

tee of 1843 there is also much information on this head. To these reports, therefore, we would wish to refer for sufficient information on the subject.

Civ. Eng. & Arch. Jour.

(To be continued.)

On the Application of Gunpowder as an Instrument of Engineering Operations, exemplified by its use in Blasting Marl Rocks in the River Severn. By GEORGE EDWARDS.

[Read at the Institute of Civil Engineers.]

Many plans have been proposed at different times for the improvement of the Severn. It is sufficient, however, for the present purpose to state, that in 1842 an Act was obtained, under the advice of Mr. W. Cubitt, V. P. Inst. C. E., for the improvement of 43 miles of its length, from Stourport to Gloucester; over which distance, in many places, there was not two feet depth of water during the summer season. The object of the proposed works is to increase this depth to six feet of navigable water during all seasons. Above Worcester, the additional depth is obtained partly by dredging, but chiefly by a series of four weirs, varying between 300 and 400 feet in length, with side locks for the traffic. Between Worcester and Gloucester, (a distance of 29 miles,) it is proposed to obtain the required depth, partly by contracting the channel by embankments of fascines, and partly by dredging. Messrs. Grissell and Peto having undertaken the entire completion of the works, from Stourport to Gloucester, the superintendence of the dredging operations was entrusted to the author. The shoals to be removed by dredging are generally isolated, varying from 100 yards to half a mile in length, and they require excavating to a depth of from three to five feet. A large proportion of these shoals consists of alluvial gravel, without flints, but principally of quartzose and granitic pebbles, varieties of porphyry and of compact and granular sandstone. This material, although very hard in some places, offered no engineering difficulties. Other shoals consist of denuded beds of hard red marl; this material being found in every instance when the river impinges upon the eastern or western limits of its valley. In most places it was so hard as to render its removal by the dredging machine quite impracticable; and it is the object of the present communication to describe the method of blasting, or breaking up, this material, with gunpowder, so as to render it capable of being dredged up with facility.

That part of the river Severn, above described, traverses nearly north and south the great plain of red marl of the new red sandstone formation, the bed of the river, from Stourport to about a mile below Holt bridge, near Ombersley, being formed through the upper strata of the new red sandstone; upon this lies the great bed of red marl, (in places saliferous,) dipping at a small angle, but irregularly, to the south-east. The river traverses the whole of this strata, which is

probably more than 1000 feet in thickness, passing through the upper strata, and entering the lias formation above Gloucester.

The red marl is generally considered by geologists to be formed from the debris of older rocks, and it appears to be totally devoid of organic remains. It lies generally in beds, rarely exceeding 15 inches in depth, and often much less. It is divided occasionally by strata of greenish grey marl, and near the upper part of the formation by thin, but very hard, beds of shaly, or imperfect lias.

It is difficult to describe the comparative hardness of materials, but when it is stated, that in many places it was impossible to cause a steel chisel-pointed boring tool to enter it by any ordinary exertion, by hand, from a boat, it will be conceived that it could not be readily raised by dredging. After exposure to the action of the air, it breaks up into small fragments, almost like the slaking of lime, so that solid blocks, which could only be broken, by the application of considerable force, into sharp-edged fragments, would, in the course of a few days, fall to pieces, and afford no criterion of its hardness in an undisturbed state.

When the dredging machine was tried upon one of these marl shoals, it was found impossible to raise above 50 or 60 tons per day, and that with constant risk and repeated accidents to the machine; but such rate of progress was totally incompatible with the required progress of the work. Attempts were first made to break it up by driving iron bars into it, and prizing it up, but this plan did not answer. A second attempt was made to loosen it with a very strong plough, something like a "subsoil" plough, which was proposed to be pulled through the marl by a powerful crab fixed on a barge, the plough being guided by a strong pole; the effect produced was, however, so superficial, and the expense of labor was so great, that this method was also abandoned, and experiments were made to ascertain the effect and probable cost of using gunpowder. These were so satisfactory, that it was determined to blast all the marl shoals, previous to dredging them. In January, 1845, as soon as the requisite materials and establishment could be prepared, this operation was commenced, and has since been carried on with no other interruptions than those occasioned by freshes in the river; the total length of blasting required (about a mile and a half) being now nearly completed, and a considerable portion of the marl since dredged up, at the rate of 200 or 300 tons per day, with perfect facility.

The most economical method of using powder, to break up a depth of rock like that described, would probably be to obtain a face of the required depth at one end of the work, to put in a row of shots at the back of it, and after each discharge to remove the loosened marl; continually repeating the process; but this method would have been open to many serious objections. The dredging machine and the blasting gang would have been constantly waiting for each other, and, having but two dredging machines to perform the work, it was of great importance to economise their time in every possible way. By such proceedings, also, a constant obstruction to the navigation would have been created, equal to the whole width of the new channel. The num-

ber of men that could have been employed in blasting would also have been very limited. These objections, in this particular instance, far outbalanced any little saving of gunpowder. It was therefore determined to put in perpendicular shots, throughout the site of the channel, at such distances as experience might prove to be best, and proceedings were commenced with spaces of six feet from centre to centre of the shot holes.

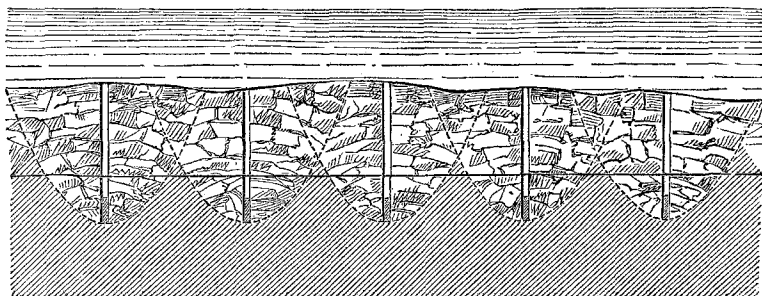
Six rafts were used, as stages to work from: they were each formed of four baulks of timber, about 40 feet long; the baulks, placed in pairs, were secured, at a distance of four feet apart, by cross pieces, six inches square, well spiked to the baulks at intervals of six feet; these were covered with deals three inches thick, laid lengthways of the raft, a space of 12 inches in width being left open along the centre. The ends of the rafts were provided with strong ring bolts to moor by. These rafts were confined to one bank of the river by ropes, and retained at the required distance from it, by a series of "sets," or booms, abutting against the bank. At the up-stream end of the raft, was a large barge fitted up as a blacksmith's shop, for the necessary repair of the tools,—with dwellings for the watchman, the ganger, &c. The bows of the barge were strongly fortified, and a strong oblique boom of large baulks reached from it to the shore, so as to protect the whole fleet from the craft coming down the river. At the down-stream end was another barge, fitted up as a powder magazine and as a shop, furnished with every necessary for the manufacture of the cartridges, and for the storing of their material. The words "powder magazine," in large letters, were painted on both sides of this vessel.

The first operation consisted in placing and securing, in their proper positions, the pipes through which the holes were to be bored. Small stakes, painted with a series of numbers, were first driven into the bank, parallel to the work, at distances of six feet apart; as far behind them as the slope would allow, was another row of stakes parallel with the first, so that a line drawn through two stakes would be at right angles with the river, and a person standing behind the two stakes could readily direct the workmen when to lower the charge-pipe, which was then secured in its place, in the opening of the raft, by a "timber-dog," driven into the raft on each side of it. The pipes were of wrought iron, drawn for the purpose by Messrs. James Russell and Sons, of Wednesbury: they were three and a half inches in diameter, three-sixteenths of an inch thick, and nine feet long.* Two collars, half inch square, were shrunk on them near the upper end, for the purpose of retaining a rope, by which they were secured when the charge was fired. When the depth of the water increased, these pipes could be lengthened four feet by an additional piece prepared for that purpose; this joint was made by shrinking on a collar, six inches long, over the joint. The pipe being in its place, was driven through any gravel that might remain and a few inches into the marl.

* Where the marl was so deep as to require three, or more, pounds of powder, it was found that the cartridges of such diameter as could be used in these small bores were so long as to lose part of the effect of the gunpowder; subsequently, pipes of 4 inches diameter were used with advantage.

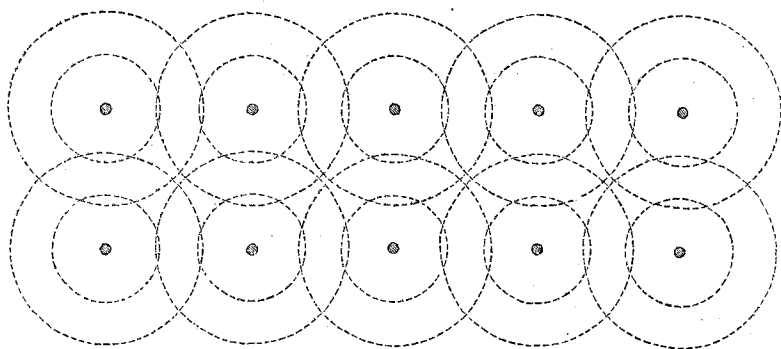
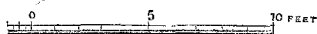
The gravel was generally so thick upon the marl, that it was requisite first to remove it, by means of the dredging machine. To protect the thin edges of the pipes whilst being driven, a cast iron cap, or plug, was used, which received the blows from a heavy wooden beetle; the interior of the pipes was next cleared of any sand, or gravel, that might have entered while putting them down. The principal tool used for this purpose was an iron bucket, or cylindrical tube, two feet in length, of as large a diameter as would pass down the hole; it was furnished, at the bottom, with a valve opening inwards, and was jointed to a round rod, of the requisite length, half an inch in diameter, and, when used with a pumping motion, quickly brought up whatever could not enter at the valve.

Fig. 1.



Horizontal line shows depth of dredging

Fig. 2.



The boring then commenced; a gang of three men being stationed at each pipe. The first operation was that of the jumper, which was made with a single steel edge, a little rounded. The jumpers were of round iron, one and one-eighth inch in diameter, except two feet in length at the lower end, which was one and a half inch in diameter. For general use, they were 15 feet long, and weighed about 52 lbs. each; after working them till they were nearly set fast, an auger was inserted to raise the plug of loosened marl, and to render the hole true.

The shell of the auger was 20 inches long, and nearly closed up, the better to retain the loosened borings.

The shot holes were bored two feet below the proposed bottom of the dredging, as it was supposed that each shot would dislocate, or break into small pieces, a mass of marl of a conical or parabolic form, of which the bore hole would be the centre, and its bottom the apex, so that four adjoining shots would leave between them a pyramidal piece of marl, where the powder would have produced little or no effect. By carrying the shot holes lower than the bottom of the intended dredging, the apex only of this pyramid was left to be removed, and in practice this was found to form but a small impediment. (figs. 1 and 2.) A second reason was, that, if the removal of the shoals should cause the level of the summer water to fall lower than was expected, the marl might still be found sufficiently broken, to enable a greater depth to be obtained without further blasting.

The cartridges, or charges, were formed of strong duck or canvas bags, somewhat tapered at the bottom; these were filled with the required charge of powder, varying from two pounds to four pounds, according to the depth of the marl;* the end of a coil of Bickford's patent fuse was inserted to the centre of the powder, and the neck of the bag was carefully gathered up round the fuse, and well tied with small twine. If the cartridge was small, it was then dipped into melted pitch, which had about one-fourth of tallow melted with it, or otherwise the melted pitch was ladled over it, till it was uniformly coated; in this state, the cartridges were hung to drain and stiffen. When hard, they were well rubbed over with tallow, and lastly powdered over with dry whiting. The tallow, whilst it insured the stopping of any little cracks in the pitch, facilitated the passage of the cartridge down the hole; the whiting also prevented the pitch from adhering to anything. It has already been stated, that the powder was ignited by means of Bickford's patent fuse; but as this material is never made in lengths exceeding 48 feet, it was found expedient, in order to save waste, to use the whole coil, cutting it off at the requisite length when absolutely in the hole, and using the remainder in the same way, till the whole was used.†

The charge was carefully pushed down into the hole by a wooden ramrod of suitable diameter, with the end rounded; the same instrument was used for ramming down the tamping. The material found to answer best for this purpose was the small fragments of hard marl, separated by the action of the weather from the lofty escarpment at each of these shoals; this was gradually filled into the holes, and rammed solidly, till the bore was full up to the surface; the timber dogs which held the pipes were then removed, the pipes were loosened

* The weights of powder used for depths of four feet, four feet six inches, and five feet, were, respectively, about two pounds, three pounds, and four pounds.

† The short remaining ends, though useful for less depths, were of little value, from the difficulty of splicing them together. This operation, though troublesome, was resorted to with success on one occasion whilst waiting the arrival of a parcel of fuse. On returning the short ends to Messrs. Bickford they allowed half the length of new fuse in exchange.

from the marl, ropes were attached to the pipes and to the raft, or to some loose pieces of timber, and the shots were fired. Generally there was little external effect beyond the pipes being lifted a few inches, though sometimes they would be blown up several feet, and occasionally the water would be forced up through the pipe to a height of 40 or 50 feet. All the gangs commenced their holes in the morning, and they were generally all ready to fire at the same time, which was always done, as it caused least interruption to the work.

It was a rare occurrence for a shot to miss fire—probably not once in a hundred shots; the failure arising generally from a leak at the joint between the fuse and the bag. If the leak was not very serious, the shots were often saved by the following somewhat singular expedient. An iron bar, $\frac{3}{8}$ inch in diameter and of sufficient length, pointed at the end, was kept in readiness, and when required the end was heated red hot, put quickly through the water into the tamping, through which it was driven as rapidly as possible into the powder, which in nine cases out of ten it was still hot enough to ignite.

The result of the whole work being invisible, great care was necessary in order to prevent mistakes and omissions. As each shot was ignited, a red mark was laid against its corresponding stake upon the bank; when it had gone off, each shot was carefully examined with a steel chisel-pointed searcher, to prove that the required effect had been produced to the determined depth; when so found, the red mark was inserted into the top of the stake, as a certificate of that shot having passed examination; the numbers so certified were then transferred to a book kept for the purpose, and if a shot was found ineffective, another was put in the same place.

To afford space for the workmen, every alternate hole was first made, and afterwards those which had been left between them; one line being completed, the whole line of raft was moved 6 feet outwards to the next line, and so on till the required width was obtained. The whole establishment was then dropped down the length of the rafts, and the process was repeated. When the men had become used to the work, each gang would sometimes get down four shots per day, so that with fifteen gangs sixty shots have been fired per day.

It may be objected to the use of the patent fuse, that the ignition of a number of charges simultaneously by the galvanic battery would have produced better effect, at less cost, and in a more scientific manner. The author commenced the work under a different impression, and subsequent experience with the battery has not altered his opinion. When it is required to separate a large stone from its bed in the quarry without breaking it, nothing can be better than the numerous simultaneous discharges, which can only be obtained by the use of the battery, but the object in this work, on the contrary, was to break the mass to pieces as much as possible, which it is conceived would be more likely to be effected by distinct discharges.

Then as regards cost: the patent fuse No. 3, carriage included, cost $\frac{6}{10}$ ths of a penny per foot; if the average length is taken at 15 feet, that is just nine-pence per shot, a sum which would barely pay for making the arrangement of wires necessary for the galvanic igui-

tion. It was also found, from the compressible nature of the canvas cartridges, that the arrangement of the wires was very liable to be disturbed, during the insertion of the cartridge into the hole, or by the subsequent ramming of the tamping. After considerable experience, therefore, and the use of nearly 100,000 feet of the patent fuse, the author feels that he is only doing an act of justice to the Messrs. Bickford, in stating the perfect satisfaction which the use of their ingeniously manufactured material has afforded him, in the prosecution of the work now described.

There now only remains to be given the cost of the operation above described. The first cost of the establishment or plant, sufficient for 6 months' work, was £300. This includes the waste and use of timber, in the raft, stages, booms, &c., hire of barges, and cost of fitting them up for the work, cost of pipes for boring, iron and steel for tools, deducting estimated value when done with, sundry ironmongery, waste and loss of ropes and other small stores.

More than four thousand shots have already been fired, and in the six months, at a low computation, six thousand will have been fired. This number gives just one shilling per shot, as the proportionate share per shot of the cost of the plant; this would of course be much less if the work was to be continued.

The cost of labor per shot varies from 2s. 6d. to 4s.; this sum, however, must be understood to cover the wages of the whole establishment as under: Superintendent of the work—Foreman and time-keeper—Examiner of the shots—Maker of cartridge and two assistants—Carpenter—Blacksmith and Hammer-man—Laborers, some at 3s., majority at 2s. 6d. and 2s. 9d.—Watchman.—Thus the total cost per shot is as under:—

Use of material, 1s.; labor, average, 3s. 3d.; pitched bag, 3d.; 3 lbs. of powder, at 5½d., 1s. 4½d.; 15 feet of patent fuse, 9d.; pitch, tallow, twine, coals, &c., say, 4½d.; making, together, 7s.

If, therefore, the shots are 6 feet apart, and an average depth of 3 feet is broken up, 4 cubic yards are prepared for dredging at the cost of one shot; or the cost of the whole operation is 1s. 9d. per cubic yard. Distances of 5 feet apart were used in some very hard shoals, and spaces of 7 feet were tried in some that were softer than usual; spaces of 6 feet apart, however, appeared to be generally sufficient.

Civ. Eng. & Arch. Journal.

The Manufacture of Ruby Colored Glass.

[The following conclusion of an article on the art of glass painting, published in Beckman's History of Inventions, is copied from the London Mechanics' Magazine. The reader will find much on the manufacture of glass, both white and colored, in the previous volumes of the Journal of the Franklin Institute, particularly the 9th, 10th, 11th, and 12th volumes of the present series.

COM. PUB.]

I shall now conclude these observations by a few notices respecting glass tinged by fusion with gold, which, though never brought into general use among glass painters, has, I know, been employed in one