Extract from a Paper on the Concrete used in the late Extension of the London Docks. Read before the Royal Scottish Society of Arts. By GEORGE ROBERTSON, C. E., F. R. S. E.

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The gravel found on the works was not always so free from clay as could be wished. It had often to be screened, to reduce the quantity of sand to the proportions necessary to form a good mortar with the lime used. Concrete is really minute rubble work of pebbles set in mortar, more or less perfect according to the care taken in mixing the ingredients. In theoretically perfect concrete, the mortar should be made, *first*, to insure a perfect matrix for the pebbles to be embedded in; but this is not the usual practice in this country. The great mass of the concrete was composed of one measure of lias lime to six measures of gravel, both being measured by boxes, and not by guess-work. Sometimes, however, a layer of gravel was spread out a foot thick, and then lime laid over it for a depth of two inches. This is not so good a way of measuring as by boxes, because the lime falls between the pebbles, and the concrete is richer in lime than the engineer intends, which is no advantage to the work, and is, of course, a loss to the contractor. When the ballast was moderately dry, 12 cubic yards of gravel and 2 cubic yards of lime made 11 cubic yards of concrete, mixed and deposited. The shrinkage of the dry materials was then 22 per cent.; but if the ballast happened to be very dry, the shrinkage was more, and the same quantities made only 10 cubic yards.

A cubic yard of concrete requires about 38 gallons of water to bring the dry materials to the requisite state of fluidity. Of this quantity nearly 8 gallons enter into chemical combination with the oxide of calcium in the lias, and 30 gallons are either absorbed mechanically by the pores of the lime, retained by capillary attraction between the grains of sand, or lost by evaporation. After the concrete has been mixed and deposited, a gradual expansion takes place from the chemical action of the lime slaking; the less of this swelling, however, the better, as it disturbs the setting of the mortar round the pebbles, and causes friability in concrete. Whenever concrete is made with quick-lime (as it usually is) there must be a certain amount of friability from this cause; and, therefore, when it is important to have no swelling, as in blocks of concrete which have to be lifted, recourse must be had to slaked lime, or else to cement, which contracts rather than expands in setting. In the one case the concrete is long in hardening, having more moisture in it than the lime can absorb; and in the use of cement more expense is incurred. Portland cement is, however, not so expensive as might at first appear from the cement being double the price of lime, because the proportion to the ballast may be considerably reduced.

Some experiments on the expansion of concrete proved to me that it varies a little with the season of the year. In hot summer weather the expansion of a cubic foot in twenty-four hours after mixing was as much as $\frac{1}{3}\frac{1}{2}$ th of its bulk, usually $\frac{1}{3}\frac{1}{2}$ d; but in frosty weather it rarely

exceeded $\frac{1}{8}$ th. The force exerted in the expansion was always sufficient to burst the box in which the concrete had been deposited; the amount might even be measured by the distance the nails were drawn out. Whenever the expansion exceeded $\frac{1}{10}$ th of the bulk, I considered the concrete too rich in lime, and that there was more than would, when slaked, fill up the interstices of the sand and flints, and coat each grain with a thin pellicle of lime. More than this is not required, for too thick a coating of lime causes weakness, and not strength.

The gravel and lime were mixed together on a platform of planks, and were turned over twice in the dry state, and twice with water gradually added. The concrete was then wheeled in barrows, and shot into the required place from planks a few feet above. The idea that concrete should be thrown in from a great height is erroneous, for it then falls with too great force, and disturbs the setting of the mass below, causing unnecessary friability. This was particularly noticeable in the deep pits for the counterforts of the north wall of the basin, where the concrete had unavoidably to be thrown from a height of 30 feet. The force of the blow set the whole mass in motion for some feet down, even after setting had fairly commenced. Lias concrete sets slowly, and in this case it was impossible to wait long enough for each layer to become perfectly hard before depositing another, as the wall had to be built with the utmost expedition, as will be seen hereafter. Anything gained in density by a fall of more than 6 feet is more than counterbalanced by the disturbances to the mass below. The grand rule in concrete is, not to disturb it after setting has once commenced. Wherever it is necessary to shovel it into corners, or pack it between stones, it should be done at once, and the concrete not touched again. The swelling of the lime during slaking causes enough natural friability, without increasing it by after-disturbance.

By arrangement in the contract with Messrs. W. Cubitt & Co., the contractors for the greater portion of the permanent work, ground lias lime was sold to them for 10*d.* per bushel; and at this price the cost of making a cubic yard of concrete was as follows.—

	s.	d.
3½ bushels of lime, at 10 <i>d.</i> ,	3	1½
Loading, waste, and bags for ditto,	0	3
Getting gravel,	0	6
Wheeling do. (say 5 runs),	0	4
Screening and selecting ditto,	0	3
Mixing and depositing,	1	1
Platforms,	0	1½
Total cost per cubic yard equal	5	8

As the quantity of gravel fit for concrete was uncertain before the ground was opened up, for the sake of simplicity the whole excavation had been estimated as barged away; and for each cubic yard of gravel used as concrete, a certain deduction was made in the monthly payments.

The supply of water for mixing the concrete was obtained from pipes laid down to the various parts of the works, either from the street

mains or from the launder of the pumping engine. In mixing large quantities the expense of laying pipes is soon saved.

The Application—Concrete was applied on the works of the London Dock extension in several ways:—1, In foundations for masonry or brickwork, as a means of spreading the weight over a large surface; 2, As the cheapest method of reaching a good foundation in the clay or gravel, whether for walls or piers of warehouses, &c.; 3, In the dock walls themselves, wherever the concrete would not be exposed to the alternate action of wind and water; 4, As counterforts or buttresses, on which nothing was to be afterwards built, but where weight was wanted.

In all these cases it is to be noticed that it was applied as a mass, in the monolithic form, which is the true use and value of concrete. Whenever it is moulded into separate blocks, to be afterwards set in proximity to each other, concrete becomes an inferior substitute for stone, although often an economical and useful one.

The whole of the side walls of the two locks rested upon a bed of concrete, of a thickness varying very much with the level of the clay, from 3 feet to 6 inches. The invert of the lock chambers was laid on concrete, and the spandrils of the arch filled up with it. The high chimney of the pumping-engine house stood on a square of concrete of considerable thickness, the pumping engine itself resting on beech piling. As this chimney was very close both to the pumping well (18 feet in diameter) and to the excavation for the lower dock, there was some risk of unequal settlement. A plumb-bob was therefore left suspended in the chimney, which at once would give warning of any inclination either way. Some time after the chimney was built the plumb-bob showed that the shaft had inclined several inches towards the excavation. A quantity of limestone was at once stacked round the base of the chimney on the opposite side, which brought the shaft back to the perpendicular.

Concrete was used as the cheapest means of reaching the clay, in the foundations for the lattice swing-bridges over the locks; the bridge pits resting on arches, the piers of which were of concrete up to a certain height. Columns of concrete were built up likewise in the proper places, upon which cranes and capstans might be placed when required. The whole of the walls and iron columns of the new warehouse rested on trenches of concrete about 8 ft. wide, and averaging perhaps 8 ft. in thickness, from the top of the natural gravel to the level of 17 feet below high water. As the concrete here was not to be exposed to the direct action of water, it was made of Dorking or grey stone lime, in the proportion of 1 of ground lime to 8 of ballast. This lime carries more sand than lias; is but feebly hydraulic, and, indeed, not permanently so at all. It is the lime used in London for building purposes, and by some engineers even in dock work when mixed with pozzuolana.

By far the largest quantity of the gravel found in the excavation was used up in the construction of the walls of the basin, in which everything below the level of 17 feet from high water was of concrete,

faced with 2 feet of Kentish rag-stone, to protect the surface from the disintegrating effects of water. At this low level there was no fear of vessels rubbing against the rough faces of the rag-stone. The general type of the basin walls was much the same as that of the West India Junction Dock walls, where Mr. Rendel used concrete of 1 part of Portland cement to 9 parts of gravel.

The concrete portion of the basin walls was 17 ft. 6 ins. broad at the bottom, and 11 ft. 6 ins. at the top, the face being curved at first to a radius of 11 ft., and then carried up with a batter to the bottom of the brickwork, which was perpendicular. Whenever concrete is faced with rag-stone, it should be built with a batter, and the layers slightly inclining away from the face. All danger of the wall bulging out, or of the face-work peeling off, is then avoided. The Kentish rag-stone facing was hammer-dressed on the joints for a specified distance in, and care was taken to have at intervals long wedge-shaped stones, with the broad end inwards, tailing well into the concrete, which was carefully packed between the joints when first deposited. About two feet high of face-work was first set, and then the concrete deposited in two layers of about one foot thick each. The first layer was allowed to harden for at least 24 hours before the second was deposited, and they were always arranged so as to break joint. A layer of concrete does not thoroughly incorporate with a previous one unless the meeting surfaces be kept rough, and free from sand. But, by sweeping off all sand, and, if necessary, picking the face in furrows, and by breaking joint with the layers, all danger is avoided of either a vertical or horizontal run of water through a mass of concrete. The brickwork of the upper half of the wall, with its counterforts, was not laid on landings, as in the lock walls, but was for three feet set in superior mortar, with hoop-iron bond every three or four courses.

Steel-Surfaced Rails.

From the London Mining Journal, No. 1371.

We learn that the use of Mr. Dodd's steel-surfaced rails, to which we have upon several previous occasions referred, is gradually becoming more extended, through the great durability which they are found to possess rendering their application very economic. The mode adopted for steeling the rails is so simple, that there is little addition to the cost, yet so great is the effect produced upon the rail that it will last at least thrice as long as an ordinary rail, and it is estimated that the saving upon each 100 miles laid is equal to nearly £120,000. We have already mentioned several of the principal lines upon which the rails have been tried, and more recently it has been decided to employ them upon several Scotch Railways, and "after great consideration and examination of rails which have undergone Dodd's patent process for steeling the surfaces," Mr. John Fowler has ordered 1200 tons for the Metropolitan Railway. The case-hardening furnace is easily worked, and in three days the surface of the rail for the depth of $\frac{1}{8}$ -inch, can be converted into hard and durable steel.