THE EFFECT OF SATURATION ON THE STRENGTH OF CONCRETE.*

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THE paucity of recorded information concerning the treatment of concrete specimens, with regard to moisture conditions during their storage while awaiting the test for strength, seems to indicate a general supposition that this feature has no considerable effect on results. Apparently corroborating this attitude is the statement in the recent report of the Special Committee on Concrete and Reinforced Concrete, in which, while specifying the exact dimensions, mixing, consistency, age, etc., of test specimens, the only requirement designed to control moisture treatment during their curing seems to be that they shall be "stored under laboratory conditions." It is the purpose of this paper to invite attention, not only to the great importance of specifying and standardizing the moisture treatment of specimens intended for testing, but also to the further fact that similar conditions, as they act on the finished structures, will affect their strength considerably, and therefore should be considered in specifying the proper unit stresses. It is evident that this factor should not be ignored when great variations in strength, to an amount of perhaps 50% above or below a mean value, result from differences in moisture conditions.

During the last six years this question, at times, has been the subject of investigation in the Washington University Testing Laboratory. Different features have been explored experimentally since 1907. Although these tests leave the greater part of the field still untouched, the results thus far obtained are so definite in their showing of a decided influence of moisture conditions on strength, and so significant in their general indications, as to authorize a summarized statement of experimental results to the engineering profession for its consideration.

The most important part of the investigation is that of the effect, on the compressive strength of concrete, produced by varying systematically the relative length of time of exposure in air and in water.

The test specimens were cylindrical, 8 in. in diameter and 16 in. high. The materials were: a standard brand of Portland cement which fulfilled thoroughly all the requirements of the standard specifications; a clean sand of good quality, weighing about 110 lb. per cu. ft. when dry, and having 36% voids; and a washed river gravel of the same weight, varying in diameter from quite small up to 1½ in., and having 33% voids. The proportions were the usual 1:2:4, by volume; the mixing was done thoroughly by hand; and the quantity of water used was such as to give a moderately wet consistency, which allowed a thorough compacting by stirring with an iron rod and a slight tamping. All details of fabrication, curing, and testing were planned so as to secure such complete uniformity as is practicable to obtain in all regards except the one for which the controlled variation formed the particular purpose of the experimental study.

The cylinders were removed from the moulds when two days old, and were tested at an age of six weeks. The intervening 40 days constituted the period in which the duration of their immersion in water was varied systematically from nothing to the full time. The average results of the 240 tests thus made are plotted on the diagram, Fig. 1, on which the abscissas represent that number of days (after the two days in the moulds and the time of exposure to air) during which each set of specimens was placed in water before crushing them; and the ordinates give the percentage of strength which each set of immersed cylinders (standing in water for the indicated number of days) was found to have, taking the compressive strength of the dry specimens from the same mix as 100 per cent. Thus, at the extreme left is represented the basis of comparison, or those which were not immersed at all; those specimens which were cured in air of ordinary humidity for 32 days and then immersed for 8 days are shown by the black circle to be 86% as strong as the air-cured concrete; those in air for 12 days and therefore finally cured in water for 28 days have gained 9% in strength; and those submerged for the entire 40 days exhibited an average compressive strength fully 50% greater than that of the air-cured specimens.

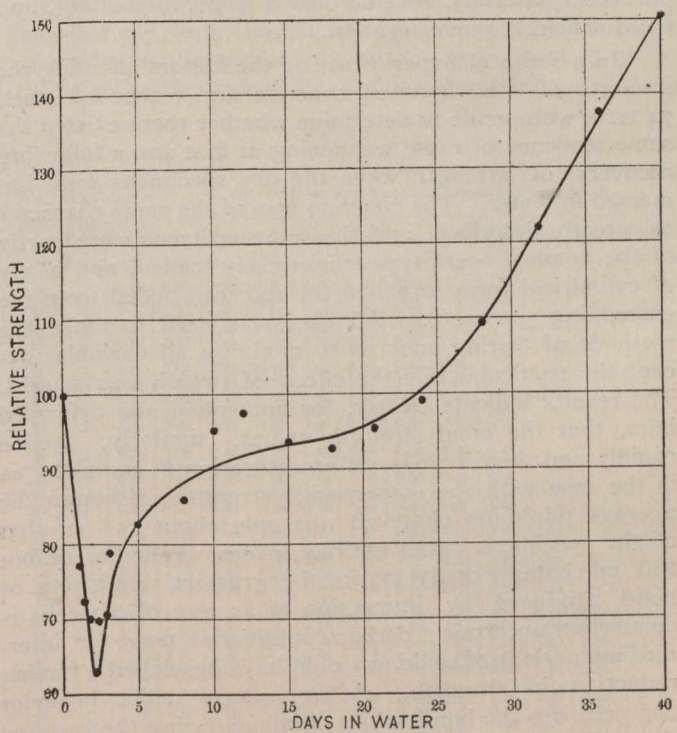

Fig. 1.

An average curve for the plotted points has been drawn as a full line, showing the systematic increase in strength as the time of submergence is lengthened beyond 2 days; but there exists the significant fact that specimens, of the dimensions used, decrease rapidly in strength when stored in air for 38 (or more) days and then placed in water for the remaining 2 days (or less). This particular feature of the rapid loss of strength on first exposure to water, and the active but slower recovery of strength as soaking continued, required a multiplication of tests to determine satisfactorily the locus of the curve in this region; and consequently more than half of the experiments were concentrated in this descending and the adjacent rising portion of the plot.

It thus appears that the compressive strength of concrete exposed only to air may be reduced nearly 40% when saturated with water, but that this loss is actively regained as the treatment is continued. The word saturation is used advisedly, because the minimum strength was found to coincide practically with the length of time required

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