PERMEABILITY OF GRAVEL CONCRETE.

THE following is a summary of tests that have been under way at the Engineering Experiment Station, University of Wisconsin. They were recently described in a paper read by Prof. M. O. Withey, before the Western Society of Engineers.

1. None of the concretes tested were absolutely watertight if we consider continuous flow into the specimen as proof of permeability, but the majority of the mixes (varying from 1 : 1 to 1 : 3 : 6) were so impervious that no visible evidence of flow appeared. For most purposes such mixes can be considered watertight.

2. The visibility of dampness on the bottom of the specimens increased with the humidity of the air and the non-homogeneity of the concrete. The minimum rate of flow for which leakage was indicated was 0.00011 gal. per sq. ft. per hr.

3. In tests of nearly all of the properly made mixes of 1 :7 proportions, or richer, the rate of flow for a 50-hr. period was less than 0.0001 gal. per sq. ft. per hr. under a pressure of 40 lb. per sq. in.

4. Through increasing the fineness of the cement a reduction in the rate of flow and a considerable increase in the strength of a 1 : 9 mix were secured.

5. By grading the sand and gravel in accordance with Fuller's curve it was possible to obtain practically watertight concrete of 1 : 9 proportions under pressures less than 40 lb. per sq. in. To secure such results, however, requires great care and careful supervision in mixing, in determining the proper consistency, in placing, and in curing the concrete.

6. In the proportioning of such materials as these, volumetric analysis coupled with a determination of the density and air voids yields very valuable information concerning the best proportions of sand and gravel for a given proportion of cement. If proportions must be selected arbitrarily a 1 : 1½ : 3 mix, by volume, is very impervious.

7. The use of the proper amount of water necessary to produce a medium or mushy consistency is one of the most important conditions in securing impervious concrete, especially when lean mixtures are used. Dry mixtures cannot be sufficiently compacted in the molds and are more difficult to cure properly than the mushy mixtures. Although the use of a wet consistency does not materially affect the imperviousness of very rich mixes, such as 1 : 1½ : 3, it greatly increases the flow through a lean mix.

8. For lean mixes made from damp sand it seems advisable to mix longer than is now common practice. These tests would indicate that for a mixer running at 30 r.p.m., a period of one and one-half to two minutes is required to secure thorough mixing of a 1 : 9 concrete. For a rich 1 : 1½ : 3 mix a one-minute period appears to be sufficient. The method of mixing in which water is first admitted to the mixer is to be condemned. A preliminary period of dry mixing lasting from 15 to 30 sec. seems desirable.

9. No stage or process in the making of impervious concrete is of more importance than curing. The results of these tests clearly demonstrate that premature drying destroys the imperviousness of 1 : 9 mixes, seriously impairs that of the 1 : 2 : 4 mixes and somewhat diminishes that of the 1 : 1½ : 3 mixes. For thin sections, not over six or eight inches thick, the curing conditions should be such that a lean concrete will be kept damp for a period of one month and a rich concrete for at least two weeks. Even after a month of proper curing, complete desiccation of a lean mix composed of these materials produces an increase in permeability, but the effect on a rich mix is not marked.

10. In these tests the imperviousness of the concrete increased rapidly with the age of the specimens for the first month; thereafter the change was not marked.

11. From the tests thus far made it seems probable that the permeability of lean concrete in a direction normal to the pouring is greater than in the direction of pouring.

USE OF CONCRETE IN WATERWORKS CONSTRUCTION.*

THE author does not pretend to advance any new theories, but rather endeavors to present in convenient form the general principles involved in the use of concrete in such structures as may be employed in connection with waterworks. There is no recognized standard test or specifications now in use for concrete. There has not as yet been developed a set of standard tests or specifications, the use of which will in cases guarantee entirely satisfactory finished work. That the cement and aggregate stand the laboratory tests is no guarantee that the workmanship will give the best of results.

Neither sharpness nor excessive cleanliness in the sand is worth seeking after if it involves much expense. Tests have shown conclusively that sand with rounded grains makes quite as strong a mortar, other things being equal, as does sand with angular grains. Comparative sand tests of cement-sand mortar should be based on compressive strength values instead of tensile strength values. The strength of all sand mortars is affected by the amount of water used over that required for normal consistencies. The more water used the greater will be the loss in strength at early periods. A fine sand takes much more water to produce a certain consistency of mortar when mixed with cement than does a coarse sand. A fine sand makes a weaker mortar than a coarse, because of the lower density. The only substitute for natural sand for concrete that need be considered is pulverized stone, either dust and fine screenings produce in crushing rock or an artificial sand made by reducing suitable rocks to powder. The danger of using stone dust is failure to secure the proper balance of large size grains. The coarseness as well as the fineness of a good concrete sand is limited. The best sands will show not more thon 40 per cent. retained on a No. 10 sieve, and not more than 5 per cent. passing a No. 80 sieve.

Upon large or important structures it pays from an economic standpoint to make very careful studies of the materials of the aggregates and their relative proportions. W. B. Fuller has shown that by changing the ordinary mixture of watertight concrete, which is about 1 :2½ :4½, and which requires 1.37 barrels of cement per cubic yard of concrete, by carefully grading the materials by methods of mechanical analyses he was able to obtain watertight work with a mixture of about 1 :3 :7, thus using 1.01 barrels of cement per cubic yard of concrete. This saving of 0.36 barrel is equivalent, with Portland cement at $1.60 a barrel, to 58 cents per cubic yard of concrete.

A better and more uniform concrete can be made with a good machine mixer than by hand. A plastic con-

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* Abstract of a paper by Edgar B. Kay before American Water Works Association.