from the centre of the blade to the axle or shaft. In new vessels it might be reduced, as there would be no necessity, as now, to place the shaft so high above the water. Instead of the edges of ten or twelve foot planks brought slap down upon it, the pointed ends of the proposed blades would silently enter it. Whenever a machine is on a wrong basis, minor movements are brought in to uphold it that increase the wear and tear and consumption of force. On a true one, the principal and adjuncts are in union and the work done with a minimum of power. As in the present case, any objection brought against it tends, when examined, to confirm it; thus, it has been intimated that the velocity of the present wheels might be too great for blades of the proposed dip. Supposing, but not admitting, some truth in this, the speed of a steamer no more depends on the rapidity with which her blades strike the water than that of a bird on its wings striking the air. She may double her revolutions and go slower. With fewer steps, the lad on stilts outstrips his associates on the ground, but turn to true exemplars, and the rule will be found to hold that lengthened blades with *diminished velocity* increases speed. Thus the laborious flutter of the partridge is exchanged for the easy and silent sweep of the eagle and hawk. Our steamers, with their clattering buckets and tremor, resemble the former instead of the latter. But marine propulsion is in its infancy, and the science of natural forms has not left the cradle.

E.

New York, December, 1865.

Experiments on the Strength of Cement, Chiefly in reference to the Portland Cement used in the Southern Main Drainage Works.

By JOHN GRANT, M. Inst. C. E.

From the London Civil Engineer and Architect's Journal, January, 1866.

This communication related to an extensive series of experiments, the results of which were recorded in voluminous tables forming an appendix to the paper, carried on during the last seven years, with a view to insure, as far as possible, that only cement and other materials of the best quality should be employed in the Southern Main Drainage Works of which the author had charge as resident engineer.

As a preliminary step, samples of Portland cement were obtained from all the principal manufacturers for the purpose of experiment. The average weight of these samples were found to be 108.6 lbs. per bushel, and they sustained breaking or tensile strains at the end of a month, varying from 75 lbs. to 719 lbs. upon $2\frac{1}{4}$ square inches. A clause was then inserted in the specifications to the effect that the Portland cement to be used in the works should be of the very best quality and ground extremely fine, weighing not less than 110 lbs. to the struck bushel, and capable of resisting a breaking weight of 400 lbs. upon an area $1\frac{1}{2}$ inch square, equal to $2\frac{1}{4}$ square inches, seven days after being made, and after being immersed in water for the whole of that time. The standard was subsequently raised to 500 lbs. on the same sectional area, which was that used throughout the experiments. During the last six years 70,000 tons of Portland cement had been used in these

works, which extended over a length of 18 miles and had cost £1,250,000. This quantity of cement had been submitted to about 15,000 tests, at a cost of only five farthings per ton. The machine devised for showing the tensile strain was a lever balance constructed by Mr. P. Adie, (Assoc. Inst. C. E.,) and its first cost was from £40 to £50. It was so simple that an ordinary workman could be trusted to test the cement, and the cost for labor did not exceed £80 per annum for each machine.

The manufacture of Portland cement required extreme care in the admixture of its two simple and well known ingredients, clay and chalk, it being necessary to vary the proportions according to the quality of the chalk; thus, in white chalk districts, the clay formed from 25 to 30 per cent., and in grey chalk districts from 16 to 20 per cent. of the whole bulk. The manufacture was carried on almost exclusively on the banks of the rivers Thames and Medway; the clay, which should be as free from sand as possible, being obtained from the creeks and bays between Sheerness and Chatham. Long experience now enabled the clerks of works and others to detect the qualities of the cements by color and by weight. Very strong Portland cement was heavy, of a blue grey color, and set slowly; in fact, the longer it was in setting the greater was its strength. Quick-setting cement had generally too large a proportion of clay in its composition, was brown in color, and turned out weak, if not useless. In the first schedule of prices 2s. 3d. per bushel was inserted; but this was far above its present market value.

But the tests were not alone sufficient. It was essential that constant supervision should be exercised to insure that only clean and sharp sand should be mixed with the cement; that the cement was only supplied with sufficient water to reduce it to a state of paste, which was best accomplished by means of a perforated nozzle at the end of a pipe or watering can; that the bricks or stones were thoroughly saturated with water, so that in setting the cement might not be robbed by absorption of the moisture necessary for its perfect hardening; and that a current of water was prevented from passing over the cement, or through the joints during the progress of setting, as this would wash away the soluble silicates.

The results, as a rule, were the average of 10 tests, the samples being immersed under water from the time of setting to the time of testing. The tables showed that, during the last six years, 1,369,210 bushels of Portland cement had been submitted to 11,587 tests, and that the cement was found to be of the average weight of 114.5 lbs. per bushel, and to possess an average tensile strength of 608.6 lbs. upon $2\frac{1}{2}$ square inches, being $51\frac{1}{2}$ and 21 per cent in excess of the two specified standards. It was also ascertained that, provided Portland cement kept free from moisture, it did not, like Roman cement, lose its strength by being kept in casks or sacks, but rather improved by age—a great advantage in the case of cement which had to be exported. Experiments, conducted over periods varying from one week to twelve months, with Portland cement weighing 112 lbs. to the imperial bushel,

gauged neat, and mixed with varying proportions of different kinds of sand, showed that neat cement was stronger than any admixture of it with sand; that mixed with an equal quantity of sand, (as had been the case throughout the Southern Main Drainage Works,) the cement might be said to be, at the end of a year, approximately three-fourths of the strength of neat cement; that with two, three, four, and five parts of sand to one of cement, the strength was respectively one-half, one-third, one-fourth, and about one-sixth that of neat cement. Other experiments show that at the end of twelve months, neat cement kept under water in a quiescent state was about one-third stronger than that which was out of water, both indoors and exposed out of doors to the action of the weather; that blocks of brickwork or concrete, made with Portland cement, if kept under water until required for use, would be much stronger than if allowed to remain dry; and that sea-water was as good for mixing with Portland cement as fresh water. Bricks of neat Portland cement, after being made three, six, and nine months, withstood a crushing force of sixty-five, ninety-two, and one hundred and two tons respectively, or equal to the best quality of Staffordshire blue bricks; and bricks of cement mixed with four and five parts of sand, bore a pressure equal to the best picked stock bricks; while Portland stone of similar size bore on its bed a crushing weight of 47 tons, and against its bed somewhat less, and Bramley Fall stone sustained on its bed 93½ tons, and against its bed 54½ tons. Portland cement concrete, made in the proportions of one of cement to six or eight of ballast, had been extensively used for the foundations of the river wall and the piers of the reservoirs at Crossness, as well as for the foundations generally both there and at Deptford, with the most perfect success. It was thought that it might be still more advantageously used as a substitute for brickwork or masonry, wherever skilled labor, stone, or bricks were scarce, and foundations had to be made with the least expenditure of time and money. Whenever concrete was used under water, care must be taken that the water was still, as a current, whether natural or caused by pumping, would carry away the cement and leave only clean ballast. Roman cement, though about two-thirds of the cost of Portland, was only about one-third its strength, and was, therefore, double the cost when measured by strength. It was besides very ill-adapted for being mixed with sand.

In conclusion, the author, whilst recommending Portland cement as the best article of the kind that could be used by the engineer or architect, warned every one who was not prepared to take the trouble, or incur the trifling expense of testing, not to use it, as, if manufactured with improper proportions of its constituents, chalk and clay, or improperly burnt, it might do more mischief than the poorest lime. Further experiments were desirable, on the strength of adhesion between bricks and cement, under varying circumstances; on the limit to the increase of strength with age; on the relative strength of concrete made with various proportions of cement and ballast; and on the use of cement in very hot climates, where probably extra care would be required in preserving the cement from damp, and keeping

it cool until the process of setting had been completed. On these and other important points, the author trusted that all who had the opportunity would record their observations and present them to the Institution.

Proc. Inst. Civ. Eng., Dec. 12, 1865.

On the Adhesion of Locomotive Engines and Certain Expedients for Increasing or Supplementing that Function. By VAUGHAN PEN-
DRED, C. E.

From the London Mechanics' Magazine, November, 1865.

(Concluded from page 91.)

Returning to the inside cylinders, we find that the piston rods are provided with cross-heads running in guides, although these last are hardly required, each piston driving two connecting rods. The piston rod of the leading cylinder is exactly over the mid-rail, and, of course, opposite to that of the after cylinders. Thus, neither of the cylinders is in line with the shafts they have to drive. But the two connecting rods from the forward cylinders proceed right and left to the two horizontal cranks on the forward vertical shafts and put them in motion precisely on the well-known system used by Cartwright, in Watt's time. The connecting rods from the after cylinder, however, do not take the crank pins of the actual trailing wheels, but instead they are forked and jointed on to the side coupling rods. The result is rather a singular motion, not very easy, perhaps, to trace out through all its stages and speeds, but giving in effect a result equivalent to that which would be produced if the cylinders worked on cranks at right angles to each other, and thus dead points are eliminated. Each of the vertical shafts is supported in two boxes, and these boxes are made to approach each other in order to regulate the amount of grip on the rails in the following manner: Across the engine, between the leading and trailing vertical shafts, runs an endless screw carrying outside the frame a worm wheel, into which a vertical screw gear, by causing the screw to revolve by means of a hand wheel, the transverse screw can also be put in motion. The brasses of the vertical shafts are carried in cast iron boxes provided with grooves, which slide on suitable ribs placed across the engine. Exactly over the mid-rail are located two horizontal worm wheels, gearing with the transverse screw before mentioned. These wheels turn on axles fixed in the frame. To each is keyed a pair of eccentrics or cams projecting in opposite directions. These rotate within a pair of boxes, one for each eccentric, and these boxes are connected by rods with the lower boxes of the vertical wheels, strong helical springs being interposed in such a way as to produce an elastic strain on the grip wheels. In order to make the wheels compress the rail, the transverse screw is caused to revolve, thus putting the large worm wheels in motion, and with them the eccentrics, which, in time, cause the low boxes to approach each other across the engine in pairs, and this motion is communicated