

TECHNICAL INFORMATION ON BUILDING MATERIALS  
FOR USE IN THE DESIGN OF LOW-COST HOUSING

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MORTAR AND BRICK PROPERTIES AND THEIR RELATION TO BOND

This is a brief digest of Research Paper RP683, "A Study of the Properties of Mortars and Bricks and Their Relation to Bond, "(May 1934),<sup>1</sup> by L. A. Palmer and D. A. Parsons, issued by the National Bureau of Standards.

Investigations were conducted at the National Bureau of Standards with cooperation of producers of brick and masonry materials. These studies extended over a twelve month period in an effort to determine the relation between some of the properties of mortars and bricks, their tensile and transverse strength, and the durability of joints in masonry construction. The physical properties of fifty different mortar compositions were determined, fifteen of these being used with six types of bricks in specimens of masonry construction which were tested for strength and durability of bond.

Materials

Bricks: Six representative types (numbered from 1 to 6 as a means of identification) showed absorption rates in their order from high to low, and surfaces in parenthesis as follows: No. 1 very high (mechanically smooth); No. 4 high (smooth but uneven); No. 6 high (very smooth for side cut bricks); No. 2 intermediate (very rough); No. 3 low (moderately rough); and No. 5 extremely low (relatively smooth for side cut bricks, also glossy). All specimens had a tendency to expand slowly but slightly, by prolonged immersion (one month) in water; these data agreeing with previous research. Average compressive strengths varied from a low of 4830 pounds to a high of 16,025 pounds for No. 6 and 5 respectively, while transverse strengths were from 609 pounds to 2665 pounds respectively for the same bricks.

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<sup>1</sup>Available from Superintendent of Documents, Washington, D. C.  
(Price 5 cents)



Mortar: Fifty varied proportions, the ingredients of which were Potomac River sand (passing through a No. 8 sieve) and twelve masonry cements, two portland cements and four limes, these cements being representative products of manufacturers in various parts of the United States. Descriptions of these mortars--their mix, materials and water-retaining capacity--given in full in Research Paper RP683 include their proportions by volume and by weight.

### Tests and Results

Water Retention Properties of Mortars: The stiffening rate of each mortar caused by the loss of water when in contact with an absorptive brick was estimated. The mortars were mixed with water in amounts somewhat greater than normally required by the brick mason; and were then subjected to a suction test for one minute, drawing water from the mortar in a manner resembling the effect produced by contact with an absorptive brick, at which time measurements were made to determine the water retaining capacities. Of the fifty mortars tested those containing slaked lime, putty, or natural cements with metallic stearates showed highest water retaining capacities. The effect produced by partially substituting lime for cement on the water-retention property of cement-lime mortars depended upon the qualities of limes. Two of the four limes used showed marked effects by increasing in water-retaining capacity.

Shrinkage of Mortars During Early Hardening: Four hundred and fifty specimens (1" x 1" x 10") of fifty mortars at three consistencies (dry, intermediate, and wet), were measured<sup>1</sup> during the first forty-eight hours showing on an average highest shrinkages for straight lime-sand and 1PC:3L:12S mortars and lowest for straight portland-cement-sand mortars.

Volume Changes of Mortars Subsequent to Hardening: Strain-gage readings were taken<sup>1</sup> for the expansion and contraction of mortar specimens (1" x 4" x 12"). Initial readings were made when the specimens were one week old; readings thereafter over a one year period. In these tests, wetting and drying cycles were produced to roughly parallel average climatic conditions; shrinkage being greater than expansion over the course of a year with greatest shrinkage taking place during the first drying period. The cement-lime mortars rich in lime showed the least and those rich in portland cement the most changes in volume subsequent to hardening. The changes of the mortars with some of the masonry cements were greater than for the cement-lime mortars; with the rest the changes were about the same.

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<sup>1</sup>By methods described in National Bureau of Standards Research Paper RP321, "Volume Changes in Brick Masonry Materials". Available from Superintendent of Documents, Washington, D. C. (Price 30 cents).

Transverse and Compressive Strengths of Mortars: Transverse strength tests were made at the end of one year with specimens (1" x 4" x 12" dry, intermediate and wet) that had previously been used for testing volume changes. Compressive tests were made with 2" cubes.

Higher transverse and compressive strengths were associated with mortars of high cement-water ratios, portland-cement-lime mortars being highest and those richer in portland-cement than the 1PC:1L:6S mix being greatest. The average strength, either transverse or compressive, of the above mortar was equal to or greater than the strongest of the twelve masonry cement mortars and that of 1PC:2L:9S mortar which compared favorably with six of the twelve masonry cement mortars. Compressive strength of lime (dolomitic hydrated) mortar, 1L:3S(1L:10.52S) at periods of three months and one year, compared favorably with four of the masonry cement mortars.

Discussions contained in Research Paper RP683 concerning "Modulus of elasticity and extensibility" and "Sorpton"<sup>1</sup> are omitted from this digest.

Brick "suction" was determined by immersing a dry brick in water to a depth of 1/8" and measuring the amount of water (in grams)<sup>2</sup> absorbed in one minute. When this suction exceeded sixty grams, poor bonding resulted by too rapid stiffening of the mortar, the area of bonding being less than with brick which were wetted, or those of lower suction. The strongest joints resulted with all mortars when the brick suction was between ten and forty grams (approximately 0.05 to 0.2 grams per square centimeter),<sup>3</sup> the bond strength of the joints increasing with the increase in compressive strength of the mortars. However, with bricks having a suction in excess of sixty grams (approximately 0.3 grams per square centimeter), the bonded area and the ratio of strength of the joint with dry absorptive bricks to that with the same bricks set wet was greatest with mortars of medium or high water retaining capacities.

Alternate wetting and drying did not cause any appreciable weakening of bond nor was there evidence to indicate that volume changes, subsequent to hardening, destroyed or weakened the bond of specimens when their initial bond was good. The effect of properties of mortars on the durability of joints exposed to cycles of wetting, freezing, thawing, and drying was determined with bricks having a suction of twelve grams or less (less than 0.06 grams per square centimeter) or which had to be wetted to produce that suction. Most of the joints were highly resistant to this treatment, the exceptions being mortars having unusually low strengths or high sorptions.

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<sup>1</sup>Sorption refers to moisture added to a body by any or all of the three processes: absorption (physical), adsorption (physico-chemical), and hydration (chemical).

<sup>2</sup>One gram = 0.0353 ounces.

<sup>3</sup>One square centimeter = 0.155 square inches.