Concreting Methods on Worcester Dam

By Ellis H. Custer

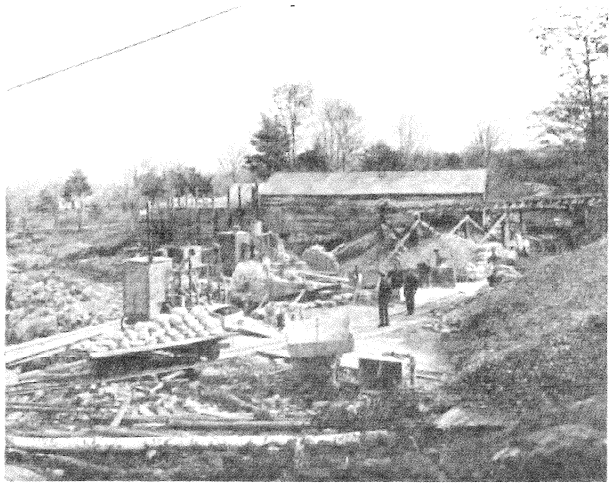
SEVERAL construction points stand out prominently in the work on the masonry dam of Cyclopean concrete, now being erected by the city of Worcester, Mass., in order to double the storage of its gravity water system. Gravity has helped extensively in the laying out and operation of a full, highly specialized and efficient plant; the ledge has been handled as tenderly as a kitten and seems successfully grouted to insure water tightness under the foundations; and manufactured sand proves highly satisfactory, giving a high-grade dense concrete. This latter is an interesting feature.

ELLIS H. CUSTER is an ideal combination of engineer and newspaper man. He knows what to tell and how to tell it. And he is right on the spot when things develop.

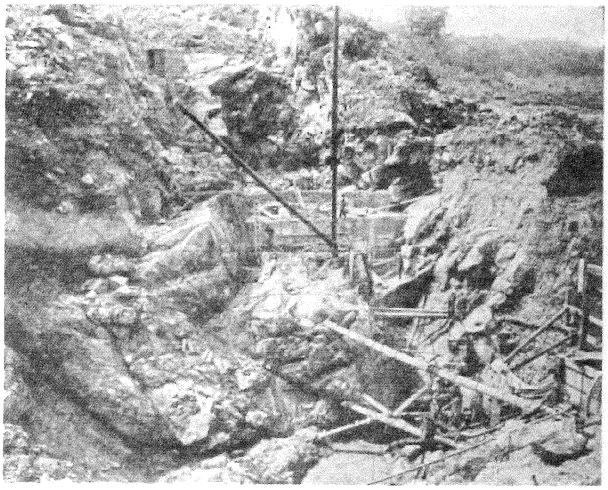
The Pine Hill dam will be 850 feet long, the masonry section of 375 feet resting on a ledge having a northerly dip. Sections on the north and south will be of earth with a masonry core wall. The longer section of earth embankment leaves the ledge and enters the earth surface on the north. The maximum height of the structure will be 120 feet above the rock, at which point the maximum thickness at the base is 80 feet, and the width at the top 17 feet. The general elevation of the dam is 920 feet. Near the center of the masonry section is an overflow, the crest of which has an elevation of 910 and the length from end to end of 83 feet. Two 4-foot piers of a three-arch bridge which spans the overflow reduce the net length to 75 feet. At the foot of the spillway will be a pool to receive the overflow and into this will discharge the 30-inch blow-off pipe controlled by a gate. The quantities for the dam are about 35,000 cubic yards of excavation, 70,000 yards of earth fill, and 50,000 yards of concrete masonry. The present estimate on the cost is $476,000 and the city will take three or four years to complete the dam by day work. The dam will be divided into ten sections, separated by transverse vertical expansion joints, and it will have an inspection gallery. The completed dam will impound 3,000,000,000 gallons of water.

On the slope of the hill at the southerly end of the dam is grouped practically the entire plant for furnishing and handling material. A cableway, steam derricks, air compressor, granite quarry, crusher, and numerous buildings, all connected by narrow-gauge railway, make the plant. A 900-foot Lidgerwood cableway was erected first, for the many services of excavation and construction. Half-way up the northerly cable derrick tower, the figures 920 show the elevation of the dam. Two Smith ½-yard mixers are poised on a platform at the top of the ledge in the southerly excavation. The narrow-gauge railway brings the supplies to this point, one Porter engine doing the shifting and another is kept in reserve. By a system of switchbacks the crusher, the quarry, the sand and cement bins, wood lot, storage sheds and carpenter and machine shops are reached. One switch makes an overhead at the east end of the mixing platform, delivering cement and sand into gravity bins beside one of the mixers. Such materials are pushed to the other mixer on a level with the platform by the dinkey locomotive. The narrow-guage railway extends a mile below the dam to Dodd Road, at Kendall reservoir dam, where the soft coal and Penn Allen cement of the present contract are received from teams which brought it three miles from the railroad. Granite is brought on narrow-guage cars by gravity from the hillside quarry to the crusher.

The sand-roll adjoins the crusher plant and is connected with its power. It receives, from a horizontal belt conveyor at the top of the towers, stone which has passed a 1-inch mesh. It delivers powdered stone the size of sand grains and pea stone in separate bins, and particles which do not pass a ⅜-inch mesh are returned automatically for a second passage through the rolls. It was decided to manufacture sand because there is no sand to be obtained within economical reach of the dam, although this is a rather unusual condition in this locality. In the concrete which has been placed in the foundations, beginning late in August, the sharpness of the fine aggregate is much remarked. It is declared to surpass sand, and is giving a dense concrete. Sand could not be bought and delivered at the cost of the manufactured supply, which is less than $1 a yard. The formula used is 1 bag of Portland cement, 3 cubic feet of sand, 1 cubic foot of pea stone and 6 cubic feet of stone. The material obtained from the sand rolls has, under test, exceeded in tensile strength standard sand employed in scientific testing materials.



Mixing Platform—Top of South End Pine Hill Dam Excavation, Worcester, Mass.



Pine Hill Dam Excavation, Worcester, Mass. Grouting Machine and Pipes in Foreground, Right. Tongue and Groove Expansion Joints, Rear.

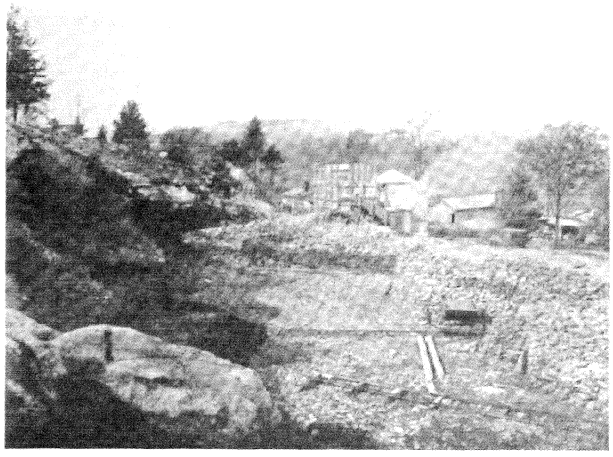
The sand-roll is a 20x14-inch balanced roll, supplied by the Sturtevant Mill Company of Boston. It is furnishing two tons of sand per hour after the coarse particles are screened out. The rock used for the purpose is a granite procured in the neighborhood.

On either side of the spur track to the engine shed are located the various shops. They bear neatly-lettered signs, "Machine Shop," "Carpenter Shop," "Oil House," etc. At the oil house, which has storage for 20 barrels, the barrels are received down a gravity skid from the narrow-guage cars. Many supplies, neatly arranged, are found in the storage lofts of the shops. Car parts are built, cars assembled and repairing done on the spot. The shops are supplied with power by Hoosier gasoline engines. The carpenter shop, fitted with Smith cut-off saw, band saws, hand-drill, etc., furnishes equipment needed for making the character of wooden forms used. Masts for the derricks, which swing by bullwheel and power cable, came from Pidgeon & Fraser, marine outfitters, Boston. The Wright Wire Company of Worcester supplied much Excelsior wire rope for fall rope and other cables.

Only employees of the city civil service list were used on the operation until the labor scarcity of the present season required a suspension of the rules. From 90 to 100 workmen are used, whereas it was expected that a force of 125 men would be maintained. Labor is paid at the rate averaging about $2.50 a day.

Excavations required for the southerly end of the dam have been completed, and the underlying ledge drilled for soundness and suitability. Ingersoll-Rand steam drills are used when the bottom is reached to test the ledge from 25 to 30 feet below the extreme depth of the excavation. Some holes were drilled over 70 feet below the bottom of the pond. Through the drill holes, water is supplied at a pressure of 60 pounds to the square inch to determine if any seams or fissures were crossed by the different drill holes. If any of the water supplied under pressure escaped, a cement grout of thin mixture was forced into the drills holes under 90 pounds pressure, and continued until the seams and fissures accepted no more. In thus caulking the ledge three lines of holes were drilled about 6 feet apart, and others where the condition of the rock indicated it was necessary. A 2-inch pipe was inserted in the drill holes, a pet cock sealed with lead, and the grout forced into the seams through a Ransome-Canniffix grouting machine. Under this treatment none of the holes took more than a barrel or so of cement.

Probably these precautions would not have been taken had it not been for an experience with leakage by ledge fissures discovered on the shore of the city's Kendall reservoir, some distance from the Kendall dam. When that ledge was treated with drilling and grouting, into one hole some eighty barrels of cement were placed, and it would still accept more. In a test there with highly-colored liquid, no trace of the color outcropping was ever found.



Quarry and Stone Crusher and San Roll Tower at Right, Pine Hill Dam, Worcester, Mass.

In general, in the excavations, even on the top of the ledge, only light blasts have been used. Down towards the bottom of the excavation the rock was loosened and taken out with picks, bars and bullpoints, without the use of powder. The bottom of the excavation is 40 feet below the bottom of the pond.

All good, hard material, as it was excavated, was brought up and stored on the side of the hill under the cableway. Many large blocks of granite were 3 to 4 cubic feet and some as much as a cubic yard in content. These are later used for plums in the Cyclopean masonry. In the storage space they are drilled and dogged. Before being lowered again into the masonry they are washed with water under pressure, to remove dirt and particles. The washing process takes place on a flanged platform, half-way down the slope, and the water used is collected on the table and drained by gravity into the basin above the dam. This water is thus kept out of the excavation, although, owing to diatomized earth found on top the granite formation and against the bank of earth which upholds the unwatering channel, there is little seepage into the excavation, and two pulsometers take care of all inflow.

All concrete is placed in ½-yard bottom-opening buckets. No chuting is done. There are two methods of lowering concrete into the excavation. One mixer discharges into a bucket resting on a car which will place it under the cable. At the other mixer the car and bucket is let down an inclined industrial track by a Dake engine and cable. The labor required to deliver concrete into the hoist bucket, ready for hoisting, is as follows: One man filling stone wheelbarrows, one man placing cement in mixer, three men placing stone by barrows in the mixer; two men placing sand and pea aggregate in the mixer; one man operating mixer. The stone crushed to size of grains of sand and pea aggregate are taken from the piles to the mixers in steel boxes which when struck off with a straightedge are measured in one portion of the formula. When pea stone is, as at times, omitted, the mixture is 1:3:6. But as pea stone is one of the products of the sand roll and crusher plant it is used as far as the capacity of the plant will go. A gravity concrete mixer, with four hoppers, is also ready for installation to speed up the concreting. Set up about half-way down the dip of the ledge, it will be supplied with materials by a car let down on the industrial track, and the batch will be removed from the bottom hopper to the place of pouring in a bucket on a car running on a continuation of the track.

In constructing the wider portions of masonry, irregular sections are laid out for benches to be filled in a continuous pouring. Lifts are made at least 30 inches, and 4 or 5 feet if possible. The walls for the sections are laid up of small stones and mortar. Within these are placed the imbedding plums and concrete. The sections are not allowed to be imposed regularly.

The expansion joints in the dam are placed about 40 feet apart longitudinally, and faced by concrete sections, forming a series of vertical tongues and grooves. The face of these joints, when the form is removed, is covered with asphalt paint to prevent bonding of the sections.

The reinforcement of the spillway arch rings is 1-inch twisted steel bars, 12 inches on centers, and the top will be reinforced with 1-inch twisted steel bars, 12 inches on centers.