having this account, that the fall of water had been ſo great, and no harm enſued; for had it been poſſible for him to be appriſed of ſuch a fall before hand, he never ſhould have recommended to Mr. Errington to have undertaken to erect a bridge upon that bed of gravel.

It

It therefore at this time appears plain, that though the Oakwood bank rubble will lie ſtill, and reſiſt a velocityof the water of nine hundred and thirty feet in a minute,yet it is capable of being all removed and carried away by the velocity of the water of, or a little exceeding, one thouſand feet per minute; a velocity reſulting from a difference of forty-four, as it was or upwards in the flood of March 1782; and that the gravel bed itſelf is capable of being torn up by a much leſs degree of velocity; the queſtion then is, How in ſuch ſituation a foundation can be laid and effectually ſecured?

Shall we attempt to build a wall acroſs the bottom of the river, according to Mr. Wooler's propoſition? Experience has ſhewn in the building of the laſt bridge, that the gravel is of ſo open a nature in the main channel of the river, that it is impracticable to drain off the water. Mr. Smeaton means not to put limits to the invention and ingenuity of men; but neither his obſervation, experience, nor invention, has hitherto ſuggeſted any effectual method of founding ſuch a wall, without draining off the water; and the ſame will apply to the penning the bottom acroſs the river.

But for a moment, ſuppoſe the thing done: this wall or this apron, muſt have a termination; and wherever it terminates, experience ſhews, a rapid current will form a deep hole, to twenty, or even thirty feet depth, and upwards; and if the gravel under the foundation gets looſe, the downfall of the whole is the conſequence.

2dly, Suppoſe we attempt to build it in an excavation upon piles encaſed, as was done at Perth, the ſame difficulty ariſes; we cannot get out the water; and if done, as rubble will not lie to defend it, the gravel bed being ſcooped out, beyond all practibility of driving piles, the piers being ſapped, the ſame unfortunate circumſtance muſt enſue.

3dly, Suppoſe we attempt it by excavation with ballaſt lighters, and drive down piles even with the bottom of the excavation pits, to found the piers upon; which may doubtleſs be done, without taking off, or drainage of the water; ſtill, if neither the bed of gravel itſelf, nor quarry rubble, is capable of reſiſting the violence of the current, when the gravel bed is deſtroyed or deranged, ſo that the piles are laid bare, the pillars will be ſapped, and deſtruction equally enſue: nay, even ſuppoſe the piles could be encaſed without taking off the water, yet this is only giving the river a little more work to do; for if rubble is carried away, as we find it muſt be, it is no defence; and we do not know the depth to which the gravel can be ſcooped out and excavated by the violence of this river; the

the foundations therefore, however deep, can be ultimately ſapped, and the ſame ruin enſue.

In ſhort, turn ourſelves which way we will, nothing ſeems certain in this buſineſs, but a very great expenſe, how commenſurate with the county's funds, muſt be left to thoſe to judge of who know them: but this Mr. Smeaton will take upon himſelf to ſay, that he ſees no way of making foundations for a bridge to ſtand upon, for the whole ſum in which Mr. Errington ſtands obligated to the county, that is likely to be attended with any certainty of permanency, much leſs alſo to build a bridge upon thoſe foundations, for the ſame ſum.