TECHNICAL INFORMATION ON BUILDING MATERIALS

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FOR USE IN THE DESIGN OF LOW-COST HOUSING

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COMMERCIAL MASONRY CEMENT INVESTIGATIONS

This is a digest of Research Paper, RP 746, "Investigation of Commercial Masonry Cements" (December 1934)[1], by Jesse S. Rogers and Raymond L. Blaine, issued by the National Bureau of Standards.

Forty-one commercial cements as well as mortars made from them were studied at the National Bureau of Standards. Cements were classified as hydrated or hydraulic lime, natural cement, portland cement with or without admixtures, mixtures of portland cement and lime, portland and natural cements, portland cement with unidentified materials, blast furnace slag with various additions, and two whose identity could not be established. About half of the cements contained water-repellent materials. The forty-one cements were used individually in four mortars: (X) 1:3 standard Ottawa sand by weight; (X-1) 1:3 mixed sand (2 parts standard Ottawa and 1 part pit run Ottawa) by weight; (Y) 1:3 mixed sand (as described in X-1) by volume; and (Z) 1 volume neat cement paste to 1.57 volumes of dry-rodded mixed sand (previously described in X-1).

Fourteen and a half minutes after water had been added to the dry mix, workability (stirring resistance) was measured. It was observed that mortars containing cement with water repellent additions generally worked more easily than those without, despite the fact that they showed a marked resistance to wetting. More water had to be added to the non-water repellent mortars to produce equal ease of working resistance values within the same range. The relation between resistance and water content of a few mortars of the "X" type was observed, demonstrating two important facts; (1) that to obtain the same resistance values for different cements in mortar "X", the water requirement

[1]Available from the Superintendent of Documents, Government Printing Office, Washington, D. C. (Price 5 cents)

varied over a wide range; (2) that the resistance values of mortars of some of the cements change more rapidly than others with equal changes in mixing water. Increased resistance was noted between mortar "X" and mortar "Y"; the latter being more resistant because of its greater proportion of sand and therefore having a lesser amount of cement-water paste, which latter furnishes the plasticizing or "work-reducing" agent in mortar. This same mortar "Y" made from graded sand and containing considerable "fines" required more water than mortar "X" containing larger sand particles.

Water retaining capacities of mortars were measured by subjecting them to a suction equivalent to that produced by a dry process brick having an absorption of about 6.5 percent in three minutes. Composition of the mortar seemed to be the dominant feature controlling this property. Natural cements, cements containing considerable hydrated lime or partially hydrated additions were high in water retention; a portland cement-hydrated lime mixture being the highest. It was not possible to say if these materials were effective only because of their extreme fineness of grind or their nature being such as to hold tenaciously large amounts of water. The least amount of water was retained by a cement largely portland; cements containing large amounts of slag and largely of portland cement lost greater percentages of mixing water than those of other classes. Cements requiring smaller amounts of water to produce workability and retaining this when on an absorbent brick usually had other good characteristics. The cements retaining no less than 0.9 and 0.85 percent of mixing water at normal flow[1] for one and three minutes of suction, respectively, retained a satisfactory workability. Water-repellent additions in cements were not effective in reducing the withdrawal of water. With but three exceptions no more water was extracted by the three minute suction than by the one minute.

Volume yields of various mortars were found to be influenced by the incorporation of air; larger yields were due to larger volumes of air in the mortar, the increase being nearly proportional to the amount of air retained. Mortars containing water-repellent cements retained the greater amount of air. The greatest amount of air contained by a non-water-repellent cement mortar was 7 percent; only two of twenty-three mortars with water-repellent cements contained less than 8 percent and only six less than 14 percent.

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[1]Normal flow determined with apparatus developed by Committee C-1, Cement, American Society for Testing Materials, for a study of a method to determine the normal consistency of portland cement pastes.

Linear change measurements, during and after hardening, were made with specimens of mortar "X" with three different proportions of water; that required for normal flow, that with 1 percent more, and that with 1 percent less. During the first twenty-four hours, shrinkage varied from .087 to .585 percent. Little difference was noted between cements with and without water-repellents at twenty-four hours; the length changes during the immediate year following being small compared to those of the first twenty-four hours. No relation could be found between linear changes and other properties of mortars, nor were there any data conclusive enough to indicate the maximum amount of changes permissible.

Compressive tests were made with all four mortars. The masonry and portland cements acted in much the same manner with increased amounts of water; such increases producing lesser strengths. Portland cement mortars and those with large proportions of portland cement gave greater strength than those with smaller proportions, and such cements as hydraulic lime, while having little strength at early ages, increased in strength with time proportionately more than most others. It is evident that a wide variety of compositions may be used and good strengths obtained. Strength was shown to increase with age in the case of all the cements. Increased strengths were also noted in mortar "X-1" (using mixed sand) as compared with mortar "X" (using standard sand). Compressive strengths varied over a wide range, the twenty-eight day strength of mortar "Y" ranging from 50 to 3,650 pounds per sq. in., and the strengths of the forty-one cements scattered between these extremes. Thirteen were below 300 pounds and twenty-two below 600 pounds per sq. in.

As in the compressive tests, cements richest in portland cement tended to give mortars with higher transverse strengths, the modulus of rupture showing an approximate relation to compressive strength, with twenty-eight day mortars varying from 25 to 590 pounds per sq. in.

The durability of the mortars when subjected to freezing and thawing tests could be predicted with reasonable accuracy in the time required for mortar specimens, each 1 x 4 x 6 in. and 28 days old, to attain 90 percent of their seventy-two hour absorption. The specimens, with one exception, requiring more than one hour to absorb 90 percent of the water that would otherwise be absorbed in seventy-two hours, were not disrupted by ten cycles of freezing and thawing. There was little difference in the destructive action of freezing and thawing on the rich mortar "X" and the leaner mortar "Y". Comparing the results of these tests with those of compressive and transverse strengths it was noted that mortars of low strength or low modulus, with one exception, showed poor resistance. Higher resistances generally resulted in mortars whose cements were rich in portland.

Water-repellent cements were, as a group, more durable than the non-water-repellent types. Mortar "X" at twenty-eight days had but three failures out of twenty-three water-repellent cements in ten freezings and thawings, whereas, thirteen non-water-repellent cements out of seventeen failed in ten freezing and thawing cycles.

The linear rise of water in the specimens also gave indication of their durability. The halves of the broken specimens previously used for transverse strength tests, were placed on end in water to a depth of one-half inch and the heights to which they became wet were measured over periods of time up to seventy-two hours. Mortars having a two inch rise in one hour or less, all failed in ten or less cycles of freezing and thawing. In fifty-nine cases, out of seventy-one, mortars showing a rise of two inches in three hours or less failed in ten cycles. The leaner mortar "Y" showed a more rapid rise than mortar "X", and with both types the rise at seven days' age was more rapid than at twenty-eight days.

Efflorescence observations were made at the end of a three months storage period showing generally that the development of efflorescence depends upon the composition of cement. Efflorescence was observed on specimens with all of the six cements containing natural cement, one of the two of unidentified composition, three of the eight of portland cement and lime, two of the six with large amounts of slag, two of the ten of portland cement and unidentified material, and one of the seven classed as largely portland cement.