Way, from which a good view may be had of the Parliament building. The minor streets are of less width, varying with the probable future traffic, and are so laid out that for the most part the lots are regular in shape, although not always rectangular. Mr. Adams states that the total cost of the land was about \$66,000. Incidental expenses of some \$15,-000 will be incurred. Streets will be macadamized to a width of 14 to 16 ft., and it is expected that this work will be done by the city. The lots are being sold for \$340 to \$600 each, or 12.8c. per square foot on the average, with a range of from 10 to 15c. Lots fronting on Rideau Terrace, which has already been provided with partial improvements, have been sold at an added price of 75c. a front foot. Most of the trees will be preserved. An effort is being made to ensure the placing of electric and telephone wires at the rear of the dwellings, so that the streets will be kept free from poles. This will mean that the street lighting will have to be arranged by underground wiring, which can be carried out inexpensively as compared with underground wiring for electric services to the dwellings.—EDITOR.]

## **Experiments Show Effect of Fineness of Cement**

Results of Over 6,000 Tests of Concrete Cylinders, 9,000 Compression and Tension Tests of Mortar, and Several Thousand Miscellaneous Tests —Summary of Paper Presented to American Society for Testing Materials

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**R** ECENT revision of the standard specifications for portland cement served to focus the attention of engineers on the function of fineness of grinding of cement in producing concrete of high strength and other desirable properties. An investigation of this subject has been under way at Lewis Institute for the past four years. Five series of tests have been completed; another series is now under way. These studies were made as a part of the investigations of concrete and concrete materials being carried out through the cooperation of the Portland Cement Association and the Lewis Institute at the Structural Materials Research Laboratory.

The portland cements used were from seven commercial mills. These plants represent the principal cement-producing districts east of the Mississippi River. Fifty-one different samples of cement were used. The cements were ground at the mill to four to seven degrees of fineness, which gave residues ranging from 2 to 43% on the standard 200-mesh sieve. In general, the aggregate consisted of sand and pebbles; in one series blast furnace slag and a light-weight aggregate consisting of burnt shale were used.

## Nine Subjects Investigated

This paper covers compression tests on 6,125 (6 by 12in.) concrete cylinders, 9,000 compression and tension tests of mortar, and several thousand miscellaneous tests. Strength tests of concrete and mortar were made at ages of seven days to one year.

Definite information has been secured on the effect of fineness of cement under the following conditions:----

(a) Effect of fineness of cement on the strength of concrete.

(b) Quality of concrete, using different cements.

- (c) Effect of the quantity of cement used.
- (d) Effect of consistency of the concrete.

(e) Effect of size and grading of the aggregate.

(f) Variation in the type of aggregate.

- (g) Effect of age of concrete.
- (h) Elongation and contraction of concrete.

(i) Effect of fineness of cement on workability of concrete.

The following may be stated as the principal conclusions from the tests:---

1.—There is no necessary relation between the strength of concrete and the fineness of the cement if different cements are considered.

2.—In general, the strength of concrete increases with the fineness of a given lot of cement, for all mixes, consistencies, gradings of the aggregate and ages of concrete. The cements with residues lower than about 10% were inclined to give erratic results in the strength tests. One lot showed an abnormal increase and two others a pronounced decrease in strength, as compared with the other tests on coarser cements in the same lot. 3. For residues higher than 10%, the strength of concrete varies approximately inversely as the residue on the 200-mesh sieve.

4.—Fine grinding of cement is more effective in increasing the strength of lean mixtures than rich ones.

5.—Fine grinding of cement is more effective in increasing the 7-day strength of concrete than at ages of 28 days to 1 year.

6.—For the usual range of consistencies, the effect of fineness of cement is independent of the consistency of the concrete. The rate of increase in strength with fineness is lowered for very wet mixtures.

7.—Ordinary concrete mixtures at 28 days show an increase in strength of about 2% for 1% reduction in the residue of the cement on the 200-mesh sieve. At 7 days, 3 months and 1 year the corresponding increases in strength are about 2.5%, 1.7% and 1.4%.

8.—The decreased benefit of fine grinding of cement with the age of the concrete does not bear out accepted opinion that the coarser particles of cement do not hydrate, but indicates that the principal result of finer grinding is to hasten the early hardening of the concrete.

9.—For the richer mixtures and the consistency necessary for building construction, the fineness of the cement has no appreciable effect on the workability of concrete as determined by the "slump" test. For leaner mixtures and wetter consistencies, the finer cements showed a somewhat greater "slump" than the coarser cements.

10.—The normal consistency of cement is increased with fineness of grinding. About 0.1% of water (in terms of the weight of the cement) must be added for each 1% reduction in residue on the 200-mesh sieve.

11.—The time of setting of the cement is shortened with finer grinding. In some instances initial setting time with the Vicat needle was shortened to 5 to 10 minutes.

## No Effect on Density

12.—The unit weight of cement decreases with fineness. For the cements used in these tests the weight varied from 76 (residue of 2.4%) to 108 lbs. per cu. ft. (residue 43.3%). For the usual range in fineness, the weight is lowered about ¾ lb. per cu. ft. for each 1% reduction in the residue on the 200-mesh sieve.

13.—In using 94 lbs. per cu. ft. as a uniform basis for proportioning the cements in these tests, the actual volume of cement in a batch of the same mix varies about 35%. If the mixtures had been proportioned in a manner that would have given a uniform volume of cement, the resulting concrete strength would not have been so favorable to the finer cements.

14.—The fineness of cement has no appreciable effect on the yield or density of concrete.

(Concluded on page 448)