EFFECT OF AGE AND CURING ON THE STRENGTH OF CONCRETE.

THE opinion is commonly expressed that the strength of concrete increases with age. It is quite true that the relation of the strength of concrete to its age is a vital consideration of the efficiency of the material. There are a number of factors, however, that have a bearing upon this relation. The rate and magnitude of the increase in strength of concrete depends primarily on (1) the nature of the ingredients, (2) proportion of cement and aggregate, (3) percentage of water, (4) thoroughness of mixing, and (5) conditions of curing.

A great deal has been said and written concerning the first four of these factors. There has been a need for information, however, concerning the relation of strength of concrete to its age for the most common curing conditions, and some results obtained by Professor M. O. Withey, of Wisconsin University, are of considerable value in this respect. These tests, as described in the Wisconsin Engineer, belong to a series of experiments lasting over twenty years and involving 450 concrete specimens. On account of the impossibility of covering all the variables effecting this particular problem, Prof. Withey decided to vary only the proportions, age and curing conditions in the tests. The test pieces were constructed in the following way:—

The volumes of cement and air-dried aggregate required for fifteen 6-in. x 18-in. cylinders were weighed. Water was proportioned by a volumetric device placed on a calibrated tank. The concrete was mixed in a No. o Smith mixer. All of the materials were mixed dry for ¾ of a minute and for 2¼ minutes after the water was added. At the end of the mixing period the entire batch was immediately dumped into three wheelbarrows. In order to collect all of the mortar from the inside of the mixer, it was allowed to drain into the last wheelbarrow for about five minutes.

Metal molds for the compression cylinders were assembled on level steel plates. Every cylinder was filled about ⅓ full of concrete from each wheelbarrow and puddled with an iron rod to expel the air bubbles. After the concrete had partially set, the tops of the specimens were roughened and capped with a thin layer of 1 : 1½ mortar.

Neat cement and mortar test pieces were made in accordance with the standard methods employed in testing cement.

After three days in the molds, the concrete specimens were marked, measured and weighed. They were then stored in a sprinkling chamber and wet twice a day for eleven days. Subsequent to this treatment the specimens were subjected to one of the following conditions:

1. Specimens were submerged in a water tank in which the temperature varied from 60° to 70° F. approximately. The water in this tank was changed frequently during the first two months and about once a month thereafter.

2. Specimens were placed end up on the ground in a cage. This cage was uncovered and had a northeast exposure so that the test pieces were subjected to atmospheric conditions prevailing in this locality. The mean temperature for the past four-year period, according to the local weather bureau, was 46.3° F., the maximum being 98 and the minimum −25° F. The mean humidity was approximately 70 per cent., with occasional departures of 25 per cent. on either side of the mean.

3. Specimens were placed end up on the ground in a cellar, the estimated range in humidity being from 50 to 75 per cent. and in temperature from 35 to 70° F. Care was taken to distribute the specimens throughout the range of testing ages so that no two specimens made in the same batch and cured under like conditions would be broken at the same age.

The neat cement and mortar test pieces were stored for one day in the moist closet and 13 days in the water bath before being subjected to the storage conditions mentioned above. The mortar specimens which were placed

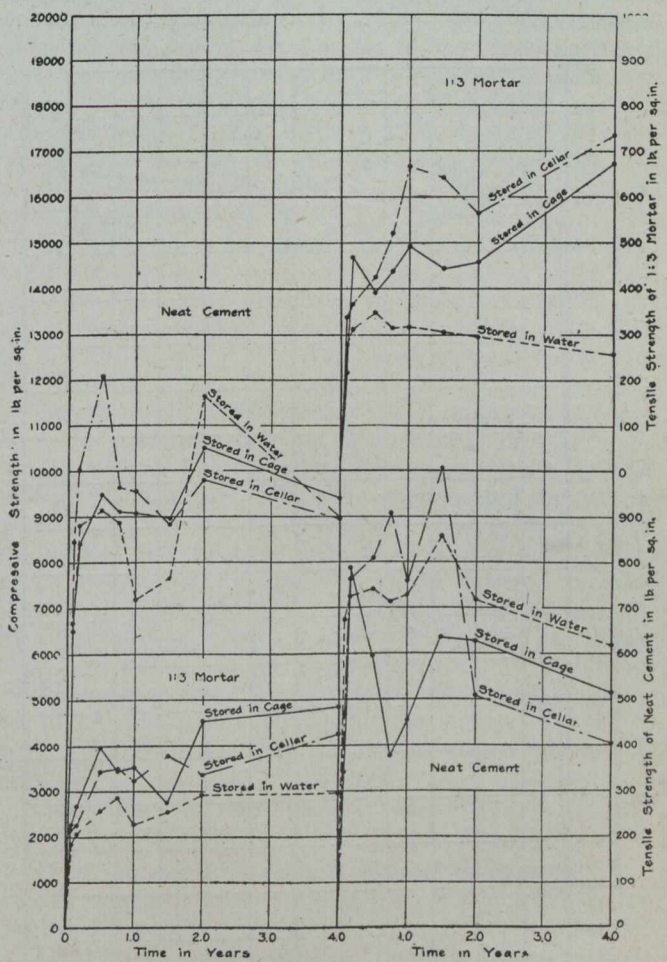

Fig. 1.—Strength-Age Curves for Neat Cement and 1 : 3 Mortars.

in the cage and in the cellar, were supported on shelves.

One week before testing the concrete, specimens were brought into the laboratory. They were again weighed on the day that they were broken. Neat cement and mortar test pieces were tested immediately upon removal from the various storage conditions. Frozen specimens were allowed to thaw before being broken.

After storage of one week in the cage, it was found that the soundness pats had left the glasses upon which they were made and had cracked. After four years they were seemingly in about the same condition. Pats stored in the cellar and in the water bath were sound at the end of the four-year period. Those which were stored in the cellar, however, had separated from the glasses. Neat briquettes and cubes which were stored in the cage were crazed, or hair-cracked, quite badly within a short time after they were subjected to that storage condition. Specimens subjected to the other storage conditions did not give evidence of these surface defects.

Figs. 1 and 3 give strength-age curves for the tests of neat cement and mortar specimens. Each point on the curve represents the average of three or four results. It