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No. 3

TESTS OF THE ABSORPTIVE AND PERMEABLE PROPERTIES OF PORTLAND CEMENT MORTARS AND CONCRETES

TOGETHER WITH

TESTS OF DAMP-PROOFING AND WATERPROOFING COMPOUNDS AND MATERIALS

BY

RUDOLPH J. WIG, Associate Engineer-Physicist
and
P. H. BATES, Chemist
Bureau of Standards

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PREFACE.

The investigations herein reported were made by the Technologic Branch of the United States Geological Survey at the Structural Materials Testing Laboratories, St. Louis, Mo., under the direction of Richard L. Humphrey.

When this work was transferred to the Bureau of Standards, July 1, 1910, the unpublished data were delivered to this Bureau.

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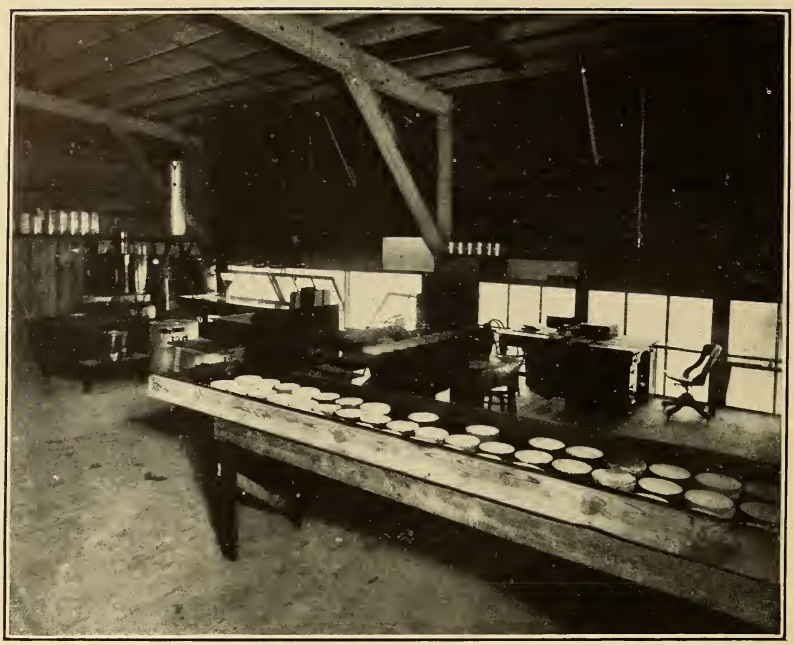

Fig. 1.—*General View of Permeability Laboratory.*

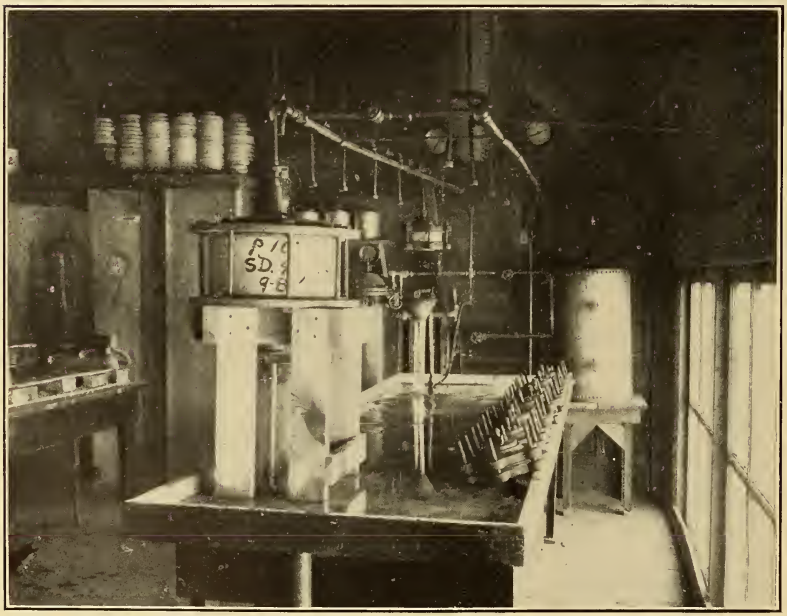

Fig. 2.—*View of Piping and Permeability Testing Apparatus.*

TESTS OF THE ABSORPTIVE AND PERMEABLE PROPERTIES OF PORTLAND CEMENT MORTARS AND CONCRETES, TOGETHER WITH TESTS OF DAMPPROOFING AND WATERPROOFING COMPOUNDS AND MATERIALS

By R. J. Wig and P. H. Bates

PART I

TESTS OF THE ABSORPTIVE AND PERMEABLE PROPERTIES OF PORTLAND CEMENT MORTARS AND CONCRETES

I. INTRODUCTION

A knowledge of the absorptive and permeable qualities of Portland cement has become imperative with its increased application, resulting from the recognition of its economy and adaptability for building and engineering construction. Intelligent and comprehensive tests for these qualities in a material so variable as concrete are difficult to execute. The constituents of concrete vary in absorptive qualities, porosity, percentage of voids, and surface qualities. These constituents may combine in numerous ways which will vary with changes in consistency, in manner of placing, in the stroke of the tamper, or the pressure of the trowel.

The investigations reported in this paper are not exhaustive. They cover some previously uninvestigated phases of this important subject and are contributory to our present meager knowledge.

The investigations are reported in two parts. Part I comprises the results of a series of tests on 11 different mortars and 23 concretes to determine their permeability at various ages, for various consistencies and thickness of test piece, and the absorption on 12 mortars at various ages and for various consistencies. Part II contains the results of a series of comparative tests of

40 compounds and several void-filling materials recommended for use or advertised as "damp-proofing" or "waterproofing" mediums, purchased privately in the open market.

All Portland cement, sand, and stone used excepting materials from the Isthmus of Panama were furnished by the following companies: Iola Portland Cement Co., Iola, Kans.; Atlas Portland Cement Co., Hannibal, Mo.; Whitehall Portland Cement Co., Cementon, Pa.; Universal Portland Cement Co., Chicago, Ill.; Edison Portland Cement Co., New Village, N. J.; Omega Portland Cement Co., Mosherville, Mich.; Old Dominion Portland Cement Co., Fordwick, Va.; Lehigh Portland Cement Co., Mitchell, Ind.; St. Louis Portland Cement Co., St. Louis, Mo.; Union Sand & Material Co., St. Louis, Mo.; American Sand & Gravel Co., Chicago, Ill.; Illinois Steel Co., Chicago, Ill.; Fruin-Bambrick Construction Co., St. Louis, Mo.

Acknowledgment is made to G. W. Riddle and C. Oliphant for their work in planning and supervising part of the first series of tests and for designing the original permeability testing apparatus and equipment. Acknowledgment is also made to R. F. Havlik for his assistance in conducting the tests.

II. PURPOSE OF TESTS

The purpose of these investigations was to determine the permeability and absorption of Portland cement mortars and concretes made with typical materials, and to determine the necessity for and the value of so-called "damp-proofing" and "waterproofing" mediums.

III. OUTLINE OF TESTS ON MORTARS AND CONCRETES

1. PERMEABILITY

Series No.	Mortar or concrete made of 1 part by volume of Portland cement to—	Consistency	Thickness of test piece in inches	Number of tests by weeks					
				1	2	4	8	13	26
1	2 parts of No. 1 sand	Quaking	1	....	....	3	3	....	2
	do	do	2	....	....	3	3	....	3
	do	do	3	....	....	3	3	....	3
	4 parts of No. 1 sand	do	1	....	....	3	3	....	3
	do	do	2	....	....	3	3	....	3
	do	do	3	....	....	3	3	....	3

I. PERMEABILITY—Continued

Series No.	Mortar or concrete made of 1 part by volume of Portland cement to—	Consistency	Thickness of test piece in inches	Number of tests by weeks					
				1	2	4	8	13	26
1	6 parts of No. 1 sand	Quaking	1	....	....	3	3	....	3
	do	do	2	....	....	3	3	....	3
	do	do	3	....	....	3	3	....	3
	8 parts of No. 1 sand	do	1	....	....	3	3	....	3
	do	do	2	....	....	3	3	....	3
	do	do	3	....	....	3	3	....	3
2	2 parts of No. 1 sand	Damp	2	3	3	3	....	....	....
	4 parts of No. 1 sand	do	2	3	3	3	....	....	....
	6 parts of No. 1 sand	do	2	3	3	3	....	....	....
3	2 parts of No. 2 sand	Quaking	2	....	....	3	3	....	3
	do	do	3	....	....	3	3	....	3
4	2 parts of No. 1 sand and 4 parts of No. 7 stone	do	2	....	....	3	3	....	3
			3	....	....	3	3	....	3
	3 parts of No. 1 sand and 6 parts of No. 7 stone	do	2	....	....	3	3	....	3
			3	....	....	3	3	....	3
	4 parts of No. 1 sand and 8 parts of No. 7 stone	do	2	....	....	3	3	....	3
			3	....	....	3	3	....	3
6	0 part of No. 4 sand and 6 parts of No. 6 stone	do	6	....	....	....	....	1	....
	½ part No. 4 sand and 5½ parts of No. 6 stone	do	6	....	....	....	....	1	....
	1 part No. 4 sand and 5 parts No. 6 stone	do	6	....	....	....	....	1	....
	1½ parts No. 4 sand and 4½ parts No. 6 stone	do	6	....	....	....	....	1	....
	2 parts No. 4 sand and 4 parts No. 6 stone	do	6	....	....	....	....	1	....
	3 parts No. 4 sand and 3 parts No. 6 stone	do	6	....	....	....	....	1	....
	0 part No. 4 sand and 9 parts No. 6 stone	do	6	....	....	....	....	1	....
	1 part No. 4 sand and 8 parts No. 6 stone	do	6	....	....	....	....	1	....
	1½ parts No. 4 sand and 7½ parts No. 6 stone	do	6	....	....	....	....	1	....
	2 parts No. 4 sand and 7 parts No. 6 stone	do	6	....	....	....	....	1	....
	3 parts No. 4 sand and 6 parts No. 6 stone	do	6	....	....	....	....	1	....
	4 parts No. 4 sand and 5 parts No. 6 stone	do	6	....	....	....	....	1	....
7	½ part No. 5 sand and 5½ parts No. 6 stone	do	6	....	....	....	....	1	....
	1 part No. 5 sand and 5 parts No. 6 stone	do	6	....	....	....	....	1	....
	2 parts No. 5 sand and 4 parts No. 6 stone	do	6	....	....	....	....	1	....
	3 parts No. 5 sand and 3 parts No. 6 stone	do	6	....	....	....	....	1	....
	1 part No. 5 sand and 8 parts No. 6 stone	do	6	....	....	....	....	1	....
	2 parts No. 5 sand and 7 parts No. 6 stone	do	6	....	....	....	....	1	....
	3 parts No. 5 sand and 6 parts No. 6 stone	do	6	....	....	....	....	1	....
	4 parts No. 5 sand and 5 parts No. 6 stone	do	6	....	....	....	....	1	....
8[1]	1 part No. 1 sand	do	2	....	....	....	....	....	....
	2 parts No. 1 sand	do	2	....	....	....	....	....	....
	3 parts No. 1 sand	do	2	....	....	....	....	....	....
	4 parts No. 1 sand	do	2	....	....	....	....	....	....
	5 parts No. 1 sand	do	2	....	....	....	....	....	....
	6 parts No. 1 sand	do	2	....	....	....	....	....	....

[1] Three test pieces made for each mixture, tested at one week and retested at succeeding periods. (Surfaces troweled.)

2. ABSORPTION

Series No.	Mortar made of 1 part by volume of Portland cement to—	Consistency	Number of tests by weeks				
			1	2	4	8	26
9	2 parts of No. 1 sand	Damp	3	3	3	3	3
	4 parts of No. 1 sand	do	3	3	3	3	3
	6 parts of No. 1 sand	do			3	3	3
	8 parts of No. 1 sand	do			3	3	3
	2 parts of No. 1 sand	Quaking			3	3	3
	4 parts of No. 1 sand	do			3	3	3
	6 parts of No. 1 sand	do			3	3	3
	8 parts of No. 1 sand	do			3	3	3
10	2 parts of No. 2 sand	Damp			3	3	3
	4 parts of No. 2 sand	do			3	3	3
	6 parts of No. 2 sand	do			3	3	3
	8 parts of No. 2 sand	do			3	3	3
	2 parts of No. 2 sand	Quaking			3	3	3
	4 parts of No. 2 sand	do			3	3	3
	6 parts of No. 2 sand	do			3	3	3
	8 parts of No. 2 sand	do			3	3	3
11	2 parts of No. 3 sand	Damp			3	3	3
	4 parts of No. 3 sand	do			3	3	3
	6 parts of No. 3 sand	do			3	3	3
	8 parts of No. 3 sand	do			3	3	3
	2 parts of No. 3 sand	Quaking			3	3	3
	4 parts of No. 3 sand	do			3	3	3
	6 parts of No. 3 sand	do			3	3	3
	8 parts of No. 3 sand	do			3	3	3

IV. EQUIPMENT AND APPARATUS

The general view of the laboratory in which these investigations were made is shown in Fig. 1, and a more detailed view of the piping and permeability testing apparatus is given in Fig. 2. A diagram of the pipe connections is shown in Fig. 3.

The apparatus for holding the test pieces for the permeability tests is shown in Fig. 4 in sections ready to assemble, and Fig. 5 is a cross-sectional view of the test piece assembled ready for testing. A, A are rubber washers of 5-inch inside diameter and 8-inch outside diameter; B, B are cast-iron top and bottom sections of the holder; C is the test piece 7½ inches in diameter and 1, 2, or 3 inches thick and is retained in corresponding short-length sections of 7½-inch diameter wrought-iron pipe as shown in Fig. 6; D is the retainer in which the water passing through the test piece is caught. In Fig. 7 is shown a large test piece, 18

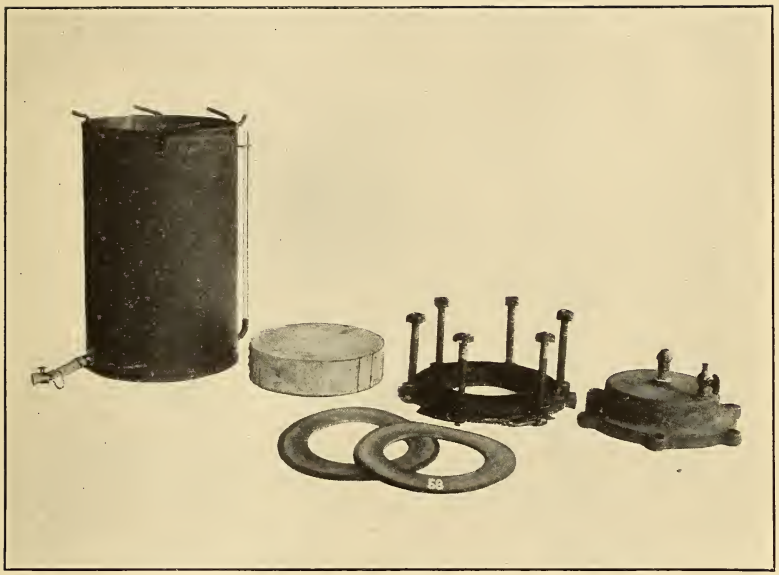

Fig. 4.—*Permeability Test Piece Holder.*

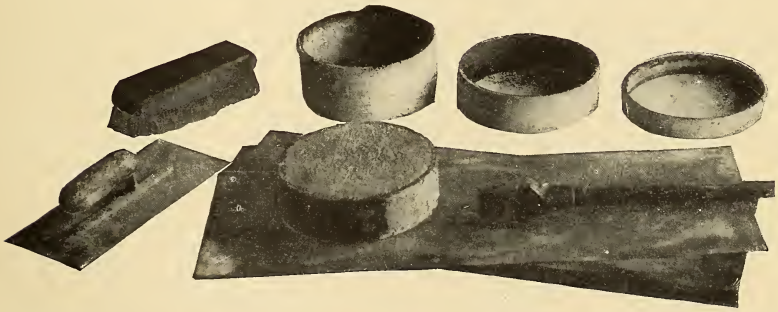

Fig. 6.—*Permeability Molds and Test Piece.*

inches in diameter and 6 inches thick with cast-iron holder and rubber washers. Concrete containing large aggregate was tested in this form.

V. TESTS OF CONSTITUENT MATERIALS

The cement used is known as typical Portland cement, and was prepared by thoroughly mixing together in a cubical mixer an

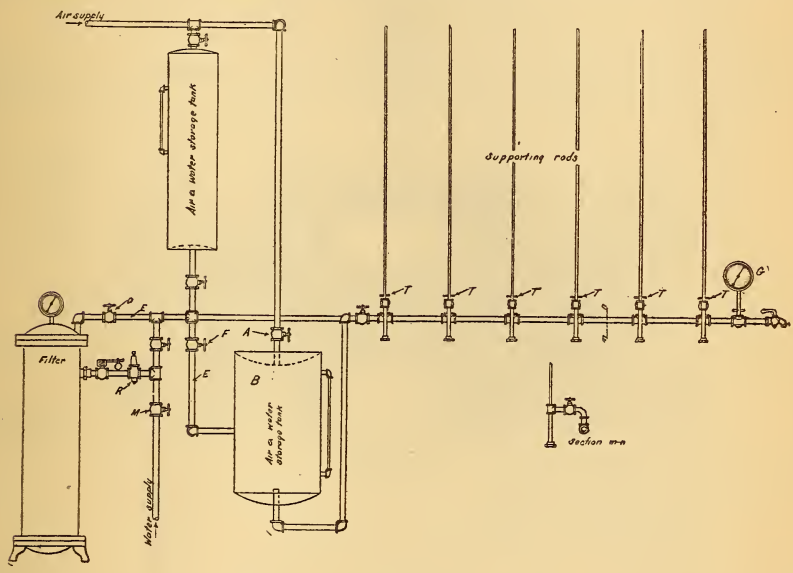

Fig. 3.—*Diagram of Pipe connections.*

equal number of sacks of nine different brands of Portland cement. Two samples were taken from each batch for making the physical tests and for chemical analysis.

The mixture was sealed in air-tight cans each of 800 pounds capacity.

1. CEMENT

The average results of chemical and physical tests are as follows:

Chemical:

Silica (SiO_2)	21.70
Alumina (Al_2O_3)	8.53
Ferric oxide (Fe_2O_3)	2.23
Lime (CaO)	62.00
Magnesia (MgO)	1.74
Sulphuric anhydride (SO_3)	1.67
Water (H_2O)	.43

Chemical—Continued.

Ignition loss		0.98
Undetermined		.94
Physical:		
Residue on 100 sieve	per cent	5.1
Residue on 200 sieve	do	21.
Specific gravity		3.108
Water for normal consistency	per cent	21.4

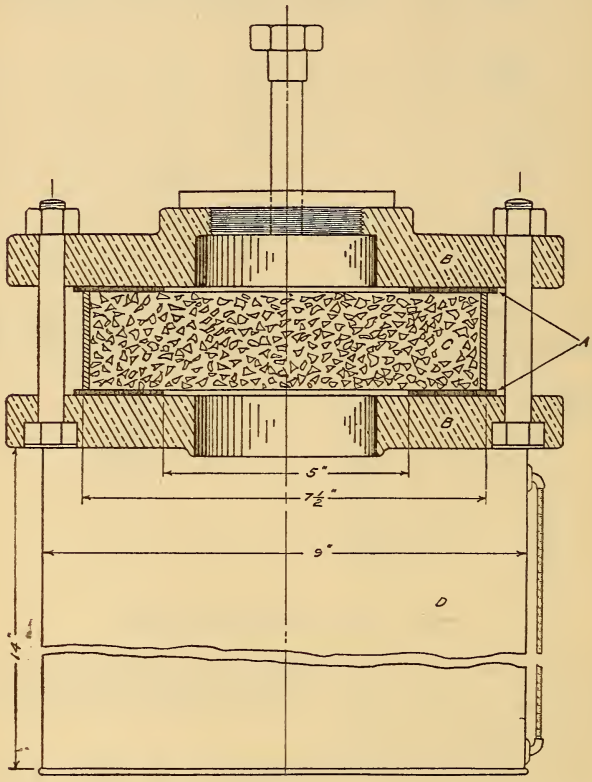

Fig. 5.—*Cross Section of Apparatus for Holding Permeability Test Pieces.*

Time of set in minutes—

Vicat—Initial	135
Final	357
Gilmore—Initial	174
Final	402

Soundness as indicated by pat test:

In air at 70° F, normal in all but 2 cases.
In water at 70° F, normal in every case.
In steam at 212° F, for 5 hours, all normal.
In water at 212° F, for 5 hours, all normal.

Strength of neat test pieces (pounds per square inch)

Age in days	Tensile	Compressive	Transverse
1	336	2 789	761
7	659	7 379	1 512
28	778	9 429	1 674
90	828	12 044	1 953
180	840	13 993	2 023

Strength of 1 : 3 standard sand mortar test pieces (pounds per square inch)

7	294	2 105	593
28	409	3 572	920
90	457	3 905	907
180	468	4 343	847

2. PHYSICAL PROPERTIES OF SANDS AND STONES

Name	Meramec River sand	Bank torpedo sand	Slag sand	Beach sand		Lime-stone	Lime-stone
Register No.	1	2	3	4	5	6	7
Location	Drake, Mo.	Chicago, Ill.		Nombre de Dios, Panama.	Quango Beach, Panama.	Porto Bello, Panama.	St.Louis, Mo.
Specific gravity	2.597	.....	2.440	2.727	2.505	2.594	2.489
Weight in lbs. per cu. ft.	100.6	119.9	82.9	105.6	91.0	102.1	97.7
Percentage of voids	37.9	26.9	45.3	37.92	41.72	36.90	37.1
Fineness in percentage passing sieve—							
200	0.20	0.70	0.60	.....	.....	.....	2.96
100	1.30	1.30	1.40	1.50	1.50	1.90	3.48
80	3.60	2.10	2.10	10.00	10.00	3.40	3.70
50	13.90	7.30	5.80	18.00	31.50	4.34	4.18
40	37.00	14.50	11.40	28.00	46.50	4.90	4.68
30	64.00	28.80	24.00	45.00	62.00	5.85	5.23
20	81.50	45.20	45.40	64.00	72.00	7.00	6.21
10	97.00	72.10	84.30	97.00	86.00	10.00	10.69
¼	100.00	100.00	100.00	100.00	100.00	19.00	28.71
½	.....	.....	.....	.....	.....	30.50	60.86
¾	.....	.....	.....	.....	.....	47.00	96.04
1	.....	.....	.....	.....	.....	59.00	99.37
1¼	.....	.....	.....	.....	.....	81.00	100.00
1½	.....	.....	.....	.....	.....	89.00	.....
1¾	.....	.....	.....	.....	.....	96.50	.....
2	.....	.....	.....	.....	.....	98.00	.....
2½	.....	.....	.....	.....	.....	100.00	.....

VI. DESCRIPTION OF TESTS

1. PROPORTIONS

The proportions of the constituent materials of the mortar or concrete were assumed according to volume measure, but since the actual quantity of sand or stone in a given volume is largely dependent upon its relative dryness and the method employed in filling the measure, it was deemed advisable to convert volume measurements into weight measurements.

The weight of the cement was assumed as 100 pounds per cubic foot, and the weight per cubic foot of the sand and stone used, reported on page 7, was determined in accordance with the methods given on page 26 of Bulletin 329, United States Geological Survey. The sand was taken directly from the storage bin without previous drying and contained an appreciable amount of moisture, for which a correction was made in the volume weights. A part of this weight was made up of moisture present in the sand and stone. This determination of the moisture was made each day, using a 300-gram sample from the material taken from the bin. The weight of the sand or stone required was increased by the percentage of moisture found to be present and the quantity of water to be added to produce a mixture of normal consistency was correspondingly decreased.

2. CONSISTENCY

The two consistencies used, designated as "damp" and "quaking," were determined for each kind of mixture previous to making the test pieces, and are defined as follows:

A mortar or concrete of damp consistency contains only sufficient water to hold the particles together when made into a ball in the hands and the ball held between the thumb and finger. The water could not be brought to the surface by troweling. This quantity of water was recorded as a percentage of the total weight of the dry material and was used for making all test pieces of the same materials and proportions.

A mortar or concrete of quaking consistency contained all the water it would hold and permit of molding into a ball in the hands and holding between the thumb and finger. Water could easily be brought to the surface under the pressure of the trowel.

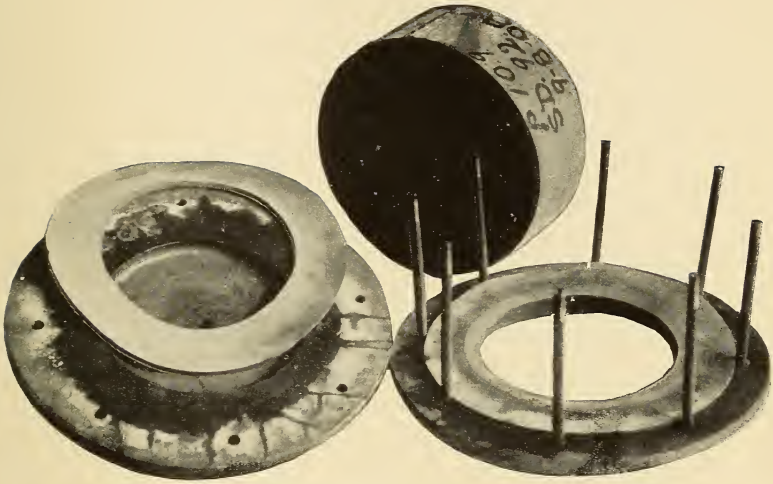

Fig. 7.—*Large Permeability Test Piece and Holder.*

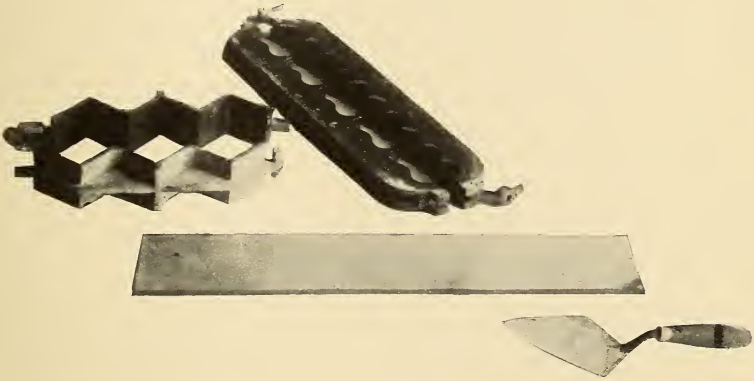

Fig. 8.—*Cube and Briquet Molds.*

3. MIXING

The materials were weighed. The stone and sand were spread on the mixing table and the cement spread evenly on top, and the materials were mixed thoroughly dry by turning with the trowel for about two minutes. A crater was then made in the center, into which the proper percentage of clean water was poured; the materials on the outer edge being turned into the crater with the aid of a trowel. As soon as the water was absorbed the materials were kneaded for about two minutes. The materials for the 18-inch diameter by 6-inch thick test pieces were mixed on a nonabsorbent floor with a shovel in a similar manner.

4. MOLDING

Three test pieces were molded from each batch. The iron molds in which the permeability test pieces were molded are shown in Fig. 6 with the pallet board which has a sheet-zinc top. These molds were cut from wrought-iron well casing, 7½ inches in diameter, in sections 1, 2, and 3 inches in length. The inner surfaces of the molds were wetted and placed on the pallet board and the mortar or concrete pressed firmly into the molds with the fingers, care being taken to exert a uniform pressure in molding all test pieces. The material was piled up and compacted above the level of the molds and struck off with the edge of a trowel. The 1-inch molds were filled in one, the 2-inch in two, and 3-inch in three operations. The test pieces of Series 8 were molded as described on page 52, Part II, of this paper, excepting surfaces were troweled hard and not brushed with wire brush.

The molds for the 18-inch diameter test pieces were filled about one-fourth full and tamped around six times with a 13-pound peen-shaped tamper, care being taken to cover the entire surface. This operation was repeated until the mold was filled, when it was leveled off with a plasterer's trowel. Twenty-four hours after molding, the top and bottom surfaces of these test pieces were brushed with a wire brush, which removed any neat cement which may have been drawn to the surface in molding, thus making the entire test piece approximately homogeneous.

13561°—12——2

The absorption test pieces were made in 3-gang 2-inch cube molds on glass plates. (Fig. 8.) The materials were pressed into the mold with the fingers and both top and bottom surfaces were smoothed with a trowel.

5. STORAGE

All test pieces were placed in a moist closet for the first 24 hours, after which the permeability test pieces were removed from the pallet board and stored on shelves in the damp room shown in Fig. 9 until tested. The iron molds were allowed to remain on the permeability test pieces until the testing was completed.

The molds were removed from the absorption test pieces 24 hours after molding, and the latter were then taken to the damp room and stored on shelves until tested.

All test pieces in the damp room were sprayed with water at regular intervals three times each 24 hours.

6. TESTING

Permeability test pieces were brought from the damp room on the morning of the day they were to be tested and both surfaces were brushed with a stiff wire brush in an attempt to remove any surface "skin" of cement drawn to the surface in molding. This was accomplished only with difficulty in some cases. They were then placed in the test-piece holders as shown in Fig. 5, page 12, a $\frac{3}{16}$-inch soft rubber gasket being placed between each of the cast-iron plates and the test piece. The two sections of the holder were drawn tightly together with the bolts as shown, care being taken to draw up evenly on opposite sides. The holder with test piece was then connected to the pipe rack by means of a union, as shown in Fig. 2. After similarly assembling and connecting all of the test pieces, the valve M (Fig. 3) was opened, admitting water through the regulating valve R to the filter, thence through the pipe E to tank B. When the water reached a mark as indicated on the gauge it was shut off and air admitted through the valve A, which was closed when the pressure gauge G registered 20 pounds (9.1 kilograms). The pet cocks on the test-piece holders were opened and valve T slowly opened until all air was exhausted from the chamber on the upper surface of the test piece and water flowed

Fig. 9.—*Storage of Test Pieces.*

freely from the pet cock. The pet cocks were then closed and the valve T opened full, thus exposing 126.68 square centimeters (19.64 square inches) of the upper surface of the test piece to the full water pressure of 20 pounds per square inch (1.4 kilograms per square centimeter), which was arbitrarily chosen for all permeability tests and is equivalent to a hydrostatic head of 46.2 feet. As the flow started the regulating valve R was set and the air cushion in the tank B assisted in steadying the pressure and preventing variation. The flow was caught for a period of one minute in a glass graduate or large calibrated retainer (see Fig. 4), dependent upon the quantity passing, at the end of the tenth, thirtieth, and sixtieth minute and each succeeding hour until the seventh when the water was turned off and the test piece removed. In some cases the test was continued for several days, a reading being taken every 24 hours, and some test pieces were subjected to a retest at a later period. The 18-inch diameter concrete permeability test pieces were tested in most cases for periods of 10, 30, 60, and 120 minutes, and 24 and 48 hour periods under the same or increased pressure.

The absorption test pieces were brought from the damp room on the day to be tested and placed in an oven where the temperature was maintained between 100° and 110° C. (212° to 230° F.). They were weighed twice daily for four or five days or until they showed no further loss in weight. They were then permitted to cool slowly in the air until the following day when they were immersed so that the top surface was 3 inches below the surface of the water. They were taken from the water, the surfaces dried with a towel and weighed; they were then replaced in water and the operation repeated daily until they showed less than one-twentieth of 1 per cent daily increase. This required from 7 to 14 days, at which time the test was considered completed.

VII. RESULTS OF TESTS

1. COMPUTATIONS

The quantity of water flowing through the permeability test pieces for one minute at each period, for which a reading was taken, was recorded.

The cubic centimeters of water passed per minute per square centimeter of surface was computed by dividing the total quantity of water that passed through the test piece in one minute by its area in square centimeters, which was 126.68 for the 7½-inch diameter test pieces, and 504.7 square centimeters for the 18-inch diameter test pieces. Only this computed result is reported in the accompanying tables and an average is taken for each three similar test pieces. Where there was no measureable drip or flow, but the surface opposite to that to which the pressure was applied continued to remain moist, showing that some moisture was penetrating, it is recorded as "moist" in the tables. Readings recorded as "zero" indicate that no moisture whatever appeared on this surface. Of course, theoretically it is possible that a very slight amount of moisture came through but evaporated so rapidly that the surface remained dry in appearance, but later tests would indicate that this was not the case.

The absorption and apparent porosity is computed from the recorded results in the following manner:

The minimum dry weight of the test piece and the maximum wet weight was recorded.

Let D equal dry weight in grams.

Let W equal wet weight in grams.

Let V equal volume of 2-inch cube in cubic centimeters.

Let A equal percentage absorption in terms of dry weight.

Let P equal percentage absorption in terms of volume, or apparent porosity.

Then $W-D$ = gain in weight or the weight of water absorbed, and $A=\frac{W-D}{D}\times 100$ = per cent absorbed in terms of the dry weight, and since 1 gram of water equal 1 cubic centimeter approximately $P=\frac{W-D}{V}\times 100$ = per cent absorption in terms of the volume, which is the apparent porosity.

2. TABULATED RESULTS AND DIAGRAMS

In some cases considerable variation is shown in three apparently similar test pieces but as a whole the results are fairly concordant. It is regrettable that the limited equipment would not permit retesting the mortars which were impermeable under the

1.405 kilograms per square centimeter (20 pounds per square inch) pressure under a greater pressure in order to show their relative values. A summary of the results are reported in tables and some comparisons are shown diagrammatically.

Tables 1 and 2 (Figs. 10 to 13).—In nearly every case the mortars 26 weeks old are less permeable than those 8 weeks old, which in turn were less permeable than those 4 weeks old.

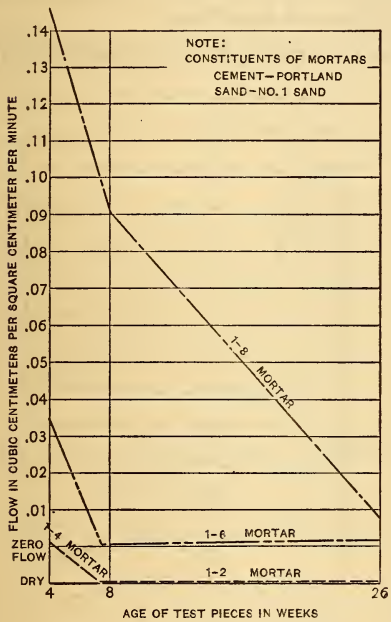

Fig. 10.—*Permeability of Mortars.*

Quaking consistency—Test pieces 1 inch thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

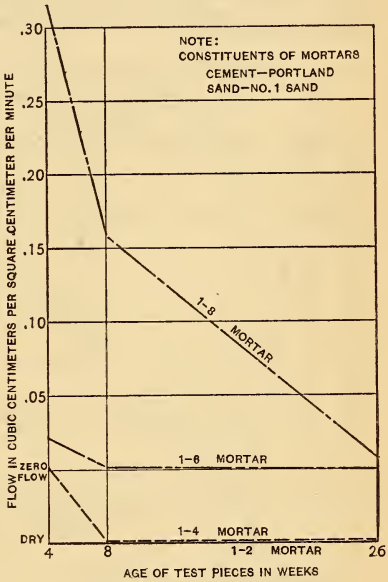

Fig. 11.—*Permeability of Mortars.*

Quaking consistency—Test pieces 2 inches thick. Hydrostatic pressure 1.4 kilograms per square centiemeter.

The richer the mixture in cement the less permeable was the mortar.

The quaking consistency was less permeable than the damp consistency.

The quantity of water passing decreases with the continuation of the flow.

The permeability was approximately the same for similar mortars whether in a 1, 2, or 3 inch thickness of test piece.

Table 3.—Comparing with Tables 2 and 3, the coarse sand mortar was more permeable than the finer grain sand mortar.

The permeability of the mortar decreased with its age.

The quantity of water passing decreased with the continuation of flow.

Table 4 (Figs. 14 and 15).—The concretes richest in cement were least permeable.

The permeability of the concrete decreased with its age.

The concrete showed very slight or no decrease in the quantity of water passing, with the continuation of the flow.

The 3-inch thickness of test piece is slightly less permeable than

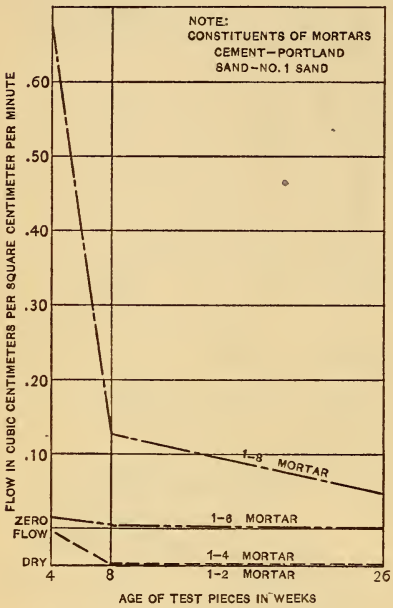

Fig. 12.—*Permeability of Mortars.*

Quaking consistency—Test pieces 3 inches thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

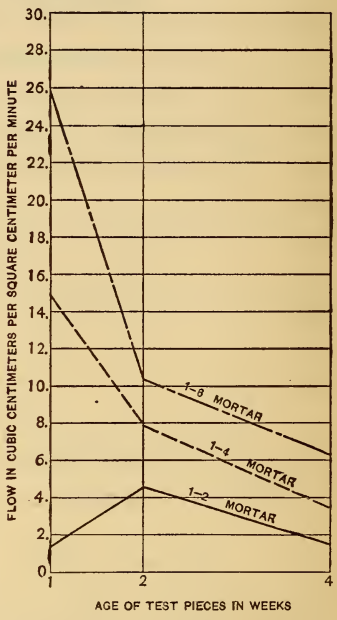

Fig. 13.—*Permeability of Mortars.*

Damp consistency—Test pieces 2 inches thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

the 2-inch, which might be expected considering the size of the aggregate.

Table 5.—The retested test pieces showed practically the same relative decrease in permeability as corresponding mortars of the same age which had not been previously tested.

Table 6 (Figs. 16 and 17).—Concretes made with sand No. 4 were slightly more permeable than those made with sand No. 5, which contained the greatest percentage of fine material.

The same proportion, 1 to ½ to 5 parts, respectively, of cement, sand, and stone was the most impermeable with both sands.

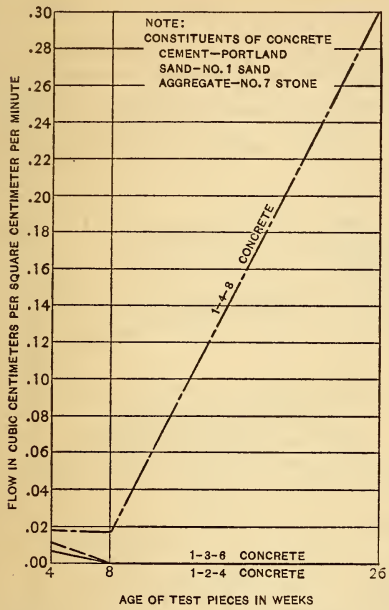

Fig. 14.—*Permeability of Lime Stone Concrete.*

Quaking consistency—Test pieces 2 inches thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

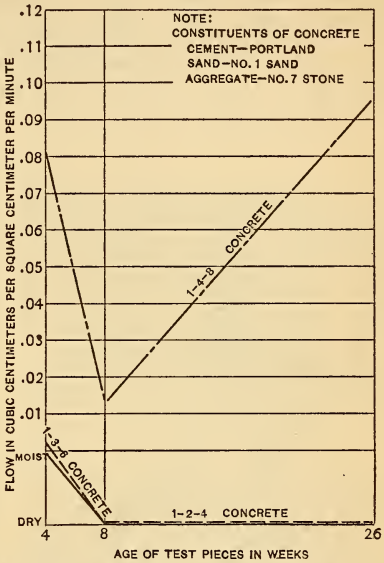

Fig. 15.—*Permeability of Lime Stone Concrete.*

Quaking consistency—Test pieces 3 inches thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

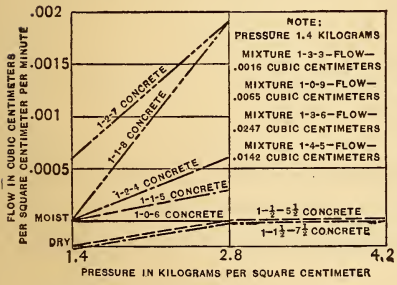

Fig. 16.—*Permeability of Concrete.*

Quaking consistency—Test pieces 6 inches thick. Age 13 weeks—Aggregate No. 4 sand, and No. 6 stone.

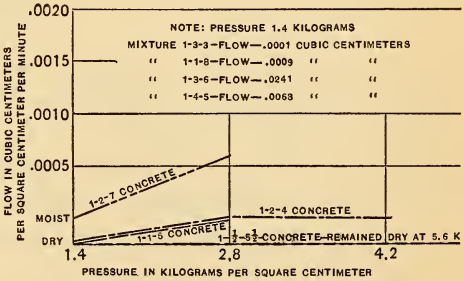

Fig. 17.—*Permeability of Concrete.*

Quaking consistency—Test pieces 6 inches thic Age 13 weeks—Aggregate No. 5 sand, and No. 6 stone.

These tests showed that the permeability of concrete was not dependent entirely on the quantity of cement used in proportion to the total aggregate but depended also upon the ratio of coarse

aggregate to fine aggregate. It will be observed in the case of sand No. 4 that the 1 to 1½ to 7½ proportion was decidedly more impermeable than the 1 to 2 to 4 proportion, although the former contains considerably less cement in proportion to aggregate.

Table 7 (Fig. 18).—The richer the mixture the more impervious the mortar. The permeability of the mortars decreases rapidly with age. The 1–5 and the 1–6 mortars were as impermeable

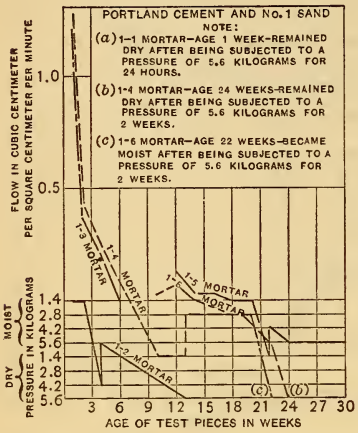

Fig. 18.—*Permeability of Mortars.*

Quaking consistency—Test pieces 2 inches thick. Hydrostatic pressure 1.4 kilograms per square centimeter.

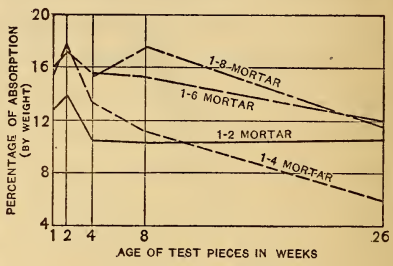

Fig. 19.—*Absorption of Mortars.*

Damp consistency—Portland cement and No. 1 sand.

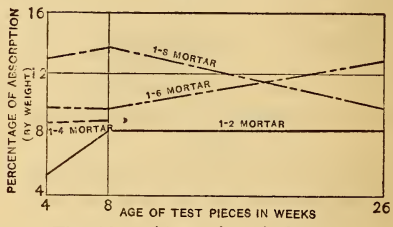

Fig. 20.—*Absorption of Mortars.*

Quaking consistency—Portland cement and No. 1 sand..

at 22 weeks as the 1–2 mortar was at 2 weeks. The value of troweling the surface is shown by these results.

Table 8 (Figs. 19 and 20).—The richer the mixture in cement the less the absorption of the quaking-consistency mortars, but the richness had less effect in the damp-consistency mortars.

The absorption was less in the quaking-consistency mortars than in the damp-consistency mortars.

The absorption increased with age from the first to the second week in the damp-consistency mortars but decreased from the second to the twenty-sixth week.

Table 9 (Figs. 21 and 22).—The absorption decreased but slightly with the richness of the mixture except in the 1–2 mixture of damp consistency, which showed a decided reduction.

The absorption was less in the quaking-consistency mortars than in the damp-consistency mortars.

The absorption decreased with age in the 1–4, 1–6, and 1–8 damp-consistency mortars and 1–2, 1–4, and 1–6 quaking-consistency mortars, but slightly increased with age in the 1–2 damp-consistency and 1–8 quaking-consistency mortars.

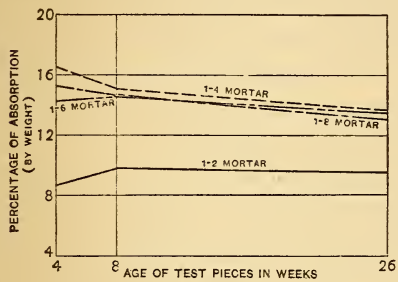

Fig. 21.—*Absorption of Mortars.*
Damp consistency—Portland cement and No. 2 sand.

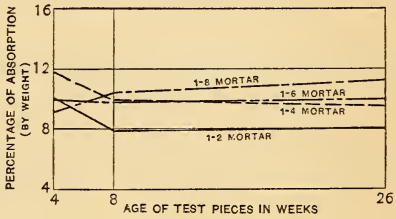

Fig. 22.—*Absorption of Mortars.*
Quaking consistency—Portland cement and No. 2 sand.

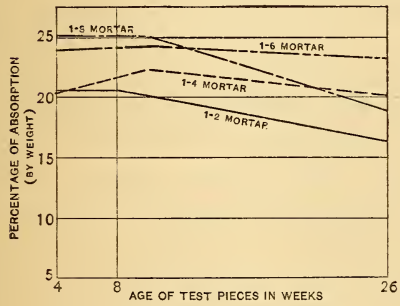

Fig. 23.—*Absorption of Mortars.*
Damp consistency—Portland cement and No. 3 sand.

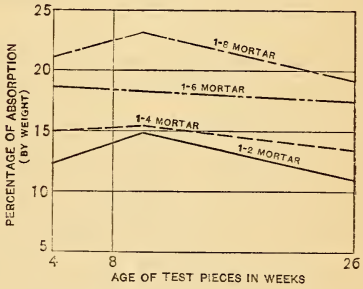

Fig. 24.—*Absorption of Mortars.*
Quaking consistency—Portland cement and No. 3 sand.

Comparing these tables with Table 8, it will be observed that the age of a mortar does not affect its absorption so much in the coarse sand mortar as in the finer sand mortar.

The coarse sand mortars were slightly less absorptive than the finer sand mortar.

Table 10 (Figs. 23 and 24).—The absorption decreased but slightly with the richness of the mixture.

The quaking-consistency mortars were less absorptive than the damp-consistency mortars.

The absorption decreased with the age of the mortar but not so markedly with the leaner mixtures.

Comparing with Table 8, it will be observed that the slag sand mortars were very absorptive, which was probably due to the porous nature and uniform size of the sand grains.

PART II

TESTS OF DAMP-PROOFING AND WATERPROOFING COMPOUNDS AND MATERIALS

An endeavor was made to conduct these tests in such a manner as to make the results of practical value as a determination of the comparative values of the various so-called "waterproofing" and "damp-proofing" mediums.

Forty different compounds were purchased in the open market and several void-filling materials were obtained for testing. A complete record of each compound is reported as to its character, chemical analysis, method of application, the result of physical tests, and noted peculiar characteristics.

Considerable difficulty was experienced in devising a method of testing which would be applicable to all compounds, making the results directly comparable and at the same time complying with the directions for using the compound as recommended by the manufacturer.

The compounds are of two general classes, the waterproofing compounds for preventing the flow of water through masonry where subjected to a hydrostatic head, as in reservoirs, cisterns, tunnels, cellars, and the like; and damp-proofing compounds for overcoming dampness resulting from the capillary attraction and absorptive qualities of masonry, preventing dampness in habitations, and the disfigurement of exterior and interior surfaces of brick, stone, and concrete walls and interior plastering and decorations due to staining and efflorescence. Many of the waterproofing compounds are also recommended for use as damp-proofing mediums.

Two series of tests were made in this investigation, one of the waterproofing or water-resisting qualities of the compounds recommended for such use, and another of the damp-proofing qualities of other compounds so recommended to be used. Some of the coating compounds were recommended for use as waterproofing mediums, but after testing two or three and finding that they failed utterly it was decided to first test all coating compounds as

damp-proofing mediums. All the waterproofing compounds tested and reported were such as were to be incorporated in a mortar or concrete and are known as "integral" compounds. No tests were made on felt papers or similar materials coated with bitumen or similar materials.

The Portland cement used in these tests was the same as described in Part I, where its physical and chemical qualities are given.

Only one kind of sand was used throughout these tests, the Meramec River sand, a description of which, with its physical properties, is given in Part I.

VIII. WATERPROOFING AND DAMP-PROOFING MATERIALS

The compounds tested were purchased from the makers or their agents under the following trade names

Anhydrol
Antihydrine
Anti-Hydro
Aquabar
Aquarex
Astralite
Blanchite
Cabot's Stain
Carbonkote
Cement Filler
Cement Floor Paint
Dehydratine No. 2
Dehydratine No. 4
Fibrous
Hydratite,
Hydrolithic Coating
Ideal Filler
Impervo
Ironite
Irono
Lewis
Limoid
Liquid Konkerit
Maumee
Medusa
Minwax
Morganite.
Novoid
R. I. W. No. 232
R. O. U. Compound
R. O. U. Liquid
Standard
Star Stettin Waterproof Cement
Te-Pe-Co.
Toxement
Universal Damproof
Waxin
Waxol
Weatherproof Granite
Wunner's Bitumen Emulsion

The above list includes practically all types of compounds which have been recommended and used for waterproofing and damp proofing with the exception of plastic coatings reinforced with fabric.

1. CLASSIFICATION OF COMPOUNDS

The tests of compounds are reported in this paper by number only, no specific reference being made to their commercial name nor to the manufacturer. They are classified according to composition in the following table of compounds:

- Coating
  - Linseed oil paints and varnishes (compounds Nos. 1, 2, 3, 4, 5, 6).
  - Bitumens
    - Asphaltums (compounds Nos. 7, 8, 9, 10).
    - Mixtures of various bitumens (compounds Nos. 11, 12, 13, 14).
    - Mixtures of bitumen with wood tar and linseed oil.
  - Liquid hydrocarbons (compounds Nos. 15, 16, 17, 18, 19).
  - Soaps (compounds Nos. 20, 21, 22).
  - Cements (compound No. 23).
  - Miscellaneous (compounds Nos. 24, 25, 26).
- Integral
  - Solids
    - Inert fillers (compounds Nos. 27, 41, 42, 43 44, 45).
    - Active fillers (compound No. 28).
    - Antipathetic or water repelling substances (compounds Nos. 29, 30, 31, 32, 33, 34, 35, 36).
    - Cements (compound No. 37).
  - Liquid, active (compounds Nos. 38, 39, 40).

This classification has been adopted, first, because all the compounds investigated have been designed for use in either of these two ways; that is, to be applied either to an outer or inner wall as a wash, plaster, or impervious membrane "coating," or to be mixed with the dry cement or mixing water to form an integral part of the resulting mortar or concrete. It may be said, however, that frequently the manufacturer of the second class of compounds recommends his product to be used also as a wash, when

mixed with cement, or cement and water, to the consistency of a cream. But this is a secondary use, and they prefer to have their material incorporated into the mass. Second, this extended classification shows what the compounds have been found to contain and what they really are, notwithstanding any claim of the manufacturers. In some cases there has been some doubt as to which class a compound belonged. For example, the majority of the water-repelling compounds contain such a very large percentage of totally inert material that they might well be placed among the "inert fillers," but they do contain a slight percentage of insoluble soaps which repel water, hence they have been classed as such.

2. CHEMICAL REVIEW

As no organic substances can be considered as truly permanent, the durability of all these compounds, except the inert fillers, can be questioned.

a. COATING COMPOUNDS

(a) **Linseed Oil Paints, Varnishes, etc.**—The compounds in this class differ in nowise from the ordinary enamel paints which are usually characterized by hardness and brittleness, due to the comparatively large amount of hard resins and the small amount of linseed oil. This causes such coatings to be very inelastic, but at the same time would apparently increase the life of the coating, since the hard resins are more inert than the linseed oil. Linseed oil is constantly undergoing changes due to oxidation, and in the presence of alkali its life is still further decreased owing to the saponification which takes place in the presence of the latter. It will be noted from the remarks under the damp-proofing tests that nearly all these coatings softened under the influence of water, thus showing that saponification was taking place.

(b) **Bituminous Coatings.**—This class includes asphalt, petroleum residuum, and coal-tar pitches. They are usually characterized by great inelasticity, and are, therefore, recommended to be used with alternating layers of felt, and being solid at ordinary temperatures are applied while hot. As they are also soluble in benzine and coal-tar naphtha they are frequently put on the market in this latter form. The materials included in this class

have, somewhat unfortunately, with one exception, been of this form. Owing to their wide distribution, their cheapness, the ever-increasing quantities which are appearing on the market, and their supposed inertness, it has been deemed advisable to make a further study of this single class. This study will include a more detailed chemical investigation and comparison of the various bitumens when subjected to various conditions, as water on one side of the bitumen and air on the other side, water on both sides, action of waters containing various salts, etc.

(c) **Liquid Hydrocarbons.**—In this class there are two kinds of compounds which act largely to fill the pores and at the same time repel water. Both are of such a nature that they do not penetrate the mass very far and are only very superficial. Like all coatings, they are rendered worthless by any minute crack in the concrete. The nonvolatile part of one of them is paraffin, which is inert, and in the other it is largely a petroleum oil, which remains unacted upon and under a slight head of water would be forced out.

(d) **Soaps.**—The use of a solution of soaps can not bring enduring results. It is quite likely that very much more of the soap is dissolved and washed off the surface than ever reacts to form insoluble compounds of the nature of lime soap. Unless such reaction does take place, which is doubtful, this class is entirely worthless.

(e) **Cements.**—There are a number of cements on the market to which have been added a very small quantity of water-repellent substances. This makes them similar to the "water-repelling" compounds discussed under that classification.

(f) **Miscellaneous Coatings.**—This class includes a number of compounds of very diverse nature. For this reason their value is discussed in detail in connection with the statement of the analyses.

b. INTEGRAL COMPOUNDS

(a) **Solid Inert Fillers.**—This class includes a number of finely ground, naturally occurring materials such as clay, sand, and a prepared filler, or hydrated dolomitic lime. The use of cement in large quantities—"rich mixes"—also places that substance to a certain extent in this class. A further discussion of this class is

hardly necessary, since it would finally resolve itself into the question of the density of the mixture. The fillers used, however, should not only be inert toward the action of the cement but also to atmospheric conditions and possible percolating waters. Hydrated lime can hardly be considered inert in this respect, though hydrated dolomitic lime would be much more so.

(b) **Active Fillers.**—This class includes several compounds which are supposed to react with certain of the constituents of the cement to form other compounds which at the same time will be inert and fill the voids. One of these is partly a resinate of potash which, in the presence of the free lime of the concrete, would react to form the more insoluble resinate of lime; the rest of the compound is, however, inert. Another contains a large quantity of saponifiable oil, which again forms an insoluble lime soap with the concrete. These lime soaps are not only almost insoluble in water but they are also not wet by it, consequently they form the basis of the succeeding class, the "water-repelling" compounds. As, however, in themselves these materials are not waterproofing but become so only as a result of a series of reactions, it would be better to use the result of these reactions directly and not depend upon something that may not always take place either wholly or in part. Consequently, it is better to use the water-repelling compounds themselves if this kind of material is desired.

(c) **Water-repelling Compounds.**—These are stearates of lime or soda and potash. The former, as stated above, is almost insoluble in water and is also not wet by it. Upon this latter fact, together with a large amount of hydrated lime (or lime and magnesia) present in them, acting as an inert void filler, depends the value of the compound. The stearates of soda and potash are ordinary soap, readily wet and soluble in water. With these there is a reaction when they are treated with water in the presence of the cement; the soda or potash soap is dissolved and precipitates the more insoluble lime soaps, the result being the same compound as the rest of this class contains. The claim made by the manufacturers that these compounds are water repellent is inconsistent, in that they must be thoroughly surrounded by water when mixed with the aggregate if the normal strength of

the concrete is to be developed. When so mixed in the concrete their water-repellent action would be lost. If it repels the water from the concrete it must necessarily repel it from the cement and prevent the latter from attaining its usual strength.

(d) **Waterproofing Cements.**—Several manufacturers have added water-repelling materials directly to cement and offered it to the public as waterproofed cements. This repelling material is similar to that used in the water-repelling compounds, consequently the remarks made under that class apply here.

3. CHEMICAL ANALYSES

The following are the analyses of the compounds investigated, grouped in the classes mentioned above:

a. COATING COMPOUNDS

(a) **Linseed-oil Paints, Varnishes, etc.**—One would expect to find in the paints used for waterproofing or damp-proofing cements a relatively large amount of resins; in the case of an enamel paint it is reasonable to expect that a short oil varnish was used in its manufacture. By putting more resins in the material, the manufacturer puts more of a stable compound in it, as opposed to the more unstable material—linseed oil. This latter will not only readily react with the alkaline water coming through the cement, but also is continually subjected to oxidation. In both of these respects the resins are much more stable.

As can be seen from the following analyses this is true in several cases. Of course it is impossible to replace all or nearly all of the oil by resin, since by doing so would give a very brittle, inelastic coating, which is so little desired.

The figures given for the insoluble resins may be taken as a relative measure of the total resins present. It is to be regretted that there is no method which will give the exact amount present. The methods used by Holly and Ladd (Analysis of Mixed Paints, Color Pigments, and Varnishes, by Holly and Ladd), by the Department of Agriculture (Bull. 109, Bureau of Chemistry), and McIlheny (Proceedings American Society for Testing Materials, 1908), give only more or less close approximations of the amount present. None pretend to give the amount actually present.

By "insoluble resins" in the following analyses is meant the resins insoluble in 87° (Baumé) gasoline.

Attempts have been made to make special cement paints. One of them put on the market was purported to be a synthetic tricalcium silicate. This same pigment also contained 50 per cent lithophone. Others have added Portland cement to varnishes and placed them on the market, but these decompose so quickly, the oil reacting with the cement, that they were withdrawn. It would seem from the analysis of the paints used in the present series of permeability tests that no special pigment has been used.

The volatile material or thinner used in these compounds is also that common to ordinary paints and varnishes.

Compound No. 1

	Per cent
Pigment	18.84
Linseed oil, driers, and soluble resins	14.81
Insoluble resins	24.03
Volatile (coal-tar naphtha, turpentine, and benzine)	42.32
	100.00

(The driers are lead, manganese, and lime resinates.)

Pigment:	
Silica	4.64
Alumina	3.24
Iron oxide	1.74
Lime	0.39
Barytes	57.66
Zinc sulphide	31.98
	99.65

This was an enamel paint characterized by a rather large amount of insoluble resins. The lime resinate is common to both the best and cheapest varnishes. The pigment is largely the material sold under various trade names as lithophone, Beckton white, phonolith, etc. It has thus far not been possible to produce a stable pigment of this character. Although a beautiful white with considerable covering power, it invariably darkens when exposed to sunlight, later bleaching out slowly. In the present case the pigment is of a cement color, tinted by the other materials shown in the analysis. Whether the lithopone has reached a stable condition is unknown.

Compound No. 2

	Per cent
Pigment	19. 52
Linseed oil, driers, and soluble resins	66. 28
Insoluble resins	3. 18
Volatile (benzine 83 per cent, turpentine 17 per cent)	11. 02
	100. 00

(The driers are lead and manganese resinates.)

Pigment:	
Lead oxide (litharge)	10. 44
Lampblack	87. 43
Alumina silicate	1. 91
	99. 78

This is a good example of a black paint such as can be bought on the market for almost any purpose. As a paint, nothing can be said against it, excepting the use of lead oxide, which is constantly combining with the oil to form a difficultly soluble soap which settles to the bottom of the container and makes almost impossible the proper incorporation of the pigment with the oil.

Compound No. 3

	Per cent
Linseed oil, driers, and soluble resins	17. 42
Insoluble resins	15. 35
Volatile (benzine 90 per cent, turpentine 20 per cent)	67. 23
	100. 00

(The driers are lead, manganese, and lime resinates.)

This is a very heavy viscous "Japan." The use of lime resinate is not generally to be favored. The "linseed oil" is strongly suspected of being "China wood oil," but it is not positively identified in the presences of the large amount of resinates.

Compound No. 4

	Per cent
Pigment	75. 06
Linseed oil, driers, and soluble resins	7. 43
Insoluble resins	3. 46
Volatile (benzine 80 per cent, turpentine 20 per cent)	14. 05
	100. 00

(The driers are lead and manganese resinates.)

Pigment:	
China clay—	
Silica	19. 37
Alumina	7. 74
Whiting—	
Calcium carbonate ($CaCO_3$)	31. 13
Magnesium carbonate ($MgCO_3$)	0. 59
Zinc white	41. 19
	100. 02

This was a paste which is to be mixed with benzine or turpentine before applying. When applied it is supposed by the makers to first set by evaporation and then to oxidize but not to crack, peel, or become brittle. There is nothing to distinguish it from any other white "pastes" on the market to be used for general purposes.

Compound No. 5

	Per cent
Pigment	58.85
Insoluble resins	4.72
Linseed oil, driers, and soluble resins	24.60
Volatile (benzine)	11.83
	100.00

(The driers are lead and manganese resinates.)

Pigment:	Per cent
White lead	24.55
Barytes	8.48
Silica	23.34
Alumina	0.38
Iron oxide	0.21
Gypsum	15.76
Lime	1.08
Magnesia	0.34
Zinc oxide	21.60
Zinc sulphide	1.68
Lampblack	2.32
	99.74

This is a paint characterized more by a large variety of materials in the pigment than anything else. The reason for using such a number is unknown; the shade—that of cement—does not require them. One can expect no better results from this than from an ordinary paint.

Compound No. 6

Distillates:	Per cent
Up to 105° (benzine and light oils)	19.40
105 to 145° (benzine and light oils)	41.00
145 to 305° (light yellow oils)	2.40
Volatile at 105°	56.06
Unsaponifiable (black viscous petroleum oil)	23.65
Saponifiable	20.29
	100.00

The saponifiable is largely linseed oil; some resins are also present, combined with lime and manganese.

This compound is a mixture of benzine, linseed oil, lime and manganese resinates, and a petroleum oil. In a very thin layer it will dry in about four weeks. Applied on concrete the linseed oil would be partly converted into linoleate of lime, which is insoluble; the benzine would evaporate and the petroleum oil remain inert, filling the surface pores. Under any considerable head of water it would be forced out.

(b) **Bitumens.**—The four following compounds are classed as asphaltums, though they may be residuums of petroleum, having an asphaltum base. Letters have been received from three of the manufacturers of the four compounds of this class, in which they state that their material will not stand the weather; and two state explicitly that it must be used between the wall and plaster and not be exposed, hence no discussion of their weathering properties is necessary.

In analyzing these compounds the percentage of volatile at 105°, the percentage of saponifiable calculated to be a linoleate, and the percentage of unsaponifiable were obtained. The material was also distilled up to 315°, changing the receiver whenever the distillate was noticed to change. When turpentine was suspected to be present a distillate was caught between 150 to 170°, and in this the amount of turpentine was determined.

Compound No. 7

		Per cent
Distillates:		
Up to 105°		27. 00
105 to 150° (Benzine and light oils.)		15. 00
150 to 315° (changed to yellow oil at 150° and continued so until end)		5. 00
Volatile at 105° (benzine and light oils)		40. 10
Nonvolatile		59. 90
	Per cent	
Bitumen and oils	97. 69	
Free carbon	. 39	
Ferruginous clay	2. 15	

The bitumen is a mixture of asphaltum and petroleum residuum.

Compound No. 8

	Per cent
Volatile at 105°	58. 70
Saponifiable (resinates, resins, and linseed oil)	21. 30
Unsaponifiable (asphaltum)	20. 00
	100. 00

(Lead and manganese driers are present.)

	Per cent
Distillates:	
Up to 105° (naphtha)	1.70
105 to 150° (benzine)	24.80
150 to 170° (benzine 85 per cent, turpentine 15 per cent)	28.40
170 to 315° (light yellow oil, containing acrolein)	11.00

This compound contains considerable linseed oil, which tends to make it more elastic. It also tends to make it reactive (less inert) to atmospheric conditions.

Compound No. 9

	Per cent
Distillates (start at 200°):	
200 to 315° (yellow oil, cloudy from presence of a wax)	9.00
Acetone extracts (dark-brown soft, waxy material)	19.30
(Chloroform almost completely extracts the residuum of the acetone.)	
Nonextractable	.15
Ash (SiO_2:Al_2O_3)	.21

This compound is a solid which becomes plastic at 30° and melts at 110°.

The material would seem to be a natural-occurring bituminous wax, especially so on account of the very small amount of free carbon and the large amount of wax.

Compound No. 10

		Per cent
Volatile at 105°		32.88
Nonvolatile		67.12
	Per cent	
Asphaltum and heavy oil	97	
Ash ($CaCO_3$)	3	
Trace nonsoluble organic matter.		
Distillates:		
Up to 105°		6.50
105 to 205°		24.50
(Benzine and light oils.)		
205 to 315° (heavy yellow oil)		10.00

(c) **Mixtures of Various Bitumens with Linseed Oil, etc.**—There are four compounds in this class, which covers a large variety of mixtures. The makers seemed to have had one purpose in mind in making these, however—to make the materials more elastic by the addition of a drying oil, as linseed oil. It is a question if they have not sacrificed durability by this addition, since it is very likely that the bitumen alone on the concrete would last longer and be more inactive than with the readily oxidizing and very active and drying oils.

Compound No. 11

		Per cent
Extractable with 87° gasoline (73.7 per cent saponifiable (linseed oil and resinates). Remainder is coal-tar oils)		23. 70
Extractable with carbon bisulphide (Coal-tar pitch.)		11. 82
Nonextractable		29. 72
	Per cent	
Carbon and hydrocarbons	23. 80	
Silica	14. 06	
Iron oxide	62. 32	
	100. 18	
Volatile (coal-tar naphtha)		34. 76
		100. 00
Distillates:		
Up to 105°		44. 00
105 to 165° (Coal-tar naphtha and light oils.)		16. 00
165 to 315° (a yellow heavy oil containing acrolein)		5. 00

(Lead and manganese driers are present.)

Compound No. 12

		Per cent
Extracted with 87° gasoline (69.5 per cent saponifiable, calculated as linoleate (linseed oil and resinates); 30.5 per cent hydrocarbons)		59. 52
Extracted with chloroform (a very brilliant, brittle coal-tar pitch)		4. 96
Nonextractable (a dull-black powder resembling ground coal)		24. 28
	Per cent	
Carbonaceous	31. 76	
Silica	23. 00	
Alumina	19. 36	
Iron oxide	10. 45	
Lime	9. 30	
Magnesia	5. 76	
	99. 63	
Volatile (90 per cent benzene and 10 per cent turpentine)		11. 24
		100. 00

(Lead and manganese driers are present.)

Compound No. 13

	Per cent
Distillates:	
Up to 105°	5. 20
105 to 150°	29. 20
150 to 170° (Benzine: Turpentine was suspected but proved to be a substitute (benzine and essential oil).)	7. 00
170 to 315° (heavy yellow oil)	5. 00
Volatile at 105° (benzine)	31. 50

(Residue is a mixture of wood-tar pitch and possibly asphaltum.)

Compound No. 14

		Per cent
Distillates:		
Up to 105° (wood alcohol, coal-tar naphtha, and benzine)		7.00
105 to 165° (coal-tar naphtha and benzine		34.00
165 to 315° (light yellow oil)		11.00
Volatile at 105°		39.90
	Per cent	
Wood alcohol	5	
Benzine (approximately)	65	
Coal-tar naphtha (approximately)	30	
Nonvolatile (soluble in acetone; contains saponifiable equivalent to 36 per cent linoleate; resins, driers, and hydrocarbons present)		31.20
Petroleum residuum		28.90
		100.00

(Lead and manganese driers are present.)

(d) **Liquid Hydrocarbons.**—There are two kinds of compounds in this class—the first is a solution of paraffin in benzine and benzol. This kind of a material has been used for a long period and has many advocates. It is readily applied to a dry wall; to a wet one it will not adhere, consequently it can not be used to stop the flow of water through a pervious wall.

The second compound is an emulsion of a petroleum oil, fat oil, with water secured by means of the use of a little ammonia. The petroleum oil would naturally render the wall water repellent and the fat oil might form a soap in the concrete which would fill the voids. The ammonia would soon volatilize.

Compound No. 15

	Per cent
Distillates:	
Up to 105°. (A little water, benzol, and benzine)	30.00
105 to 165° (5 per cent low-boiling turpentine (recovered from wood chips), light-burning oils)	24.50
165 to 315° (light yellow oils containing a little paraffin)	28.50
(Residue is a soft brown paraffin).	
Volatile at 105° (benzol and benzine)	80.75

Compound No. 16

	Per cent
Water	84.99
Ammonia	.23
Petroleum oil	9.78
Fat oil	5.00
	100.00

The petroleum oil is paraffin oil.

The fat oil was not positively identified; it was semidrying and had some of the characteristics of rape oil.

The ammonia is reported as anhydrous.

The above is a very stable emulsion of the oils and water; on long standing a little oil separates out but is very readily incorporated again by slight shaking. We doubt whether the oils would remain in the pores of the concrete under a very slight head. The fat oil is a very slow drying one in itself; mixed with the petroleum oil it is entirely nondrying, also very slowly saponifiable.

Compound No. 17

	Per cent
Distillates:	
110° (water, benzol, and benzine)	31.5
110 to 165° (water, light-burning oils, and 7 per cent turpentine)	30.3
165 to 260° (yellow paraffin oil and 22 per cent turpentine)	17.2
260 to 315° (yellow viscous oil)	5.5
(Residue is a soft brown paraffin.)	
Volatile at 100°	79.2

The material is benzol, benzine, wood turpentine, paraffin oils, and paraffin.

Compound No. 18

	Per cent
Volatile at 105°	66.5
Nonvolatile (paraffin; melting point, 46°.1)	33.5
Distillates:	
98 to 130° (naphtha and benzol)	50.0
130 to 190° (benzine)	15.3

The material is paraffin dissolved in petroleum and coal-tar naphtha.

Compound No. 19

	Per cent
Volatile at 105°	77.6
Nonvolatile (paraffin; melting point, 44°.4)	22.4
Distillates:	
158 to 193° (benzine, benzol, and 13 per cent wood turpentine)	50.0
193 to 249° (light yellow oil)	16.0
249 to 325° (light yellow oils)	6.0

The material is paraffin dissolved in pertoleum and coal-tar naphtha, wood turpentine, and light petroleum oil.

(e) Soaps, Solid and in Solution.—The use of soap solution in connection with alum is one of the oldest waterproofing methods. The use of soap alone is more recent and less frequently used. The value of the soap alone is also rather doubtful, since it is soluble in water

and may easily wash away if used as a coating before reacting with the concrete to form insoluble soaps. This latter is accomplished almost immediately in the soap-alum process on adding the alum wash.

The nature of the compounds in this class is apparent from their analyses.

Compound No. 20

	Per cent
Water	96.00
Soap	3.91

(The soap is potassium linoleate.)

According to the manufacturer, the value of this compound is due to the hardening of solids contained in the emulsion. They can not be washed away or changed by oxidation. As this is simply a solution of soap and water, it is difficult to see how the makers' claims can be fulfilled. If there is no reaction between the lime of the cement and the potassium of the soap, the latter will inevitably go into solution when in contact with water.

Compound No. 21

	Per cent
Water	8.15
Soda (Na_2O)	8.71
Potash (K_2O)	.43
Free fat	10.45
Fat acids (a mixture of fat acids at 30° consists of a liquid acid with a large quantity of crystalline acid)	67.12
Rosin	2.90
Blue vitriol ($CuSO_4$)	2.65
	100.41

This soap has been made partly of a fish oil. The purpose of the copper sulphate is unknown unless as a germicide or fungicide.

Compound No. 22

	Per cent
Distillates:	
80 to 150° (benzine, sp. gr. 0.757)	10.2
150 to 200° (benzine, sp. gr. 0.782)	35.8
200 to 260° (light yellow oil, sp. gr. 0.821)	34.0
260 to 310° (yellow oils, sp. gr. 0.841)	10.0
Nonvolatile at 105° (yellow paraffin, 3.7 per cent; remainder alumina resinate)	3.2

The material is a mixture of paraffin, light yellow petroleum oil, benzine, and alumina resinate.

(f) Cements as Coatings.—The addition of a water-repelling material to a cement to be used either as a coating or directly in making mortars and concretes has often been suggested, and several of such products are now on the market. Two of these have been used in the present investigations—one, however, as a coating and the other directly as a cement.

The analysis of the former follows. It will be seen that the cement has been mixed with a large quantity of sand. See also the remarks under "Water-repelling compounds," following later

Compound No. 23

	Per cent	Per cent
Passes 100-mesh sieve		27.73
Silica	22.40	
Alumina	7.98	
Iron oxide	3.63	
Lime	59.34	
Magnesia	1.85	
Sulphuric anhydride	1.15	
Carbon dioxide	2.16	
Organic	.32	
Water	.93	
	99.76	

(The organic is fat acids with a melting point of 52° and the combined weight of 268; they are present as a lime soap.)

Retained on 100-mesh sieve	72.27
	100.00

	Per cent
Silica	54.09
Alumina	4.47
Iron oxide	1.36
Lime	13.47
Magnesia	7.72
Ignition loss (carbon dioxide=18.13 per cent)	18.27
	99.38

(This is a sand (all passing one-eighth sieve) composed of quartzite and dolomite. There is a trace of fat acids also present.)

(g) Miscellaneous Coatings.—Four compounds have been placed in this class. They are distinct from each other and the other compounds examined. Their analyses follow, together with such remarks as will make their composition and possible value clear.

Compound No. 24

	Per cent
Silica	27.27
Alumina	.79
Iron oxide	.52
Lime	23.91
Magnesia	14.02
Sodium oxide	.26
Potassium oxide	Trace
Sulphuric anhydride	1.01
Carbon dioxide	15.50
Casein	3.19
Glue	8.48
Water	4.82
	99.77

This is a mixture of asbestos, whiting, casein, glue, and possibly a little free or hydrated lime to hold the casein in solution. This is the only compound examined which contained casein, which fact is rather peculiar in view of its well-known use in "cold-water paints," where it has been highly successful. The glue has no value for waterproofing. Some preservative—as boracic acid—should have been added to this material, as in damp places it rapidly decomposes, giving rise to very offensive odors.

Compound No. 25

	Per cent
Carbon	3.92
Silica	4.40
Manganese	.57
Phosphorus	1.00
Sulphur	.12
Lime	1.02
Magnesia	.25
Iron	85.04
Sal ammoniac	3.49
	99.81

According to the manufacturer this compound is a filler, but applied on the surface in a water-paste form. Hence, it can only be a surface filler and does not penetrate. There may be a reaction between the concrete and the material; but the one reaction upon which the value of the compound depends is the corrosion of the iron by the sal ammoniac in the presence of water. If the resulting corroded iron will adhere to the concrete, the material should have considerable value as a waterproofing material.

Compound No. 26

	Per cent
Volatile at 105° (water with less than 0.10 per cent phenol)	93.90
Fat acids (mostly stearic)	.80
Glue	2.10
White lead	2.11
Lead oxide (litharge)	.94
Sodium oxide [2]	.03
Potassium oxide [2]	.05
	99.93

Another sample of this material was received at the laboratories and analyzed as follows:

	Per cent
Volatile at 105° (water, with a very little phenol)	92.58
Fat acids (largely stearic)	.85
White lead	3.52
Glue	2.85
Sodium oxide [2]	.04
Potassium oxide [2]	.06
	99.90

It will be seen that these materials differ in that the one contains litharge and the other does not. While the actual amount of the lead oxide may be small, especially in terms of percentage of material, yet in percentage of solids it is quite large. Its absence is also readily noticed by the color, the first material having a decided yellow or orange tinge, while the second is white. Later a third sample was received and this again contained litharge, judging from the color, in even larger amounts than the first sample. However, the material is intended to be an emulsion of soap, glue, white lead, water, and sometimes litharge. It may happen that during the evaporation of the water part of the lead oxide, especially when the litharge is present, combines with the glue to form a compound which, after evaporation, dissolves with difficulty. This is especially true when evaporated at 105° C.; the residue is then quite gummy and elastic and almost insoluble in water either hot or cold. When evaporated at ordinary temperatures the residue crumbles easily and when heated with water to about 70°C. it will form an emulsion like the original material.

[2] Combined with the fat acids, as soap.

b. INTEGRAL COMPOUNDS

All of the remaining compounds investigated are to be added directly to the cement before making it into mortar or concrete, or to the water used.

INERT FILLERS

Clays, Sand, Feldspar, Hydrated Lime

	No. 41, N. Y. clay	No. 42, fire clay	No. 43, Mo. clay	No. 44, feldspar	No. 45, sand	No. 27, hydrated lime
Silica	58.30	52.86	72.91	64.02	89.50	1.34
Alumina	16.85	32.36	15.01	19.38	2.36	.45
Ferric oxide	6.41	1.44	2.79	.70	2.58	.13
Manganese oxide	.06	.02	.03	Trace.	.12	.....
Lime	4.22	.39	.59	.87	1.37	46.90
Magnesia	2.92	.22	.85	.33	.57	32.19
Sulphuric anhydride	.12	.10	.12	.10	.21	[3] 4.02
Sodium oxide	.77	.21	.80	2.52	.26	.....
Potassium oxide	2.71	.43	2.12	11.76	.70	[4] 15.05
Water (105°)	.60	1.69	1.12	.06	.20	.....
Ignition loss	7.00	10.49	3.81	.54	2.35	.....
	99.96	100.21	100.15	100.28	100.22	100.08
Rational analysis						
Free silica	25.56	13.86	43.60	.....	.....	.....
Clay material	44.29	66.82	29.89	.....	.....	.....
Felspathic	22.55	7.14	21.58	.....	.....	.....
Ignition loss	7.60	12.18	4.93	.....	.....	.....

[3] Carbon dioxide. [4] Total water.

(a) **Inert Fillers.**—The first class of this division of compounds comprises all the inert fillers; that is, those materials which act as void fillers or increase the density of the concrete and are without any action on the cement and do not themselves change. We have included in this class hydrated dolomitic lime, clays, finely ground sand, and finely ground feldspar. Some of these compounds may be partly changed in time when in the concrete. The hydrated lime may be partly carbonated, especially on the surface; the feldspar may decompose by the leaching out of the alkalies;

the sand will change but very little, being a high-grade quartz sand; the clays will be very inert, although some theories have been brought forward which assume a very important rôle for clay when mixed into concrete.

According to these theories, colloids (the plasticity of clays is a direct function of the amount of colloids present) are an excellent means of keeping slightly soluble salts in solution, in that they unite the salt ions and form aggregates which do not necessarily precipitate. By this means the precipitation of the slightly soluble salts is retarded or suppressed; in other words, the colloids of the clay protect the calcium compounds from quick hydration, and consequently prevent increase in volume due to chemical action.

The clays, sand, and feldspar were ground to pass a 200-mesh sieve before adding to the cement mortar. The analyses of these compounds follow.

(b) **Active Fillers.**—There is but one compound in this class. It is a white powder with a strong aromatic odor of kauri resin. This being in combination with potassium will possibly partly dissolve in the mixing water and in turn be decomposed by the lime present to the corresponding lime resinate, which is comparatively insoluble. The greater part of the compound is entirely inert, being china clay and hydrated lime.

Compound No. 28

	Per cent
Silica	46.66
Alumina	16.71
Iron oxide	.93
Lime	11.97
Magnesia	.72
Sulphuric anhydride	2.73
Soda	.34
Potassium oxide	1.44
Ignition loss	18.64
	100.14

(Extracted by alcohol=14.69 per cent=a resinate of potash.)

(c) **Water-Repelling Compounds.**—In this class of compounds we have stearic acid combined either with soda and potash or lime. The amount of these necessary to combine with the acid is not very great, in no case exceeding 7.5 per cent. Consequently it can be seen that the greater part of the material is hydrated

lime and magnesia lime. These act simply as void fillers. As a whole, they are inert toward the cement and water, according to the admissions of the manufacturers. However, those in which the stearic acid is combined with the soda and potash must react with the lime of the compound to form the more insoluble lime soap, or else they are valueless, owing to the ready solubility of the former soap in water.

The substance referred to as stearic acid is of course not a chemically pure stearic acid, or even in some cases a commercially pure article, but it is fat acids, obtained from various sources, which are solid at temperatures higher than ordinary room temperatures. The characteristics of the acids used in the various compounds are given in the table "Fat acids." Much difficulty was experienced in separating this small amount of organic material from such a large amount of inorganic, especially without oxidation or overheating.

	Compound No.—							
	29	30	31	32	33	34	35	36
Silica	3.74	0.74	0.59	0.33	1.11	10.22	0.43	0.32
Alumina	2.23	.62	.42	.19	.37	4.70	1.05	.....
Iron oxide	.61	.22	.18	.22	.45	.22	.21	.14
Lime	60.55	44.24	44.79	29.86	64.43	43.82	40.75	29.15
Magnesia	.86	29.91	30.54	20.56	.86	.70	26.54	21.07
Sodium oxide	2.42	Trace.	Trace.	Trace.	2.12	.34	.13	Trace.
Potassium oxide	.46	.00	.00	.00	.23	.70	.41	Trace.
Sulphuric anhydride	Trace.	Trace.	Trace.	Trace.	Trace.	1.32	.06	.60
Carbon dioxide	2.63	4.67	3.20	1.60	2.71	4.21	2.72	1.22
Total water	18.55	15.90	16.87	9.70	20.48	17.29	23.69	9.01
Paraffin	.....	.....	.....	.....	.....	.....	3.52	.....
Fat acids	7.98	3.20	3.30	37.73	6.99	16.20	.64	38.91
	100.03	99.50	99.89	100.19	99.75	99.72	100.15	100.42
Fat acids—								
Melting point °C	53.0	46.0	43.0	57.5	54.5	55.0	.....	56.1
Combining weight[5]	256	278	233	276	272	256	.....	258
Iodine figure	2.21	Trace.	Trace.	2.10	1.00	.....	.....	.....

[5] Compounds Nos. 29 and 33 combined with sodium and potassium; Compounds Nos. 30, 31, 32, and 33 combined with calcium.

(d) **Waterproofing Cements.**—Two waterproofing cements have been investigated. One of these was recommended especially as a coating, and has been already given under that division. The remarks given there apply here also. The analysis of the cement follows:

Compound No. 37

	Per cent
Silica	23.75
Alumina	5.96
Iron oxide	1.97
Lime	64.44
Magnesia	.91
Sulphuric anhydride	1.21
Sodium oxide	.11
Potassium oxide	.73
Ignition loss	1.07
	100.15

	Per cent
Carbon dioxide	0.52
Organic (fat acid)	.10
Water	.45

This is a cement to which a certain amount of water-repelling material has been added. As extracted, this consists of a potash soap of a mixed fatty acid. The quantity was so small that it could not be identified.

(e) **Active Liquid Fillers.**—There are three compounds in this class. The first is a coal-tar product, the volatile oils having been almost entirely removed. The tar would tend to bind together the particles of the cement and fill the voids. The exact nature of the chemical action which takes place, if any, is not known.

The second compound is a mixture of a semidrying fish oil with water glass. The former would tend to be slowly saponified by the lime of the cement; the latter would also form a lime silicate, in part. Both are much in excess, however, of all lime available.

Compound No. 38

Distillates:	Per cent
Up to 105° (water and ammonia, 48 per cent benzol, light oils)	2.50
105 to 210° (benzol, light oils; small quantity naphthalene)	3.20
210 to 240° (almost entirely naphthalene)	13.00
240 to 310° (heavy red oils containing a little naphthalene)	20.00
(Residue is a very hard brittle pitch.)	
Volatile at 105°	30.70
Free carbon	15.00
Ash	.40

Compound No. 39

	Per cent
Soap	1.05
Oil	47.29
Ash water glass (sodium silicate)	11.64
Volatile (water)	40.02
	100.00

The oil is a very offensive semidrying fish oil; specific gravity at 15° equals 0.9277; iodine figure, 163; saponification equivalent, 266; melting point of the fat acids, 36.5°C. It is menhaden oil.

The small amount of soap is a result of the combination of some of the free alkali of the water glass with the fish oil.

Compound No. 40

	Per cent
Silica	Trace
Alumina and iron oxide	0.25
Calcium chloride	27.19
Magnesium chloride	0.04
	27.48

(Remainder is water. Contains 0.15 per cent of a flocculent material which is an iron resinate (resin-shellac).

The calcium chloride in this material might form in the concrete an oxychloride cement. These, under certain conditions, have considerable value, but are not hydraulic, such as would be the case when used with a hydraulic cement for waterproofing purposes, as shown by the permeability tests. The value of the very small amount of iron resinate is unknown.

IX. OUTLINE OF TESTS OF DAMP-PROOFING AND WATERPROOFING MATERIALS

1. PERMEABILITY

Number of compound	Quaking-consistency mortar of 1 part Portland cement to—	Thickness of test piece in inches	Number of test pieces	Age in weeks when tested	Age in weeks when retested
0	4 parts sand	2	3	2	4, 13, 26
	do	2	3	4	13, 26
	do	2	3	13	26
	do	2	3	26	.....
	do	2	3	2	4, 13, 26, 52
	6 parts sand	2	3	2	4, 13, 26, 52
	8 parts sand	2	3	2	4, 13, 26, 52

1. **PERMEABILITY**—Continued.

Number of compound	Quaking-consistency mortar of 1 part Portland cement to—	Thickness of test piece in inches	Number of test pieces	Age in weeks when tested	Age in weeks when retested
27–40	4 parts sand	2	[7] 3	2	4,13,26,52
	6 parts sand	2	[7] 3	2	4,13,26,52
	8 parts sand	2	[7] 3	2	4,13,26,52
23		2	3	2	4,13,26,52
41–45	4 parts sand	2	[7] 3	4	13,26,52

[7] Each.

2. **ABSORPTION**

Number of compound	Quaking-consistency mortar of 1 part Portland cement to—	Number of tests by weeks				Total tests
		4	13	26	52	
0	4 parts sand	3	3	3	3	12
	6 parts sand	3	3	3	3	12
	8 parts sand	3	3	3	3	12
27–40	4 parts sand	3	3	3	3	[8] 12
	6 parts sand	3	3	3	3	[8] 12
	8 parts sand	3	3	3	3	[8] 12
23				3	3	6
41–45	4 parts sand	3	3	3	3	[8] 12

[8] For each compound.

3. **DAMP PROOFING**

Compounds Nos. 27 to 40, inclusive, were incorporated in a 1–4, 1–6, and 1–8 quaking-consistency mortar. Three disk-shaped test pieces 7½ inches in diameter and 2 inches thick were made and tested for each mortar.

Compound No. 23 was made into similar disk-shaped test pieces of the same size and tested.

Compounds Nos. 1 to 26, inclusive, known as "coating compounds," were tested by applying them to the surface of disk-shaped test pieces 7½ inches in diameter and 2 inches thick of 1–4 mortar in which the sand passing a No. 20 sieve was removed so as to make the material more absorptive and present a more open surface. The coating was applied to one surface and entirely around the edge, the coated surface being exposed to water and

the opposite surface being covered by a moisture-indicating medium.

4. TENSION AND COMPRESSION

Number of compound	Quaking-consistency mortar of 1 part Portland cement to—	Number of each tension and compression test by weeks						Total tests
		1	2	4	13	26	52	
0	4 parts sand	3	3	3	3	3	3	36
	6 parts sand	3	3	3	3	3	3	36
	8 parts sand	3	3	3	3	3	3	36
27–40	4 parts sand	3	3	3	3	3	3	504
	6 parts sand	3	3	3	3	3	3	504
	8 parts sand	3	3	3	3	3	3	504
23		3	3	3	3	3	3	36
41–45	4 parts sand	3	3	3	3	3	3	180

X. LABORATORY EQUIPMENT USED IN WATERPROOFING TESTS

The general equipment and apparatus used in these tests was the same as described in Part I, with the following additional apparatus: Tension briquette molds, 2-inch cube molds, and glass pallets, as shown in Fig. 8; a 10 000-pound capacity compression testing machine, as shown in Fig. 25; a 40 000-pound capacity hydraulic pressure compression testing machine, as shown in Fig. 26; and a 1000-pound capacity briquette-testing machine.

XI. DESCRIPTION OF TESTS OF DAMP-PROOFING AND WATERPROOFING MATERIALS

1. PROPORTIONS

All batches were computed and computations checked in a record book previous to mixing, the proportions being by volume, but were converted into weight measure for greater accuracy as fully described in Part I.

2. CONSISTENCY

Only one consistency was used, which has been designated as a quaking consistency which, when molded into a ball with the hands, would adhere when held between the thumb and finger,

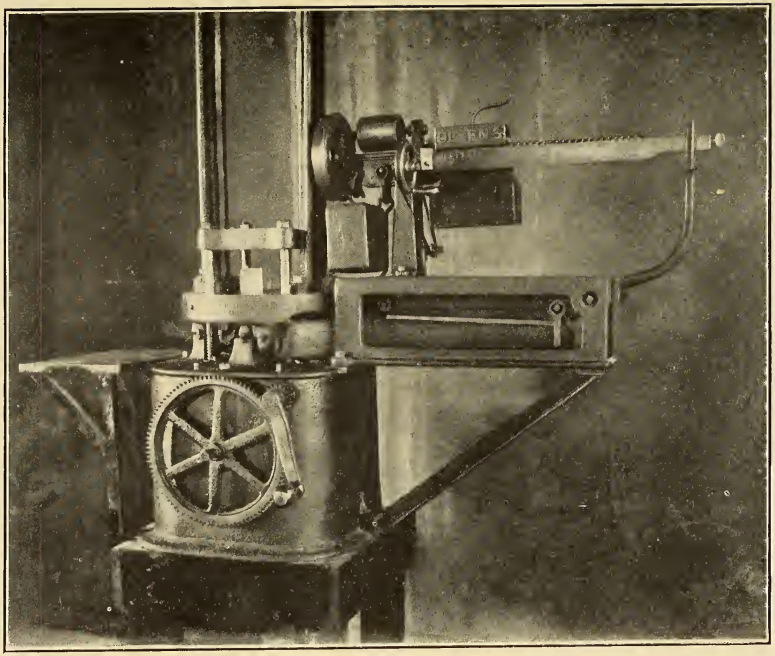

Fig. 25.—*10,000-pound Capacity Compression Testing Machine.*

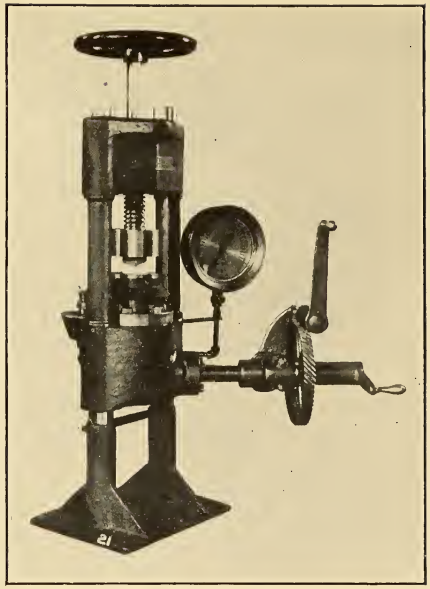

Fig. 26.—*40,000-pound Capacity Hydraulic Pressure Compression Testing Machine.*

but which would not do so with the addition of any more water. The percentage of water required in terms of total dry weight of sand and cement was predetermined for each mortar and kept the same throughout the series regardless of the addition of compounds which might cause a slightly drier resultant. Water could easily be brought to the surface with a trowel.

3. MIXING

Three permeability test pieces, 12 absorption test pieces, 18 compression test pieces, and 18 briquettes were all molded from one batch so as to insure like conditions. The mixing was done by hand in a manner as fully described in Part I, page 15. The damp-proofing test pieces were molded separately, three in a batch.

The recommendations of the manufacturers were followed in proportioning and incorporating the integral compounds. It was found that any mortar richer in cement than a 1–4 proportion was impervious in itself under a hydrostatic pressure of 20 pounds to the square inch; thus even though some manufacturers stated that their compound must be incorporated into a 1–2 or a 1–3 proportion of mortar, their wishes must obviously be disregarded in this respect.

The quantity of each compound incorporated in the mortars and the method of incorporating is given in accompanying table:

Integral Compounds, Quantity Used, and Manner of Incorporating

No. of compound.	Quantity of each compound used.	Manner of incorporating in mortar.
	Grams compound to grams cement.	
[9] 23		
27	2–100	Mixed with dry cement before mixing with sand and water.
27*b*	10–100	Do.
28	5–100	Do.
29	2–100	Do.
30	2–100	Do.
31	2–100	Do.
32	2–100	Do.
33	2–100	Do.

Integral Compounds, Quantity Used, and Manner of Incorporating—Con.

No. of compound.	Quantity of each compound used,	Manner of incorporating in mortar.
	Grams compound to grams cement.	
34	25–1000	Mixed with dry cement before mixing with sand and water.
35	1–100	Do.
36	2–100	Do.
[10] 37		
38	5–100	Mixed with dry sand and cement.
	Cubic centimeters liquid compound to cubic centimeters water.	
39	416–10000	This mixture was used as the mixing water.
40	10–100	Do.
	Grams compound to grams cement.	
[11] 41	13–100	Mixed with dry cement.
[11] 42	16–100	Do.
[11] 43	16–100	Do.
[11] 44	20–100	Do.
[11] 45	22–100	Do.

[9] This is a waterproofed cement mortar and was tested as received.
[10] This is a waterproof cement, and it was substituted in place of all of the Portland cement.
[11] These materials are all so proportioned that, assuming the weight of cement at 100 pounds per cubic foot (1.60 grams per cubic centimeter), the compound is 20 per cent by volume of the cement. The relative weights in grams per cubic centimeter are as follows: 41=1.04, 42=1.28, 43=1.28, 44=1.65, and 45=1.75.

4. MOLDING

a. PERMEABILITY TEST PIECES

The molds for these test pieces were made from wrought-iron well casing, 7½ inches in diameter, cut into sections 2 inches in length. They were painted white on the outside and marked with the test number when filled.

The empty molds were wetted on the inside and were placed three in a set on a board which had an oiled galvanized-iron top. The mold was filled in three operations, each layer being thoroughly and systematically tamped with a 1-pound peen-shaped tamper, and the top struck off level with the edge of a trowel, the surface being left rough. After storage for 24 hours in the moist closet both the top and bottom surfaces were brushed with

a wire brush which removed any thin "skin" of cement which may have been brought to the surface, making the surface rough and homogeneous with the mass. The iron mold was not removed from the test piece till the test was completed.

b. DAMP-PROOFING TEST PIECES

The damp-proofing test pieces were of the same size and shape as the permeability test pieces, but they were molded in heavy galvanized-iron molds which could be opened and removed from the test piece immediately after molding. These test pieces were tamped and leveled off in the same manner as the permeability test pieces, but the mortars containing compounds to be tested were mixed with a slightly less amount of water so that the molds could be removed immediately. The surfaces of those test pieces made with coarse sand, which were to be coated, were not brushed with a wire brush, as the surface was rough and porous. The test pieces were stored in the damp room.

c. ABSORPTION TEST PIECES

These were 2-inch cubes, molded in three-gang brass molds, illustrated in Fig. 8. The mold was filled and the material pressed into place with the thumbs and thoroughly compacted and troweled. The mold was then turned over on a glass plate and the other surface compacted and troweled. The test pieces were stored in the moist closet for 24 hours, the molds removed, and the test pieces stored on shelves in the damp room until tested.

d. COMPRESSION TEST PIECES

These were of the same size and shape as the absorption test pieces and were made in the same molds and manner as above described.

e. TENSION TEST PIECES

The molds for these test pieces were the standard five-gang tension briquet molds illustrated in Fig. 8. The material was pressed into place with the thumbs, the mold being turned and both surfaces compacted and troweled. After 24 hours' storage in the moist closet the molds were removed and the test pieces were stored in the damp room.

5. STORAGE

All test pieces were stored on shelves in the damp room illustrated in Fig. 9, between the time of molding and testing, and were sprinkled three times each 24 hours.

6. TESTING

a. PERMEABILITY TEST PIECES

The permeability test pieces were brought from the damp room on the morning of the day when they were to be tested, placed in the test-piece holder, connected to the pipe rack, and the test was conducted in the same manner as described in Part I. The piping was so arranged that two sets of tests at different water pressures could be conducted at the same time.

b. DAMP-PROOFING TEST PIECES

The damp-proofing test pieces having compounds incorporated were brought from the damp room when 21 days old and permitted to surface dry in the air for from 4 to 6 days, when a round filter paper 6 inches in diameter was secured to one surface with a thin wheat-flour paste, the filter paper being struck with the palm of the hand, so that it conformed to the roughness of the surface as shown in Fig. 27. The filter paper was now painted with an alcoholic solution of phenol-phthalein, which turns pink in the presence of alkaline water. The test piece was placed, filter-paper side up, in a trough of water one-half inch deep on the morning of the twenty-eighth day. The test piece being 2 inches thick and the water in which it was placed only one-half inch deep, if moisture was absorbed by the material to the upper surface it carried with it enough alkali from the cement to indicate the moisture on the filter paper. An examination of the specimen was made every hour for the first 8 hours and once every 24 hours thereafter.

The damp-proofing test pieces to be coated were brought from the damp room when 6 days old and allowed to thoroughly surface dry in the air which required from 4 to 6 days, when one surface and the entire edge was given the first coat of compound in the manner prescribed by the manufacturer. After permitting this

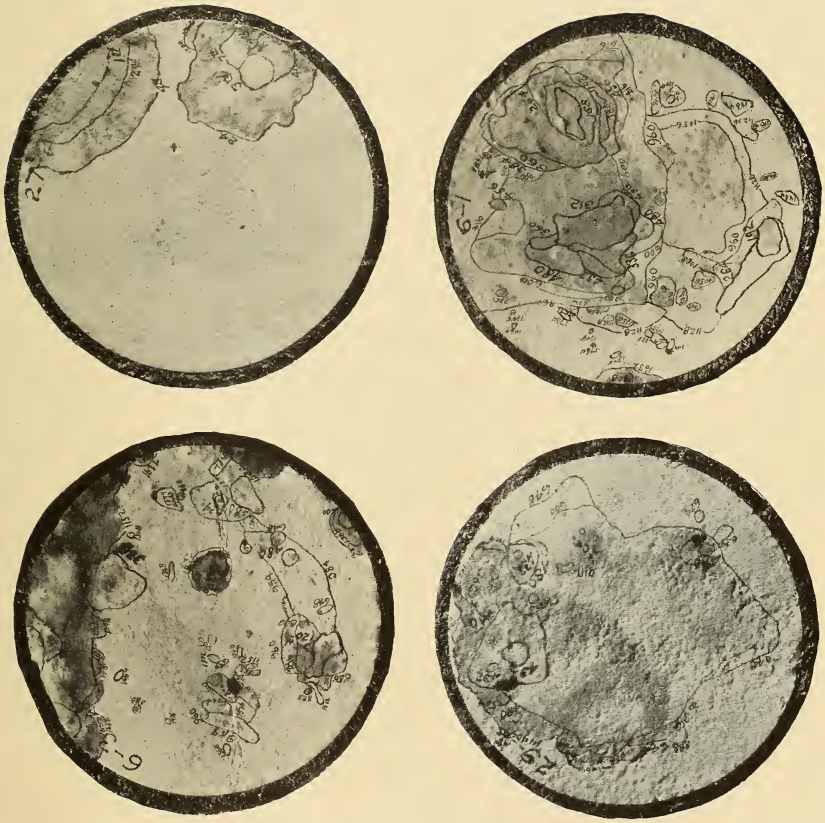

Fig 27 —*Damp-proofing Test Pieces.*

to dry for the period as specified by the manufacturer, the second coat was applied. Two coats of each compound were applied, although some manufacturers stated that one coat would be sufficient. On the twenty-first day after molding the filter paper was applied, the test piece placed in the trough of water when 28 days old, and the test conducted as described above. Of course, the slightest break in this coating would permit the moisture to enter and, by capillarity, be carried to the upper surface. Some test pieces which did not fail in the half-inch depth of water were placed in a trough in which the water was 1 inch deep. These are indicated with the period of exposure, in the tables.

c. ABSORPTION TEST PIECES

These were brought from the damp room on the day when tested, weighed to one five-hundredth of a gram and immersed so that the top surface was 3 inches below the surface of the water. The test pieces brought from the damp room when 28 days old were immersed for a period of 28 days previous to drying, when they were weighed. However, the gain in weight after this 28-day immersion was found to be less than 1 per cent of the original weight when first taken from the damp room, showing that the test pieces had absorbed nearly the maximum amount of water in the damp room. Hence, the test pieces tested at subsequent periods, 13, 26, and 52 weeks, were immersed for only 7 days instead of 28 days, previous to drying.

After this initial immersion the test pieces were placed in an oven the temperature of which was maintained between 100° and 110° C. (212° to 230° F.), where they were dried, being weighed twice each day until they showed no further loss in weight, which required about six days. They were taken from the oven and allowed to cool slowly in the air until the following day, when they were again immersed to the same depth as the first immersion. The test pieces were taken from the water and weighed after 1, 3, 7, 14, and 28 days' immersion. The purpose of this long immersion was to give the compound time to leach out and lose any antipathetic properties it might have. The test pieces tested at the 26-week period were also weighed after 30 minutes' immersion.

d. COMPRESSION TEST PIECES

The 2-inch cubes, upon which the compressive strength was determined, were tested in the 10 000-pound hand-power testing machine, or test pieces requiring more than 10 000 pounds total load were tested in the 40 000-pound hydraulic testing machine. Practically all test pieces gave a theoretical break forming a cone top and bottom.

e. TENSION TEST PIECES

The tension briquettes were tested on a standard testing machine. A little trouble was experienced in testing the very lean mixtures in that they would break in the grips, but the greatest care was observed and results are uniform and comparable.

XII. RESULTS OF TESTS

1. COMPUTATIONS

a. PERMEABILITY TESTS

The quantity of water flowing through the permeability test pieces for one minute at each period when a reading was taken was recorded.

The cubic centimeters of water passed per minute per square centimeter of surface was computed by dividing the total quantity of water passed through the test piece in one minute by its area in square centimeters (126.68). Only this computed result is reported in the accompanying tables, and an average is taken for each three similar specimens. Where there was no measurable flow or drip but the exposed surface continued to remain moist, showing that some water was penetrating, it is recorded in the tables as "moist." Readings recorded in the tables as zero indicate that no moisture whatever appeared on the exposed undersurface.

b. DAMP-PROOFING TESTS

There were no computations on these tests, but the observed results of the test are reported directly in the tables. In Fig. 10 is shown in detail four test pieces which have failed and are typical of all failures.

c. ABSORPTION TESTS

The absorption in terms of the weight and volume is computed from the recorded results in the manner as stated in Part I, page 18.

d. COMPRESSION TESTS

The compression test pieces being 2-inch cubes, had a total sectional area of 4 square inches underload; thus the ultimate strength in pounds per square inch was obtained by dividing the total load by 4. Only a summary of this computed value is reported in the tables.

e. TENSION TESTS

The tension briquettes have a sectional area of 1 square inch; so that the total breaking load is in pounds per square inch, and a summary is reported directly in the tables without computation.

2. TABULATED RESULTS AND DIAGRAMS

It will be observed that the quantity of water passing through the test pieces in some cases is very small; especially is this so with the 1 : 4 proportion mortars. From the appearance of the lower surface the water comes through evenly, collecting on the lower surface and finally dripping.

One drop under these conditions was found to be equal to approximately one-tenth of a cubic centimeter, and this divided by the exposed area, 126.68 square centimeters, is 0.0008 cubic centimeter or 0.8 cubic millimeter per square centimeter of exposed surface. Thus it will be seen that although three similar test pieces may apparently seem to be widely divergent in permeable qualities, in reality they are not, and as a whole the tests are very regular and uniform. The comparative results are also shown diagrammatically.

Tables 11 and 12 (Figs. 28 and 28a).—The untreated mortar is slightly permeable at all ages, but the permeability decreases with the continuation of the flow at the earlier periods. In the later tests it will be observed that the flow is about the same at the end of the seventh or twenty-fourth hour as at the first hour. This decrease in flow at the two and four week tests is probably due to a silting up of the mortar, the water loosening up small particles and carrying them into and filling up the pasageways.

In comparing the results of tests on untreated mortars of Part II with similar mortars of Part I, it will be observed that those of Part II are the more permeable, which may be explained by the fact that the surfaces of the test pieces of Part I were not brushed with

a wire brush soon after molding, as were those of Part II, and after a period of several weeks this surface became so hard it was prac-

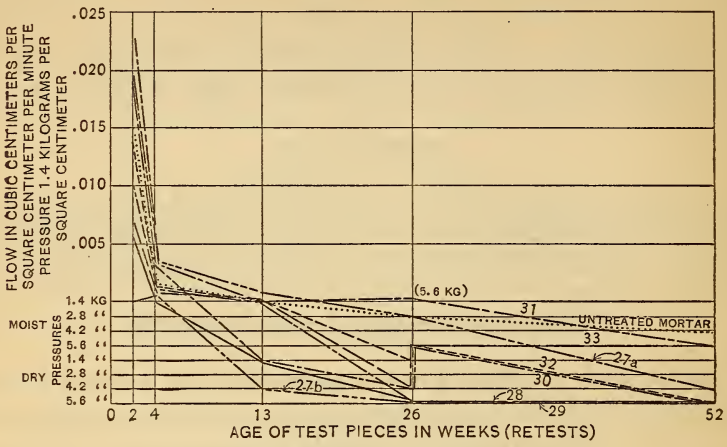

Fig. 28.—*Permeability of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

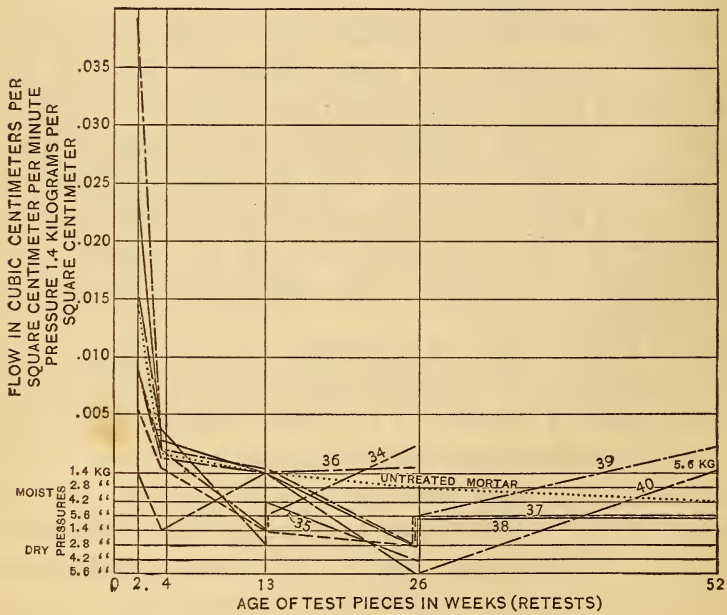

Fig. 28a.—*Permeability of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

tically impossible to clean the surface so effectively with a wire brush. Compare with Table 17.

Compound No. 32.—The value of the addition of this compound is not apparent until the 13-week test. At 26 and 52 weeks it is somewhat less permeable than the untreated mortar. However, it is a question as to whether this more impermeable quality is not due to the fact that the added material simply furnished more fine particles for closing up the voids. If its greater impermeability is due to the "water-repelling" qualities of the compound, it should have been as effective at the two-week test as at later tests.

Compound No. 31.—The value of this compound is slightly apparent at the 26-week period, and to some extent at the 13 and 52 week periods, but not so markedly as the previous compound. It is peculiar how the individual test pieces vary; at 13 weeks No. 1 was permeable and No. 2 was not; at 26 weeks conditions were reversed; and at 52 weeks they were again reversed.

Compound No. 33.—The addition of this material had very little effect on the permeability of the mortar. However, it was more impermeable after the four-week period than the untreated mortar.

Compound No. 30.—The result of the addition of this compound was about the same as 32, showing a marked decrease in permeability after the four-week tests.

Compound No. 29.—The apparent value of the addition of this material has been delayed until the 26-week test, after which test pieces were much less permeable than the plain mortars.

Compound No. 28.—The value of this compound is evident from the earliest test and continues to the 52-week test. Its value, however, can probably be attributed to the large quantity (5 per cent) used, which simply as inert void-filling material would be expected to yield the results obtained. Compare with 27b.

Compound No. 27a.—The reason for the greater permeability at the early period of these test pieces containing 2 per cent of the inert filler, hydrated dolomitic lime, is not apparent. From this test it would seem that the fatty repelling substance in the above compounds is of considerable value if only a small quantity of inert material is used, but from the succeeding test it will be observed that the same or even greater beneficial results can be obtained by the addition of a larger percentage of the inert material.

Compound No. 27b.—This is the most efficient medium employed and resulted in an almost impermeable mortar at the two-week

test. Its value is probably due to its void-filling properties and the same results could be expected from any other finely ground inert material, such as sand, clay, etc.

Compound No. 37.—It is slightly less permeable than the untreated mortar, but its value is not apparent until the 13-week test. Since this is simply a cement with the repelling substance added and it was used in the same proportion as the Portland cement used in the untreated mortar, it would seem that either the cement was of different quality or the fatty repellent substance plays a part and is beneficial.

Compound No. 40.—The addition of this material has affected the mortar and made it much more impermeable; in fact, at four weeks it is the most impermeable of any of the mortars. This may be explained by the fact that the addition of the compound made the mixture of wetter consistency; but it seems to be very irregular, for at 13 weeks and 52 weeks it seems to lose its impermeable qualities slightly.

Compound No. 39.—These tests indicate that the addition of the compound is not markedly beneficial.

Compound No. 38.—The mortar treated with this compound has little value over the untreated mortar in so far as its permeable qualities are concerned.

Compound No. 34.—The addition of this compound somewhat decreased the permeability, which, however, was not apparent until the 13-week test. This compound is very similar to 32, as it contains a very large percentage of repellent substance. The cause of the failure of two of the test pieces at the 26-week period is not known.

Compound No. 35.—The value of the addition of this compound was apparent at the 13-week period, and continued so through the 26-week test. It is peculiar that these specimens should be so impermeable, considering the fact that only 1 per cent of the compound was added.

Compound No. 36.—The addition of this compound only slightly affected the permeability.

Compound No. 23.—This test can not be directly compared with the others, as it is practically a test on a 1–3 proportion mortar. (See analysis.)

Tables 13 and 14 (Figs. 29 and 29a).—In these tests it will be observed that the value of the addition of the compounds was not

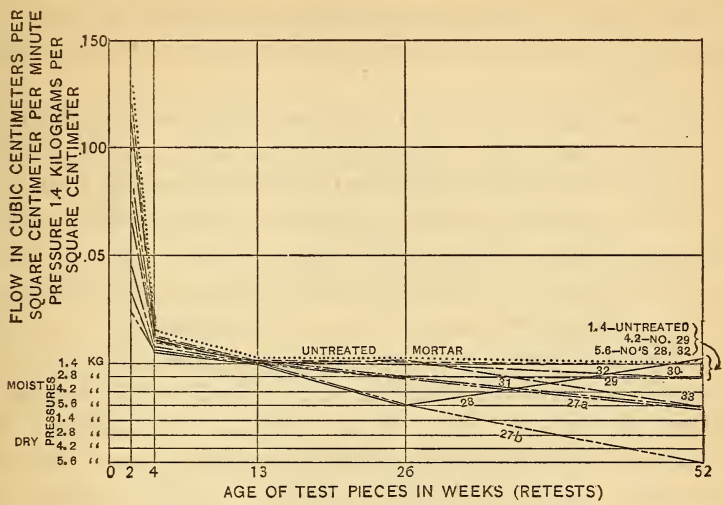

Fig. 29.—*Permeability of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

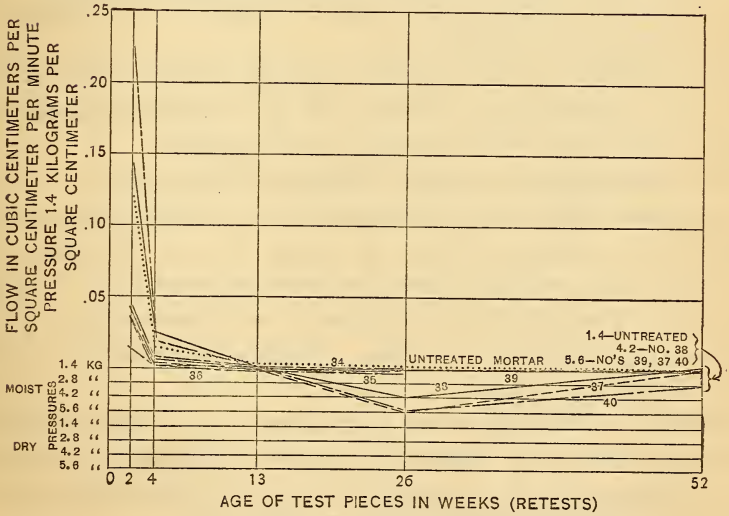

Fig. 29a.—*Permeability of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

apparent in most cases until the 26-week period, and some of the compounds which were somewhat effective in the 1–4 mixture were

not at all effective in the 1–6 mixture. The efficiency of 2 per cent of inert hydrated dolomitic lime filler is apparently as great as that of any of the water-repelling compounds in this mortar. Compound No. 27b was the most effective waterproofing medium in this mortar.

The permeability decreased with the continuation of the flow at the two and four week tests, but not at later periods; in fact, in several cases it increased with the continuation of the flow. However, most of the test pieces decreased in permeability with age.

Comparing these tables with Table 1, Part I, it will be noted that the test pieces of the latter were the more impermeable, which may be explained by the fact that the test pieces in Part II were brushed with a wire brush while the cement was still green. Those of Part I were brushed after the cement had acquired a hard set.

Tables 15 and 16 (Figs. 30 and 30a).—The addition of the compounds to this lean mortar had no effect in any case on the permeability up to the 26-week period. At the 52-week period several of the mortars containing compounds are slightly less permeable than the untreated mortar, but not to any decided degree. As a whole, the addition of so small a quantity of compound to so lean a mixture is valueless.

The quantity of water passing through the test piece decreased with the continuation of flow, but to a greater extent at the earlier tests than at the 26 and 52 week periods.

The permeability of mortar decreased with its age.

Compared with the 1–6 mortar, the 1–8 mortar was as impermeable at 4 weeks as the 1–6 mortar was at 2 weeks, and at 52 weeks both mortars have the same permeability. Compared with the 1–4 mortar, the 1–8 mortar is as impermeable at 52 weeks as the 1–4 mortar is at 13 weeks. These comparisons are between the untreated mortars.

Table 17.—The purpose of these tests was to show the effect of retesting, that is, the value of a test piece which had been tested at an earlier age as compared with one of the same age which had not been previously tested.

Since this was a 1–4 mortar, Nos. 1, 2, and 3 should be directly comparable with the untreated mortar of Table 11, and the result of the tests should be, and are, similar.

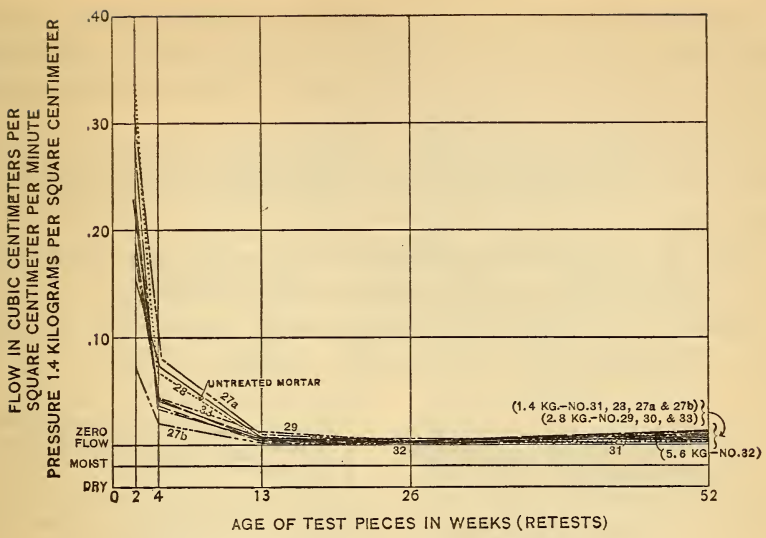

Fig. 30—*Permeability of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

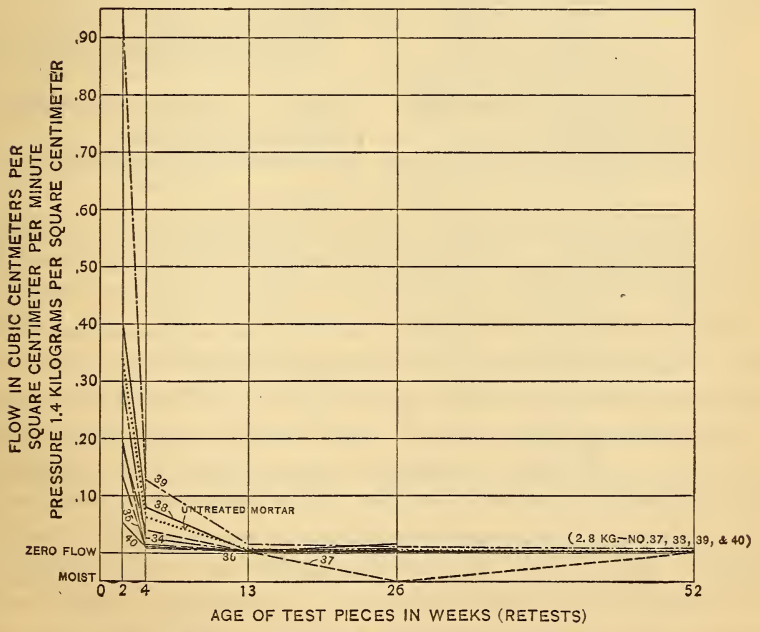

Fig. 30a.—*Permeability of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

Comparing the tests with the retests—at 4 weeks they were both practically the same; at 13 weeks there was also little or no difference; at 26 weeks the retested test pieces were more impermeable than the original test pieces at this age.

All test pieces become more impermeable with age and also slightly less permeable with the continuation of the flow at the early ages.

Table 18.—All the fillers are quite effective, but the clays appear to be slightly more effective than the sand or feldspar.

Table 19.—The value, for damp-proofing purposes, of the addition of compounds to a 1–4 mortar mixture is evident from the

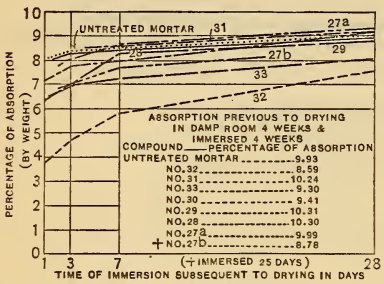

Fig. 31.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 4 parts No. 1 sand.

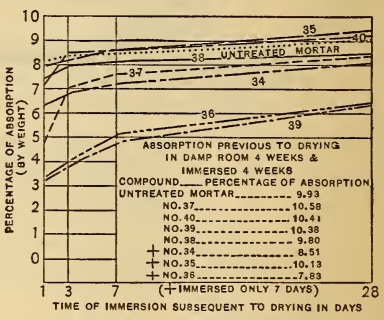

Fig. 31a.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 4 parts No. 1 sand.

result recorded in the table. It will be observed that all the mortars containing water-repelling compounds were damp proof; also the mortar containing 10 per cent of the inert hydrated lime filler, but the mortar containing only 2 per cent of the hydrated lime failed. Compound No. 38, which showed little or no value in the permeability tests, also does not seem to be effective in this test.

This damp-proofing test of itself should not condemn these materials, as all damp-proofing compounds are not expected to stand constant exposure to water. The tests were made to furnish comparable data, and it is believed that they have served the purpose. In the lean mortars the results were more striking, in that several of the compounds were unquestionably effective to a marked degree and the inert filler failed. The same compounds which were the most effective in the permeability tests were the most effective in these tests with one or two exceptions.

Considering the damp-proofing tests as a whole, several of the compounds were effective, but it would also seem that the same effective and possibly a more positive result can be obtained more

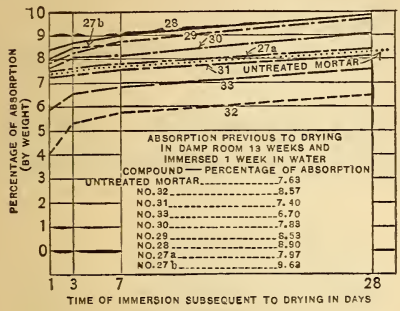

Fig. 32.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 4 parts No. 1 sand.

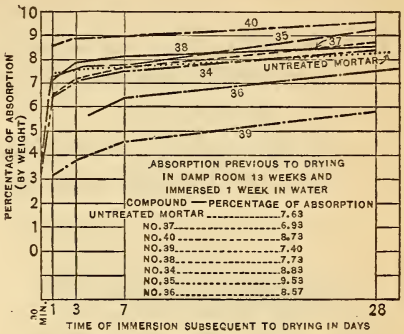

Fig. 32a.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 6 parts No. 1 sand.

economically by using sufficient cement and correct proportioning of the materials entering into the mortar or concrete and thus obtaining a maximum density.

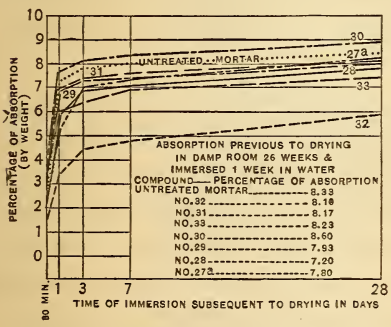

Fig. 33.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 4 parts No. 1 sand.

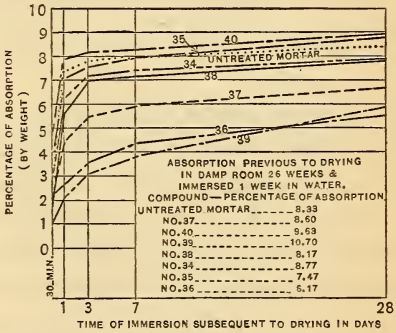

Fig. 33a.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 4 parts No. 1 sand.

Table 20 (Figs. 31, 31a, 32, 32a, 33, 33a, 34, 34a.).—The results of the absorption tests are very uniform; in fact much more so than had been expected.

The moisture contained in the test pieces after storage in the damp room and immersion previous to drying, was the same

in almost every case regardless of the compound incorporated. The absorption after drying, however, varies with the different compounds. In some cases the absorption is very slow at first, but after the 28 days' immersion they all have approximately the same absorption, with a few exceptions.

The inert filler seems to have very little or no effect on the absorption at any time.

Comparing with the results of 4 and 13 week tests, it will be observed in the 26-week tests that the absorption after drying, of

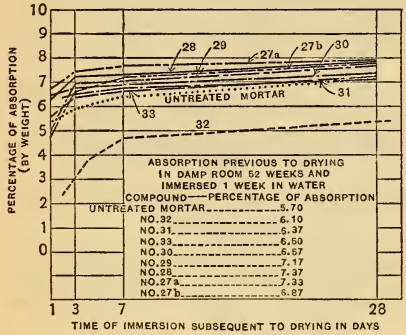

Fig. 34.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 4 parts No. 1 sand.

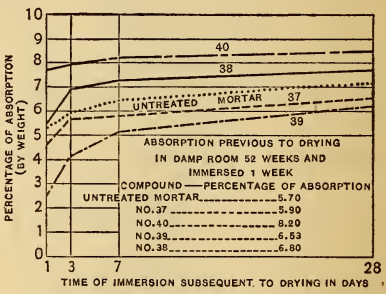

Fig. 34a.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 4 parts No. 1 sand.

the mortars having compounds incorporated have decreased much more rapidly with age than the untreated mortars.

At the 52-week period it would seem that most of the treated mortars had lost their increased effectiveness, not that they have increased any in absorption over the 26-week tests but that the untreated mortar has decidedly decreased in absorption between the 26 and 52-week period and is now as low as the treated mortars. In fact, previous to drying, the untreated mortar is even less absorptive than the treated mortars.

The rate of absorption after drying, however, was less in several cases for the treated mortars than for the untreated mortar.

The absorption has decreased with the age of the mortar in every case.

Table 21 (Figs. 35, 35a, 36, 36a, 37, 37a, 38, 38a).—The value of the addition of the compounds was not as apparent in

this leaner mortar. The total absorption before drying was practically the same in every case, irrespective of the addition of the compound, but the rate of the absorption after drying was

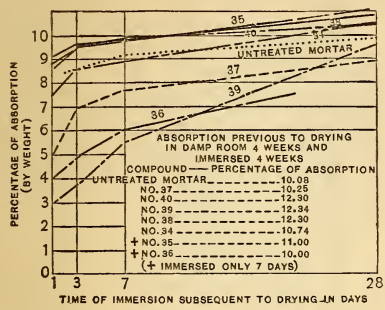

Fig. 35.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 6 parts No. 1 sand.

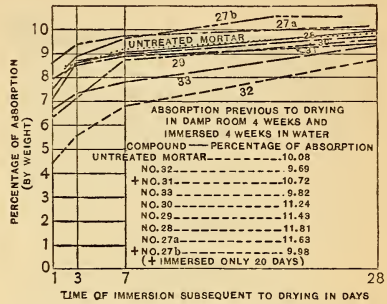

Fig. 35a.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 6 parts No. 1 sand.

much slower in several cases in which the compound was incorporated, than with the untreated mortar. The inert filler is again practically valueless. After 28 days' immersion subsequent to the drying, all compounds have practically lost their effectiveness and the absorption is nearly the same as that of the untreated mortar.

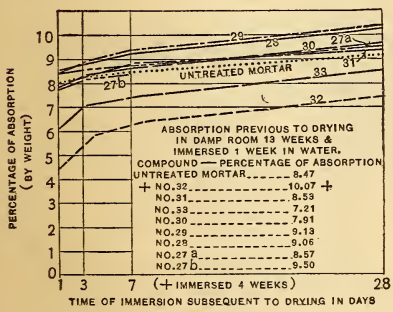

Fig. 36.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 6 parts No. 1 sand.

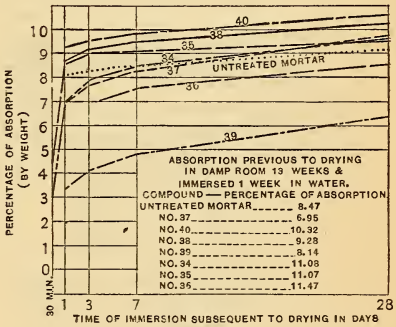

Fig. 36a.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 6 parts No. 1 sand.

Comparing the 13-week tests with the 4-week tests, it will be observed that the absorption after drying at the end of 28 days is only slightly less at 13 weeks than at 4 weeks.

In the 26-week tests the rate of absorption after drying is slightly less in the case of some of the mortars containing compounds, but the absorption before drying is approximately the same in every

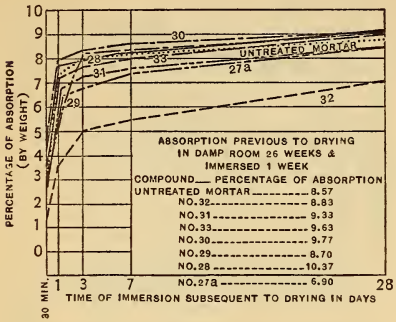

Fig. 37.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 6 parts No. 1 sand.

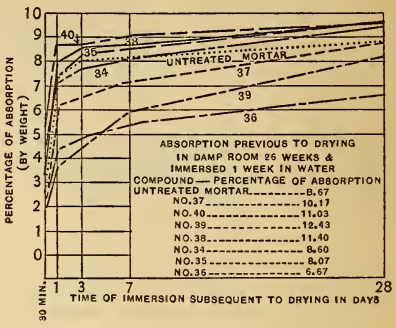

Fig. 37a.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 6 parts No. 1 sand.

case. Also at 28 days after drying the absorption is practically the same with the treated as with the untreated mortar, with one or two exceptions.

At the 52-week period several of the treated mortars still show a slower rate of absorption after drying than the untreated mortar,

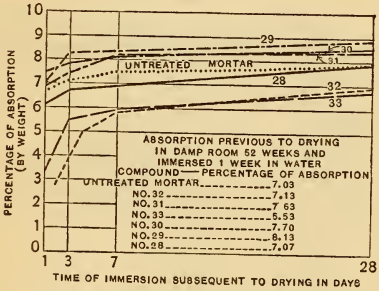

Fig. 38.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 6 parts No. 1 sand.

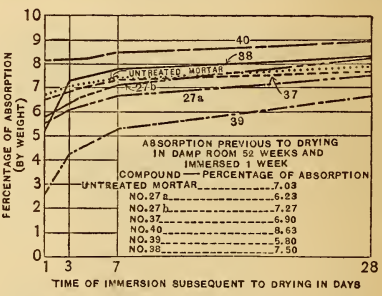

Fig. 38a.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 6 parts No. 1 sand.

but as in the previous earlier tests the absorption previous to drying was practically the same for the treated mortars as for the untreated mortar.

The absorption has decreased slightly with the age of the mortar.

Table 22 (Figs. 39, 39a, 40, 40a, 41, 41a, 42, 42a).—In the 4-week tests, previous to drying, the absorption is practically the same for the treated as for the untreated mortar. The rate of absorption after drying is practically the same for both in all but

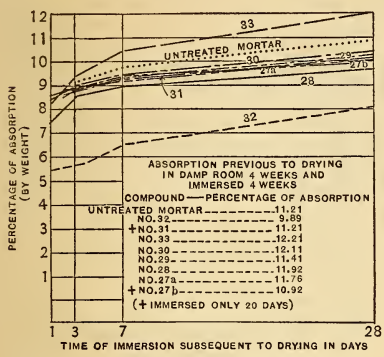

Fig. 39.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 8 parts No. 1 sand.

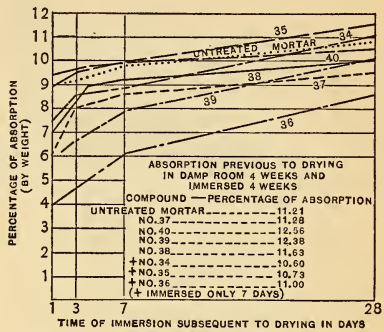

Fig. 39a.—*Absorption of Waterproofed Mortars.*

Age 4 weeks—1 part Portland cement to 8 parts No. 1 sand.

one or two cases. The effect of the addition of the compound is marked, however, in these several exceptions.

Comparing with Table 20, it will be observed that the lean mortar is slightly more absorptive than the richer 1–4 mortar.

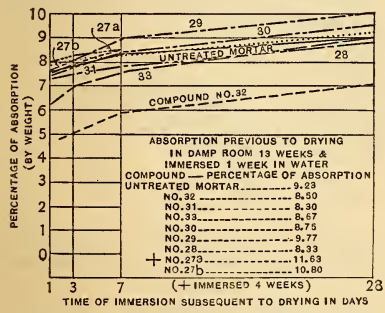

Fig. 40.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 8 parts No. 1 sand.

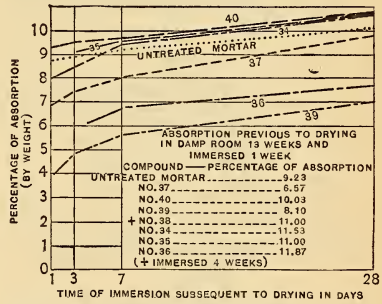

Fig. 40a.—*Absorption of Waterproofed Mortars.*

Age 13 weeks—1 part Portland cement to 8 parts No. 1 sand.

In almost every respect the results of the tests made at the 13-week period were the same as those made at the 4-week period. One exception seems to be Compound No. 39, which was consider-

ably more effective at the 13-week period than at the 4-week period.

At the 26-week period most of the mortars containing compounds have practically the same absorption as the untreated

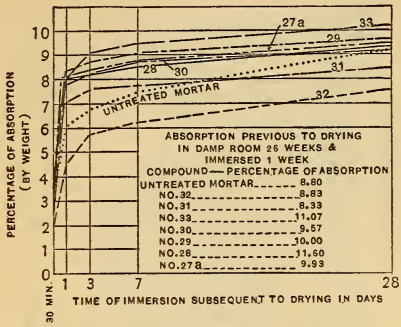

Fig. 41.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 8 parts No. 1 sand.

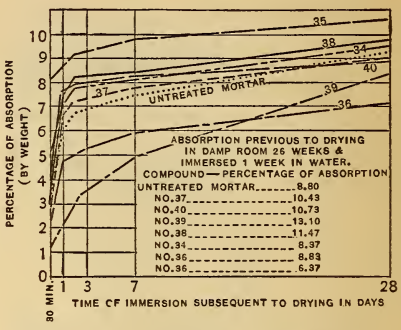

Fig. 41a.—*Absorption of Waterproofed Mortars.*

Age 26 weeks—1 part Portland cement to 8 parts No. 1 sand.

mortar but there are several exceptions. Compound No. 36 had decreased the absorption somewhat from the preceding age as has also Compound No. 32.

The absorption has decreased with the age of the mortar.

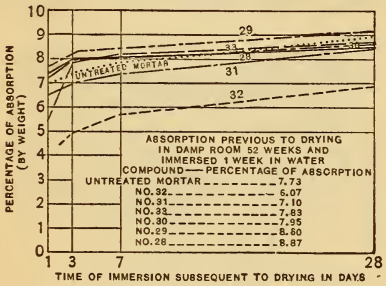

Fig. 42.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 8 parts No. 1 sand.

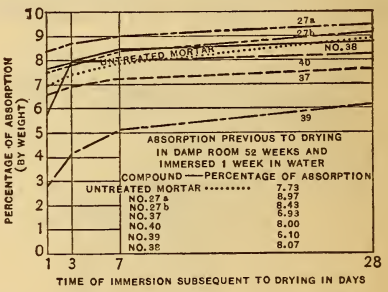

Fig. 42a.—*Absorption of Waterproofed Mortars.*

Age 52 weeks—1 part Portland cement to 8 parts No. 1 sand.

The effectiveness of only two of the compounds was evident at the 52-week period, all other mortars containing compounds having approximately the same absorption as the untreated mortar.

Comparing with Tables 20 and 21, it is of interest to note what a very little difference there was in the absorption of the lean and

rich mortars. While there was a small decrease, it is very small compared with the total absorption and the difference in the cement content.

Considering all of the absorption tests, it is evident that some of the compounds are slightly effective in reducing the absorption

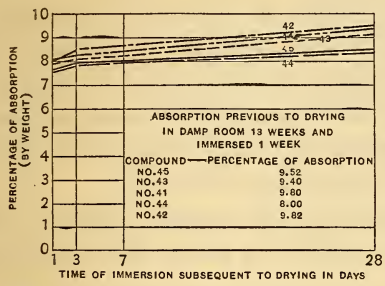

Fig. 43.—*Absorption of Mortars Containing Inert Fillers.*

Age 13 weeks—1 part Portland cement to 4 parts No. 1 sand.

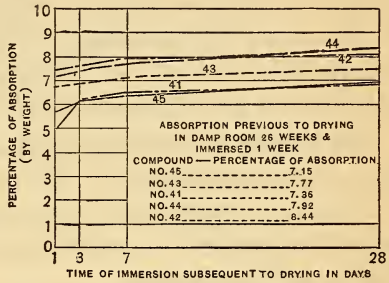

Fig. 44.—*Absorption of Mortars Containing Inert Fillers*

Age 26 weeks—1 part Portland cement to 4 parts No. 1 sand.

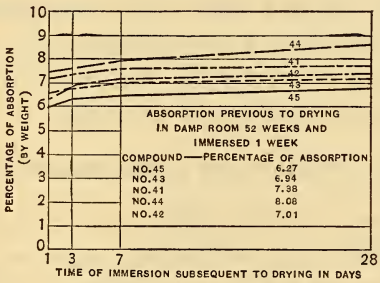

Fig. 45.—*Absorption of Mortars Containing Inert Fillers.*

Age 52 weeks—1 part Portland cement to 4 parts No. 1 sand.

after drying, even in the leaner mixtures and that hydrated lime is valueless, but on the other hand it is questionable if the slight reduction obtained is sufficient to warrant their use, and of course it is not practical to apply heat in actual construction.

Table 23 (Figs. 43, 44, 45).—The addition of inert materials seems to have little effect on absorption.

Table 24 (Figs. 46 to 51a).—In the 1–4 proportion mortar the addition of the compounds has in many cases slightly reduced the compressive strength.

The tensile strength was not perceptibly affected at the early ages and only slightly at 26 and 52 weeks by the addition of the compounds to the 1–4 proportion mortars.

The compressive strength has been slightly increased or practically unaffected in almost every case by the addition of the compounds to the 1–6 mortar, which might be expected in the case of the compounds acting as fillers and helping to increase the density of the mass. In fact, the mortar containing the 10 per cent of hydrated lime developed the greatest strength in compression.

The tensile strength has been practically unaffected by the addition of the compounds to the 1–6 proportion mortars.

In the 1–8 mixture at the early ages the treated mortars are slightly stronger in compression, but after 13 weeks the untreated mortar is the stronger.

The tensile strength in the 1–8 mixture has not been reduced by the addition of the compounds but in most cases has been slightly increased.

Table 25 (Figs. 52 and 53).—The compressive strength is increased by the addition of all but one of the inert fillers. The tensile strength has been slightly increased at early ages but is less than the untreated mortar at 52 weeks.

3. VALUE OF COATINGS AS DAMP-PROOFING MEDIUMS

Test pieces were 2 inches thick and 7½ inches in diameter. The mortar of which they were made was composed of 1 part of typical Portland cement to 4 parts of Meramec River sand retained on a No. 20 sieve.

In each case the coating was applied to one flat surface and entirely around the edge.

Compounds Nos. 1 and 3.—These compounds are manufactured by one firm and are used together. Compound No. 3 was first applied as a paint with an ordinary 3-inch flat brush, well brushed into the surface and permitted to dry for 24 hours, when Compound No. 1 was applied with the same style of brush.

All three test pieces failed in one-half inch of water. After removing from the water the coating was found to be soft and sticky.

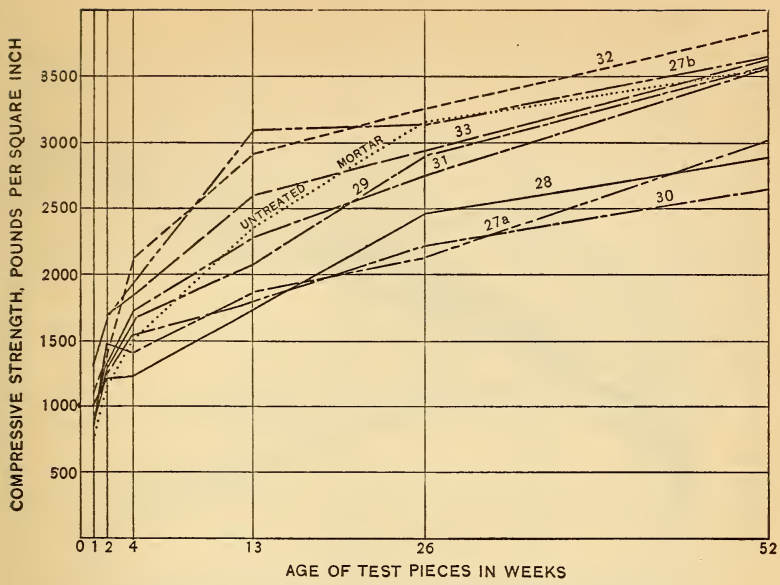

Fig. 46.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

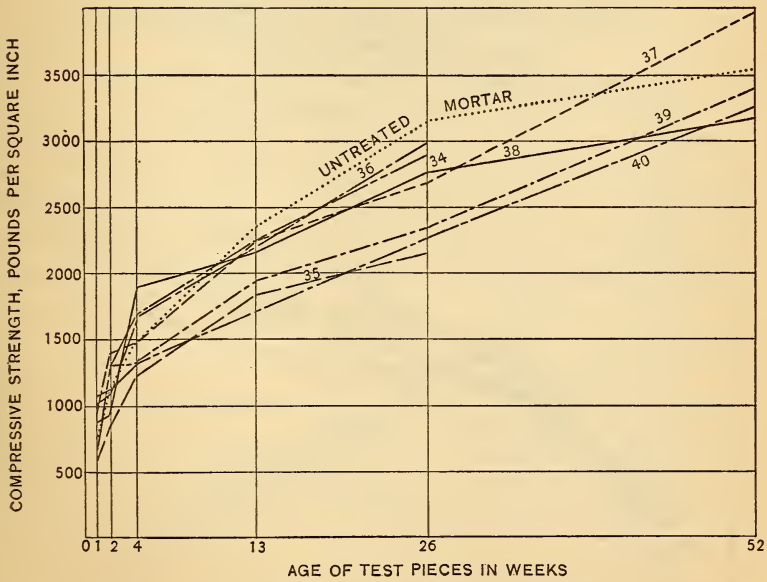

Fig. 46a.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

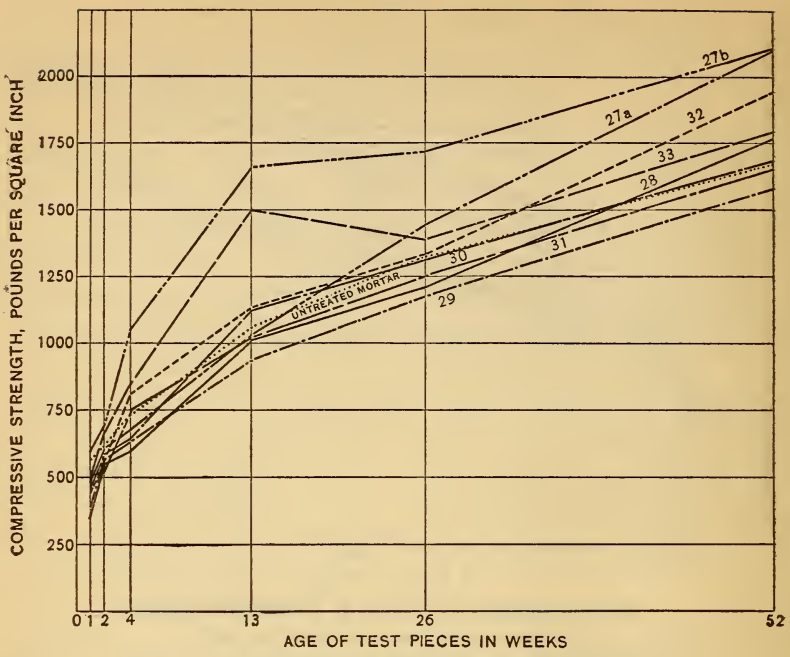

Fig. 47.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

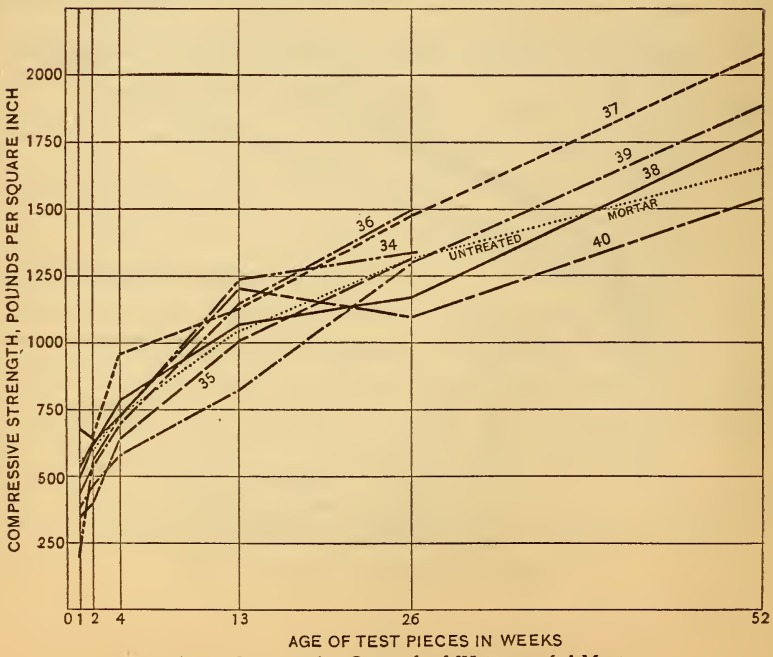

Fig 47a.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

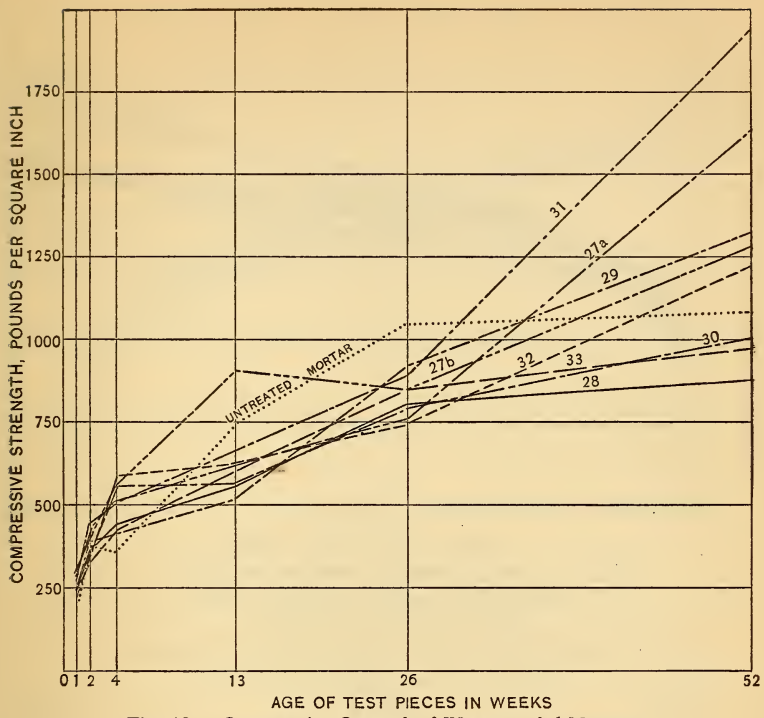

Fig. 48.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

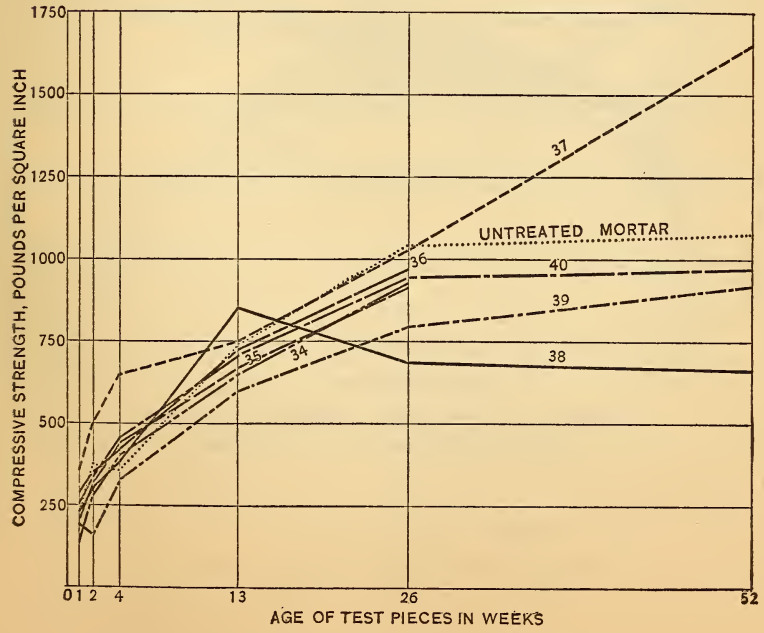

Fig. 48a.—*Compressive Strength of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

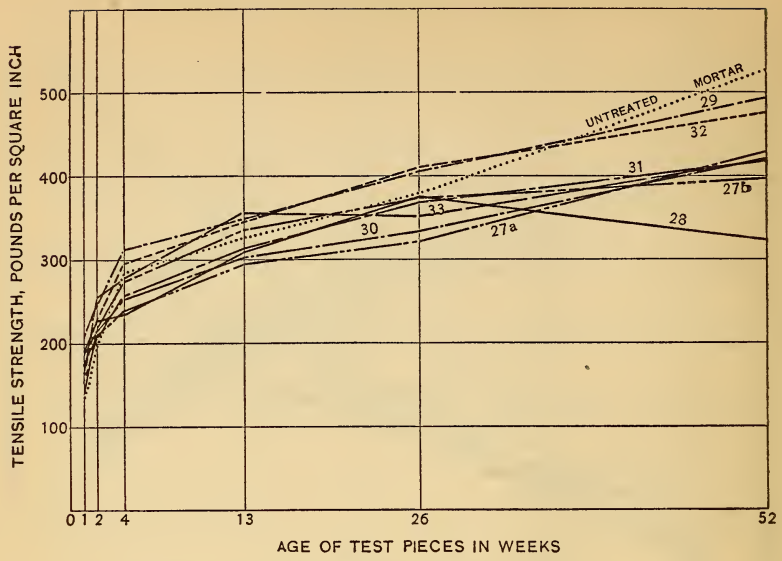

Fig. 49.—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

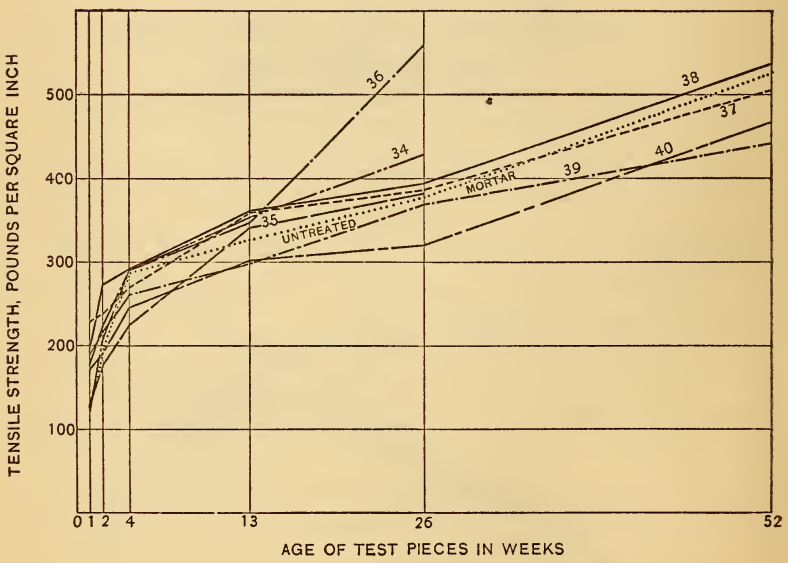

Fig. 49a.—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 4 parts No. 1 sand.

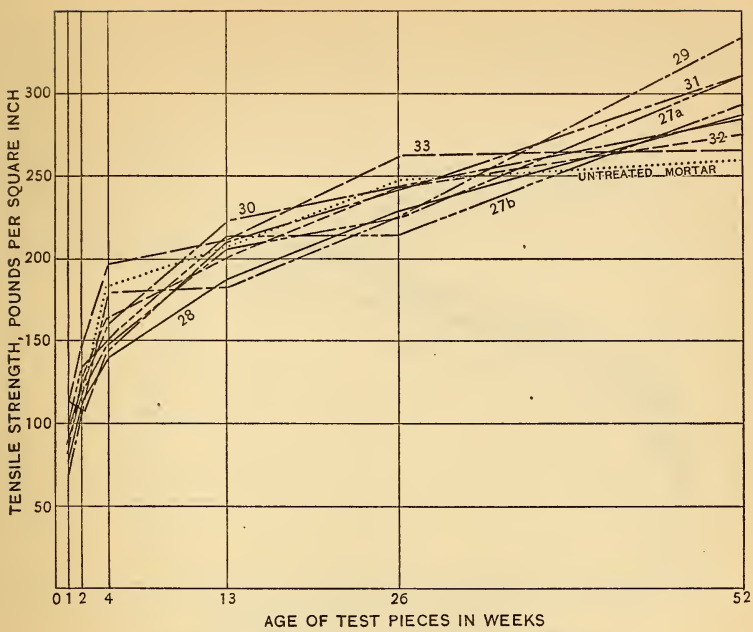

Fig. 50.—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

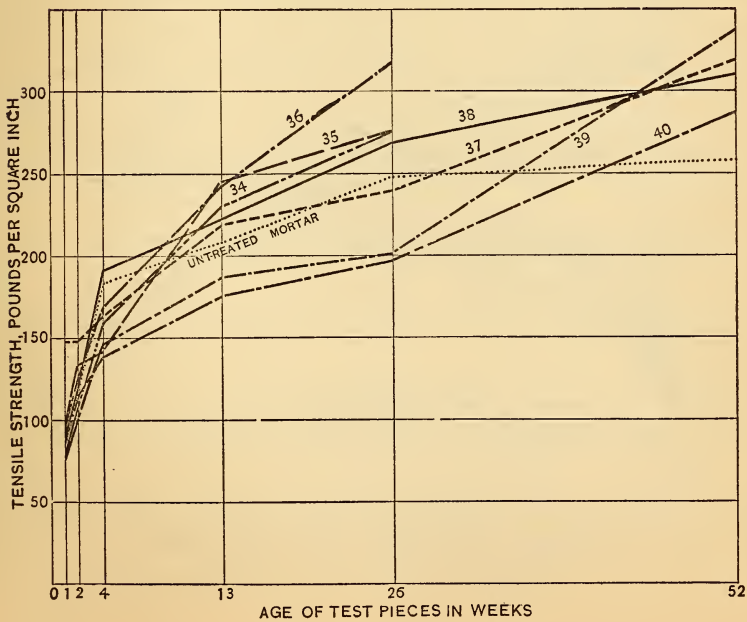

Fig. 50a.—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 6 parts No. 1 sand.

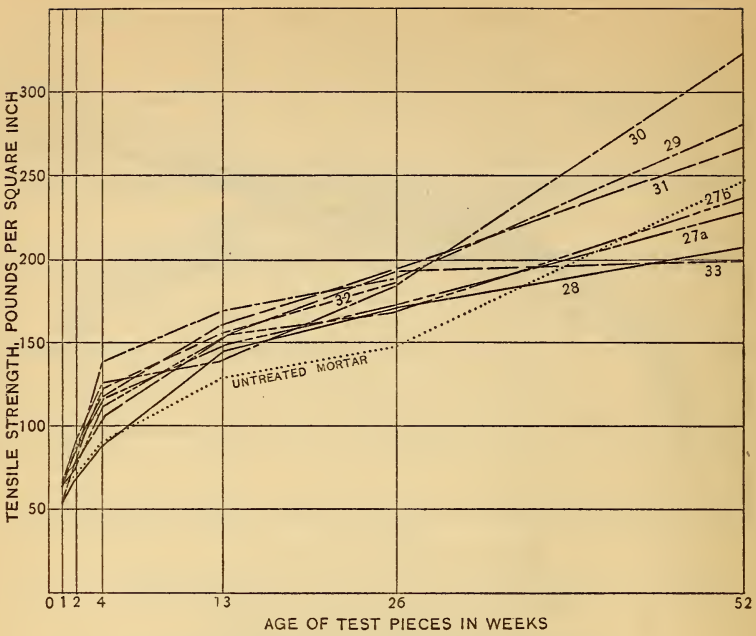

Fig. 51.—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

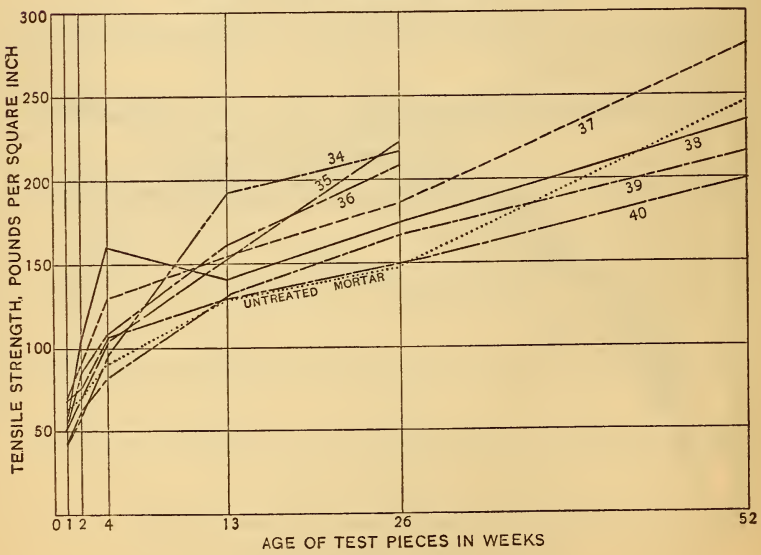

Fig. 51a—*Tensile Strength of Waterproofed Mortars.*

One part Portland cement to 8 parts No. 1 sand.

Compound No. 2.—Two coats of this compound were applied with a 3-inch flat brush, 24 hours intervening between coats.

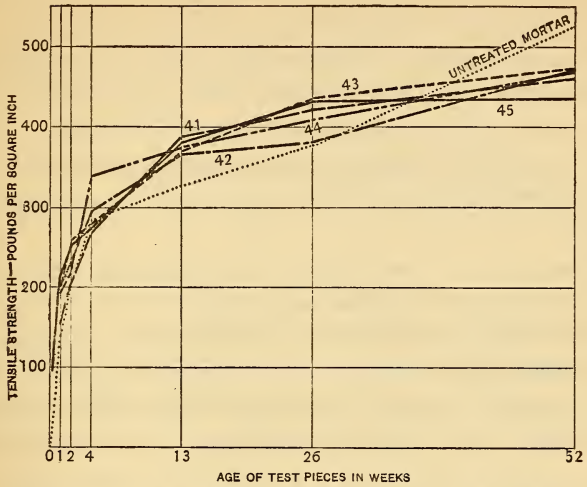

Fig. 52.—*Tensile Strength of Mortars Containing Inert Fillers.*

One part Portland cement to 4 parts No. 1 sand.

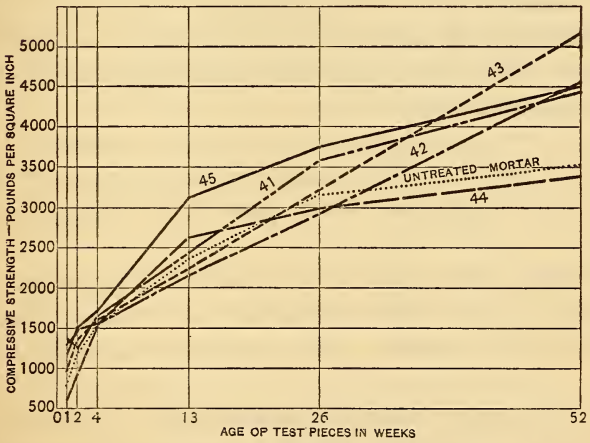

Fig. 53.—*Compressive Strength of Mortars Containing Inert Fillers.*

One part Portland cement to 4 parts No. 1 sand.

All three test pieces failed in one-half inch of water. After removing from the water the coating was found to be very soft, so that it could be rubbed off with the fingers.

Compound No. 4.—This compound was mixed with benzine to a paint consistency and applied with a 3-inch flat brush in two coats, 24 hours intervening between coats.

All three test pieces failed in one-half inch of water.

There was no visible change in the condition of the coating.

Compound No. 5.—The material was applied with a 3-inch flat brush as received in two coats at 24-hour intervals.

All three test pieces failed in one-half inch of water.

After removing from the water the coating was found to be soft and sticky.

Compound No. 6.—Two coats of this material were applied with a 3-inch flat brush at 24-hour intervals.

All three test pieces failed in one-half inch of water.

As this material was of a thin consistency and was mostly absorbed into the mortar, no change was visible, excepting the surface of the water near the test piece was observed to be oily at times.

Compound No. 7.—While this material was tested in the same manner as the others, it is hardly a fair test, considering the fact that the manufacturer recommends it for use only between the plaster coat and wall surface, where it will not be directly exposed to moisture. However, two coats were applied at 24-hour intervals in the usual manner.

All three test pieces failed in one-half inch of water.

Compound No. 8.—The remarks under Compound No. 7 also apply to this compound. Two coats were applied at 24-hour intervals.

All three test pieces failed in one-half inch of water.

Compound No. 9.—This compound was in a solid state and had to be melted to be applied. One coat only was applied with a flat brush.

Only one test piece failed in one-half inch of water.

The coating appeared in perfect condition when removed from the water and the failure was probably due to imperfect covering at the time coating was applied.

Compound No. 10.—The same remarks made under Compound No. 7 also apply to this compound. Two coats were applied, 24 hours intervening between coats.

All three test pieces failed in one-half inch of water.

Compound No. 11.—The material had settled in the container, and it was remixed only with considerable difficulty. Two coats were applied, 24 hours intervening between coats.

All three test pieces failed in one-half inch of water.

The coating was soft and sticky after removal from the water.

Compound No. 12.—Two coats of this compound were applied at 48-hour intervals.

All three test pieces failed in one-half inch of water.

The coating was soft and sticky after removal from the water.

Compound No. 13.—Two coats were applied at 24-hour intervals.

All three test pieces failed in one-half inch of water.

Compound No. 14.—Two coats were applied at 24-hour intervals.

All three test pieces failed in one-half inch of water.

The coating was soft and sticky after removal from the water.

Compound No. 15.—This compound is about of the consistency of kerosene oil, and was applied to the surface in two coats at 24-hour intervals. The mortar absorbed the compound very rapidly, and before placing in the water it was observed that the compound had penetrated to the opposite surface entirely through the 2-inch thickness.

All three test pieces failed in one-half inch of water.

Compound No. 16.—The compound as received from the manufacturer is of the consistency of milk, but before applying was thinned down according to directions, with two parts of water. Two coats were applied to the surface with a 3-inch flat brush at 24-hour intervals.

All three test pieces failed in one-half inch of water.

Compound No. 17.—Two coats were applied at 24-hour intervals.

Two test pieces failed in one-half inch of water, but the third test piece withstood this exposure for three months, when it was placed in 1 inch of water, where it failed.

Compound No. 18.—Two coats were applied at 24-hour intervals.

One test piece failed in one-half inch of water, and after three months the other two test pieces were placed in 1 inch of water, where they failed.

Compound No. 19.—Two coats were applied at 24-hour intervals.

Two test pieces failed in one-half inch of water, but the third test piece did not fail, although exposed for three months. It was then placed in 1 inch of water, where it failed.

Compound No. 20.—This compound was applied to the surface in two coats at 24-hour intervals.

All three test pieces failed in one-half inch of water.

Compound No. 21.—The compound was received in solid form and was dissolved in hot water, as directed by the manufacturer. It was applied to the surface in two coats, at 24-hour intervals.

All three test pieces failed in one-half inch of water.

Compound No. 22.—Two coats were applied at 24-hour intervals.

One test piece failed in one-half inch of water, and after three months the other two were placed in 1 inch of water, where they failed.

Compound No. 24.—This compound was mixed with water in the proportion of 1 part by volume of water to 2 parts of compound. It was thoroughly stirred until the mixture was smooth and free from lumps, when it was thinned down with additional water to the consistency of thick cream, after which it was further thinned down and applied. Two coats were applied at 24-hour intervals.

All three test pieces failed in one-half inch of water. The coating was in very bad condition when the test pieces were removed from the water. The odor was very bad and parts of the coating had molded, breeding maggots.

Compound No. 25.—Water was added to this compound, complying with the directions of the manufacturers, until the mixture was about the consistency of paste. It was applied to the mortar with a stiff brush in two coats at 24-hour intervals. The test pieces were kept in a damp atmosphere after applying coating.

All three test pieces remained sound in one-half inch of water for three months and in 1 inch of water for three months. The

coating could be rubbed off somewhat by the fingers but otherwise it appeared sound.

Compound No. 26.—Two coats of this compound were applied at 24-hour intervals.

All three test pieces failed in one-half inch of water.

XIII. SUMMARY

Portland cement mortar and concrete can be made practically water-tight or impermeable (as defined below) to any hydrostatic head up to 40 feet without the use of any of the so-called "integral" waterproofing materials; but in order to obtain such impermeable mortar or concrete considerable care should be exercised in selecting good materials as aggregate and proportioning them in such a manner as to obtain a dense mixture. The consistency of the mixture should be wet enough so that it can be puddled, the particles flowing into position without tamping. The mixture should be well spaded against the forms when placed, so as to avoid the formation of pockets on the surface.

The addition of so-called "integral" waterproofing compounds [12] will not compensate for lean mixtures, nor for poor materials, nor for poor workmanship in the fabrication of the concrete. Since in practice the inert integral compounds (acting simply as void filling material) are added in such small quantities, they have very little or no effect on the permeability of the concrete. If the same care be taken in making the concrete impermeable without the addition of waterproofing materials as is ordinarily taken when waterproofing materials are added, an impermeable concrete can be obtained.

The terms "permeability," "absorption," and "damp proof" should not be confused. A mortar or concrete is impermeable (not necessarily damp proof), as defined and used throughout this report, when it does not permit the passage or flow of water through its pores or voids. The absorption of a mortar or concrete is the property of drawing in or engrossing water into its pores or voids by capillary action or otherwise. If the pores or voids between

[12] Since the completion of the investigation reported above subsequent tests of similar materials have urther shown the ineffectiveness of such materials.

the grains or particles or in the individual grains are sufficiently large and connected from surface to surface of the wall, the concrete will be permeable to water. If the pores or voids are very minute, but connect one with another, theoretically they may act as capillary tubes, absorbing or drawing in and filling themselves with water; but the capillary forces will tend to hold the water in the pores and will prevent the passage or flow of water, even though one surface of the wall may be exposed to a considerable hydrostatic pressure. For all practical purposes a wall under such conditions would be considered perfectly water-tight and impermeable, although it may be highly absorptive. If these minute pores do act as capillary tubes and are never minute enough to prevent capillary action, the moisture either as water or water vapor would in time penetrate entirely through and fill a concrete wall, no matter what the thickness or composition. In such a case the capillary forces would not permit an actual flow of water, but these forces may carry moisture, entirely filling the wall, and, unless evaporation is retarded, the opposite face of the wall would appear dry. In such a case the concrete would be considered impermeable, but not damp proof.

The damp-proofing tests as conducted would indicate that Portland cement mortars can be made not only impermeable but damp proof as well, as defined above, without the use of any damp-proofing [13] or waterproofing compound. However, these tests should be interpreted with caution, as the evaporation may have been sufficient to care for the slight amount of moisture coming through the test pieces without indicating on the filter paper. Thus it can not be stated that if a material were used which was damp proof according to this test, if used as a basement wall, one surface being constantly exposed to moisture and the other surface in an inclosed room where there would be little or no circulation of air, that the interior surface would not appear damp and the atmosphere become saturated with moisture. The tests of coating materials as damp-proofing mediums can be considered as only preliminary, but the results, considered along with the chemical discussion, throw some light on their comparative merits. The

[13] See note on p. 83.

mortar used in these tests was, perhaps, too coarse and too absorptive for a fair test. The purpose of the rough surface was to test the flowing qualities of the coating, and it would seem that many of the failures may be due to the poor or imperfect spreading and adhesive quality. Several of the compounds deteriorated and proved their unfitness for the purpose intended.

Well graded sands containing considerable graded fine material are preferable for making impermeable concrete, but if such is not to be had, fine material in the form of hydrated lime, finely ground clay, or an additional quantity of cement will be found of value.

Where Portland cement mortar is used as a plaster coat, if sufficient cement be used and the sand contains sufficient fine material (or a fine material be added) and the mortar be placed without joints and well troweled (care being taken not to overtrowel, which may cause crazing), the coating will be effective as an impermeable medium without the use of any waterproofing compound.

As a precaution, under certain conditions, it is undoubtedly desirable to use bituminous or similar coatings, even on new work, as protection where cracks may occur due to settling of foundation or expansion and contraction caused by temperature changes. In large or exposed work it is practically impossible to prevent some cracks, but where cracks can be prevented no coating whatever is required to make the structure impermeable.

The permeability of Portland cement mortars and concretes rapidly decreases with age.

None of the integral compounds tested materially reduced the absorption of the mortars before they were dried by heating at 212° F. Thus they would have little or no practical value. But some of the so-called integral waterproofing compounds did decrease the absorption obtained after drying the mortars at 212° F., and the rate of absorption was much slower in these cases. The addition of hydrated lime and clays seemed to have little or no effect on the absorption.

The addition of any of the compounds tested to a mortar in the quantities as used in these tests does not seriously affect the com-

pressive or tensile strength. The addition of the inert void fillers to mortars, as used in these tests, up to 20 per cent of the volume of cement increases the compressive strength.

WASHINGTON, D. C., August 24, 1911.

Table of equivalents

Pounds per square inch	Kilograms per square centimeter	Cubic inches		Cubic millimeters	Avoirdupois ounces		Grams
20	1.41	0.000061	=	1	0.03527	=	1
40	2.81	0.000122	=	2	0.07055	=	2
60	4.22	0.000183	=	3	0.10582	=	3
80	5.62	0.000244	=	4	0.14110	=	4
		0.000305	=	5	0.17637	=	5
		0.000366	=	6	0.21164	=	6
		0.000427	=	7	0.24692	=	7
		0.000488	=	8	0.28219	=	8
		0.000549	=	9	0.31747	=	9

TABLE 1.—Permeability of Mortars

Thickness of Test Piece, 1 Inch. Consistency, Quakin

[The values are averages of 3 test pieces, except that individual values are given at end of test.]

Proportion, by volume, of Portland cement to Meramec River sand	Age in weeks when tested	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. 1-minute readings taken at end of periods given.								
			Average								
			10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours [First three are individual values]
1-2	4	1, 2, 3	0	0	0	0	0	0	0	0	0, 0, 0, 0
	8	4, 5, 6	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	7, 8, 9	0	0	0	0	0	0	0	0	0, 0, 0, 0
1-4	4	10, 11, 12	0	0	0	0	0	10	10	10	10, 10, 10, 10
	8	13, 14, 15	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	16, 17, 18	0	0	0	0	0	0	0	0	0, 0, —, 0
1-6	4	19, 20, 21	—	395	579	474	421	395	369	342	—, —, —, —
	8	22, 23, 24	0	0	0	0	5	8	8	8	8, 8, 8, 8
	26	25, 26, 27	5	21	29	21	27	19	19	19	8, 24, 24, 19
1-8	4	28, 29, 30	1820	1680	1550	1500	1510	1550	1490	1490	1820, 1180, 1340, 1450
	8	[13] 31, 32, 33	1190	985	985	985	985	985	985	905	1180, 630, 905
	26	34, 35, 36	30	120	130	130	110	100	110	90	50, 100, 80, 80
Thickness of Test Piece, 2 Inches. Consistency, Quaking											
1-2	4	37, 38, 39	0	0	0	0	0	0	0	—	—, —, —, —
	8	40, 41,[14]42	0	0	0	0	0	0	0	0	0, 0, —, 0
	26	43, 44, 45	0	0	0	0	0	0	0	0	0, 0, 0, 0
1-4	4	46, 47, 48	0	0	0	0	0	10	10	10	10, 10, 10, 10
	8	49, 50, 51	0	0	0	0	0	0	0	0	—, —, —, —
	26	52, 53, 54	0	0	0	0	0	0	0	0	[15] 0, [15] 0, 0, 0
1-6	4	55, 56, 57	270	270	290	290	270	240	240	240	280, 160, 200, 210
	8	58, 59, 60	0	0	0	20	20	20	20	20	20, 20, 20, 20
	26	61, 62, 63	0	0	0	3	8	8	16	8	8, 8, 8, 8
1-8	4	64, 65, 66	3690	3030	3550	3240	3240	3420	3320	3240	4190, 3400, 2130, 3240
	8	67, 68, 69	1580	1580	1500	1390	1400	1320	1320	1320	—, —, 1580, 1580
	26	70, 71, 72	0	180	160	130	110	90	90	90	60, 110, 90, 90
Thickness of Test Piece, 3 Inches. Consistency, Quaking											
1-2	4	73, 74, 75	0	0	0	0	—	—	—	—	—, —, —, —
	8	76, 77, 78	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	79, 80, 81	0	0	0	0	0	0	0	0	0, 0, 0, 0
1-4	4	82, 83, 84	0	0	0	0	0	0	0	0	10, 0, 0, 3
	8	85, 86, 87	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	[16] 88, 89, 90	0	0	0	0	0	0	0	0	—, —, 0, —
1-6	4	91, 92, 93	290	290	290	210	210	210	210	170	80, 160, 200, 150
	8	94, 95, 96	30	40	40	50	50	50	50	50	40, 40, 80, 50
	26	97, 98, 99	0	0	0	0	0	0	0	5	8, 0, 8, 5
1-8	4	100, 101, 102	15100	12800	11300	10500	9610	8950	8150	7490	9870, 5920, 4340, 6710
	8	103, 104, 105	2310	2180	1920	1710	1500	1370	1390	1260	2370, 240, 1180, 1260
	26	106, 107, 108	1420	1240	970	890	770	660	640	430	710, 550, 150, 470

[13] No. 31 broken while clamping.
[14] No. 42 broken while clamping.
[15] Test continued for 144 hours. No. 52, 24 hours surface moist; 48, 72, 96, 120, and 144 hours moist. No 53, 24 hours surface moist; 48, 72, and 96 hours moist; 120 and 144 hours dry.
[16] Two specimens remained impermeable throughout test; third specimen showed a flow varying from 5130 to 3630 tenths of cubic millimeters.

TABLE 2.—Permeability of Mortars

Thickness of Test Piece, 2 Inches. Consistency, Damp

Proportions by volume of Portland cement to Meramec River sand	Age in weeks when tested	Test piece No.	Cubic centimeters of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at end of following periods								
			10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
1–2	1	109	17.20	12.20	8.45	2.53	1.82	1.66	1.26	1.58	1.58
	1	110	22.90	8.10	6.00	2.13	1.66	1.34	0.99	1.22	1.18
	1	111	78.90	55.30	31.60	27.60	20.80	16.00	13.90	.....	.....
Average	.....	.....	39.70	25.20	15.35	10.75	8.09	6.33	5.38	1.40	1.38
1–2	2	112	32.40	22.10	19.70	12.70	11.10	8.14	7.98	7.11	6.71
	2	113	16.70	11.60	10.40	7.42	6.71	5.53	5.61	5.21	4.90
	2	114	20.20	5.92	5.13	3.24	3.08	2.92	2.13	1.97	2.05
Average	.....	.....	23.10	13.21	11.78	7.79	6.96	5.53	5.24	4.76	4.55
1–2	4	115	8.69	6.87	4.98	4.30	3.24	2.45	1.82	1.42	1.42
	4	116	7.11	5.92	4.74	4.26	3.32	2.84	2.13	1.66	1.58
	4	[18] 117	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	.....	7.90	6.40	4.86	4.28	3.28	2.65	1.98	1.54	1.50
1–4	1	118	29.80	20.10	15.80	12.60	6.71	5.21	3.87	3.75	3.24
	1	119	23.70	14.60	10.70	8.17	3.87	2.84	2.05	2.05	1.74
	1	120	94.80	92.60	82.10	71.10	62.00	55.80	45.10	44.20	39.50
Average	.....	.....	49.40	42.40	36.20	30.62	24.19	21.58	17.01	16.67	14.83
1–4	2	121	19.20	14.10	11.10	7.89	5.61	3.95	3.79	3.84	3.24
	2	122	8.77	6.48	5.13	2.53	2.53	2.25	1.82	1.90	2.13
	2	123	105.00	98.70	78.90	57.70	41.10	32.40	28.60	25.30	18.20
Average	.....	.....	44.32	39.76	31.71	22.71	16.41	12.87	11.40	10.23	7.86
1–4	4	124	11.60	7.89	6.56	3.24	3.24	2.37	1.82	1.93	2.25
	4	125	19.10	16.00	12.10	4.98	4.42	4.11	3.24	3.16	3.16
	4	126	61.60	37.10	23.70	9.64	7.74	7.11	5.84	5.29	5.05
Average	.....	.....	30.80	20.33	14.12	5.95	5.13	4.53	3.63	3.46	3.49
1–6	1	127	40.30	28.00	25.70	13.60	13.50	11.80	9.95	8.60	7.89
	1	128	117.60	109.40	102.70	86.90	77.50	71.10	59.40	57.60	54.50
	1	129	104.30	63.00	53.30	44.20	32.40	19.70	17.80	16.00	15.00
Average	.....	.....	87.40	66.80	60.60	48.20	41.10	34.20	29.05	27.40	25.80
1–6	2	130	36.70	30.40	23.90	15.00	10.10	8.29	7.74	6.32	4.90
	2	131	55.70	51.30	45.00	26.10	23.70	19.50	19.40	18.00	15.80
	2	[18] 132	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	.....	46.20	40.90	34.50	20.60	16.90	13.90	13.57	12.16	10.35
1–6	4	133	13.00	11.10	8.45	6.40	5.05	4.38	4.30	4.26	3.55
	4	134	31.00	29.50	22.20	16.70	14.20	12.10	10.40	9.87	8.69
	4	[18] 135	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	.....	22.00	20.30	15.33	11.55	9.63	8.24	7.35	7.07	6.12

[18] Not tested.

TABLE 3.—Permeability of Mortars

Consistency, Quaking

Proportions by volume of Portland cement to torpedo sand	Thickness of test piece in inches	Age in weeks when tested	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at end of following periods								
				10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
1–2	2	4	190	0	0	0	0	0	0	0	0	0
	2	4	191	79	110	103	46	39	24	32	20	20
	2	4	192	631	671	553	197	126	72	72	72	59
Average	....	....	.....	237	260	219	81	55	32	35	31	26
1–2	2	8	193	0	0	0	0	0	0	0	0	0
	2	8	194	0	0	0	0	0	0	0	0	0
	2	8	195	0	0	0	0	0	0	0	0	0
Average	....	....	.....	0	0	0	0	0	0	0	0	0
1–2	2	26	196	0	0	0	0	0	0	0	0	[19] 0
	2	26	197	0	0	0	0	0	0	0	0	[19] 0
	2	26	198	0	0	0	0	0	0	0	0	[19] 0
Average	....	....	.....	0	0	0	0	0	0	0	0	0
1–2	3	4	199	0	0	0	0	0	0	0	0	0
	3	4	200	0	0	0	0	6	5	4	4	4
	3	4	201	0	0	0	0	6	6	3	3	3
Average	....	....	.....	0	0	0	0	4	4	2	2	2
1–2	3	8	202	9880	8290	7900	6710	5530	3950	3550	3160	3160
	3	8	203	18950	9480	7110	3950	2370	1580	1420	1420	1180
	3	8	204	47000	35500	34800	26900	19000	17400	16600	15800	15000
Average	....	....	.....	23280	17760	16600	12520	8970	7640	7190	6790	6450
1–2	3	26	205	0	0	0	0	0	0	0	0	[19] 0
	3	26	206	0	0	0	0	0	0	0	0	[19] 0
	3	26	207	0	0	0	0	0	0	0	0	[19] 0
Average	....	....	.....	0	0	0	0	0	0	0	0	0

[19] Test continued for 23 hours; all surfaces dry, no flow.

TABLE 4.—Permeability of Limestone Concrete

Thickness of Test Piece, [a]2 and [b]3 Inches. Consistency, Quaking

["Proportions" of cement, sand, and stone (by volume).]

Proportion of material	Age in weeks when tested	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure, one-minute readings taken at end of periods given. [m=moist]								
			Average								7 hours [First three are individual values]
			10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	
[a] 1-2-4	4	136,137,138	70	60	70	60	50	50	50	50	120, 0, 20, 50
	8	139,140,141	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	142,143,144	0	0	0	0	0	0	0	0	0, 0, 0, 0
[a] 1-3-6	4	145,146,147	60	60	90	.....	90	.....	90	.....	60, —,120, 90
	8	148,149,150	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	151,152,153	0	0	0	0	0	3	[20] 3	[21] 4	—, —, —, —
[a] 1-4-8	4	154,155,156	240	200	200	.....	490	.....	330	.....	320, 80,120,170
	8	157,158,159	110	160	160	160	160	160	160	160	160, 160,160,160
	26	160,161,162	4100	3650	3430	3300	3100	3200	3100	[22] 2990	—, —, —, —
[b] 1-2-4	4	163,164,165	0	0	0	0	0	0	0	0	m, m, m, m
	8	166,167,168	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	169,170,171	0	0	0	0	0	0	0	0	0, 0, 0, 0
[b] 1-3-6	4	172,173,174	7	7	7	20	20	20	20	20	20, 20, 20 ,20
	8	175,176,177	0	0	0	0	0	0	0	0	0, 0, 0, 0
	26	178,179,180	0	0	0	0	0	0	0	0	0, 0, 0, 0
[b] 1-4-8	4	181,182,183	740	820	920	990	1080	1240	970	840	1180,1180, 80,810
	8	184,185,186	390	260	260	260	130	130	130	130	0, 400, 0,130
	26	187,188,189	1240	1370	1150	1010	1010	900	930	950	1580,1260, 20,950

[20] Separate values m, o, 8. [21] Separate values —, o, 8. [22] Separate values 16, 8850, 100

TABLE 5.—Retest of Permeability Test Pieces

Consistency, Quaking

Thickness of test piece in inches	Test piece No.	Proportion of cement to sand or sand and stone	Age in weeks when retested	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrastatic pressure. One-minute readings taken at end of following periods								
				10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
1	4	1-2	12	0	0	0	0	0	0	0	0	0
	10	1-4	12	0	0	0	0	0	0	0	0	0
	13	1-4	12	0	0	0	0	0	0	0	0	0
	28	1-8	8	950	790	630	550	790	790	950	950	950
2	37	1-2	8	0	0	0	0	0	0	0	0	0
	40	1-2	12	0	0	0	0	0	0	0	0	0
	46	1-4	8	0	0	0	0	0	0	0	0	.....
	49	1-4	12	0	0	0	0	0	0	0	0	0
	55	1-6	8	0	0	0	0	0	0	0	0	0
	58	1-6	12	40	40	40	30	30	20	20	20	20
	136	1-2-4	8	0	0	0	0	0	0	0	0	0
	145	1-3-6	8	0	0	0	0	0	0	0	0	0
	154	1-4-8	8	0	40	40	40	40	40	40	40	40
3	82	1-4	8	0	0	0	0	0	0	0	0	0
	85	1-4	12	0	0	0	0	0	0	0	0	0
	91	1-6	8	0	0	0	0	20	20	20	20	.....
	100	1-8	8	4340	4340	4110	.....	3550	3320	3320	3160	3160
	181	1-4-8	8	240	240	240	240	240	240	160	160	160

TABLE 6.—Permeability of Concrete

Quaking consistency. Age 13 weeks. Thickness 6, inches

Proportions (by volume) One part typical Portland cement to given parts of sand and stone	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface. One-minute readings taken at the end of the periods given. [m=moist]										Remarks
	Subjected to 1.4 kilograms hydrostatic pressure						2.8 kilogram pressure		4.2 kilogram pressure		
	10 minutes	30 minutes	1 hour	2 hours	Period in hours	Flow	Period in hours	Flow	Period in hours	Flow	
No. 4 sand to No. 6 stone											
0–6	0	0	m	m	22	m	24	m	.....	.....	Moist around edge only
½–5½	0	0	0	0	24	0	24	m	24	m	Moist in spots
1–5	0	0	0	0	8 24	0 m	24	3	.....	.....	Moist evenly
1½–4½	0	0	0	0	24	0	24	m	24	3	Leaked irregularly
2–4	0	0	m	m	48	m	24	6	.....	.....	Leaked evenly
3–3	0	0	3	6	22	16	.....	.....	.....	.....	Do.
0–9	114	102	65	.....	.....	.....	.....	.....	.....	.....	Leaked around edges
1–8	m	m	15	9	4 22	6 m	2	19	.....	.....	Leaked evenly
1½–7½	0	0	0	0	24	0	24	m	24	m	Moist evenly
2–7	m	m	12	12	3	6	22	19	.....	.....	Leaked evenly
3–6	241	247	278	247	.....	.....	.....	.....	.....	.....	Leaked in spots
4–5	142	136	108	108	.....	.....	.....	.....	.....	.....	Do.
No. 5 sand to No. 6 stone											
½–5½	0	0	0	0	24	0	24	0	24	0	Tested 5.6 kilograms pressure 24 hours remained dry
1–5	0	0	0	0	24	0	48	m	.....	.....	Moist in spots
2–4	0	0	0	0	24	0	24	m	72	m	Water drops hanging
3–3	0	0	0	m	3 4	m 1	.....	.....	.....	.....	Leaked 1 drop in 3 minutes
1–8	m	m	6	6	6 24	6 9	.....	.....	.....	.....	Leaked evenly
2–7	0	0	0	0	6 24	0 m	2	6	.....	.....	Do.
3–6	123	216	222	241	.....	.....	.....	.....	.....	.....	Do.
4–5	0	0	m	77	3	68	.....	.....	.....	.....	Do.

TABLE 7.—Permeability of Mortars

Quaking Consistency. Test Pieces 2 Inches Thick, Surfaces Trowelled.

Proportion by volume of cement to No. 1 sand	Age in weeks when tested	Pressure in Kg. per cm.²	Flow in cu. cm. per sq. cm. per minute		Proportion by volume of cement to No. 1 sand	Age in weeks when tested	Pressure in Kg. per cm.²	Flow in cu. cm. per sq. cm. per minute	
			Hours exposure	Flow [23]				Hours exposure	Flow [23]
1-1	1	5.6	24	0, 0, 0, 0	1-5	12	1.4	7	.10, .10, .20, .13
1-2	1	1.4	2	m, m, m, m		14	1.4	7	.1, m, m, .03
	2	1.4	3	m, m, m, m		16	1.4	24	.1, m, m, .03
	4	1.4	24	0, 0, 0, 0		18	1.4	24	m, m, m, m
	4	2.8	24	0, 0, 0, 0		20	1.4	24	0, 0, m, m
	4	4.2	24	0, 0, 0, 0		22	1.4	24	0, 0, 0, 0
	4	5.6	4	m, m, 0, m		22	2.8	24	0, 0, m, m
	13	5.6	6	0, 0, 0, 0		22	4.2	24	m, m, m, m
1-3	1	[24]5.6 and 1.4	3	1.2, .6, 1.8, 1.20		24	5.6	24	m, m, m, m
	2	1.4	3	.5, .4, .2, .37		26	5.6	24	m, m, m, m
	4	1.4	3	.1, .3, .2, .20		28	5.6	24	m, m, m, m
	6	1.4	3	0, m, m, m		30	5.6	24	0, m, m, m
1-4	1	1.4	4	1.4, 1.3, 1.1, 1.27	1-6	10	1.4	7	.1, m, m, .03
	2	1.4	2	.5, .4, .4, .43		12	1.4	5	.1, .1, m, .07
	4	1.4	2	.3, .2, .2, .23		14	1.4	24	m, m, m, m
	10	1.4	2	0, 0, 0, 0		16	1.4	2	m, m, m, m
	13	1.4	24	0, 0, 0, 0		18	2.8	24	m, m, m, m
	13	2.8	24	m, m, m, m		20	2.8	24	m, m, m, m
	17	2.8	24	m, m, m, m		22	5.6	24	0, 0, 0, 0
	19	2.8	24	0, 0, m, m		22	5.6	[25] 2	0, 0, m, m
	22	5.6	24	0, 0, m, m					
	24	5.6	[25] 2	0, 0, 0, 0					

[23] Shown by Test Pieces Nos. 1, 2, 3, and average, in the order indicated.
[24] This high pressure was applied for one hour by mistake.
[25] Weeks.

TABLE 8.—Absorption of Portland Cement Mortars

MERAMEC RIVER SAND NO. 1

[Results are averages of 3 test pieces for each set]

Proportion of cement to sand	Consistency	Per cent water used	Age of test pieces in weeks	Dry weight in grams	Percentage of absorption	
					Weight	Volume
1-2	Damp	8.67	1	239.5	12.76	23.3
			2	241.5	13.87	25.6
			4	251.5	10.54	20.2
			8	253.3	10.23	19.8
			26	248.3	10.50	19.9
1-2	Quaking	13.67	4	279.3	5.27	11.2
			8	267.8	8.26	16.9
			26	266.2	8.30	16.8
1-4	Damp	6.50	1	228.3	15.48	26.9
			2	221.0	17.87	30.1
			4	235.0	13.20	23.7
			8	243.3	11.11	20.6
			26	239.2	5.99	10.9
1-4	Quaking	13.00	4	248.7	8.66	16.4
			8	251.3	8.86	17.0
1-6	Damp	6.00	1	230.0	15.95	28.0
			2	224.8	17.20	29.5
			4	227.5	15.60	27.1
			8	234.2	15.25	27.2
			26	230.7	11.96	21.1
1-6	Quaking	12.50	4	241.3	9.74	17.9
			8	250.0	9.67	18.4
			26	244.4	12.83	23.9
1-8	Damp	5.50	4	217.8	15.22	25.3
			8	225.2	17.47	30.0
			26	222.7	11.49	19.5
1-8	Quaking	12.00	4	234.5	12.94	23.1
			8	232.1	13.74	24.3
			26	233.5	9.72	17.3

TABLE 9.—Absorption of Portland Cement Mortars

TORPEDO SAND NO. 2

[Results are averages of 3 test pieces for each set]

Proportion of cement to sand	Consistency	Per cent water used	Age of test pieces in weeks	Dry weight in grams	Percentage of absorption	
					Weight	Volume
1-2	Damp	6.20	4	271.5	8.61	17.8
			8	264.5	9.84	19.9
			26	262.1	9.51	19.0
1-2	Quaking	10.16	4	263.3	10.14	20.3
			8	273.1	7.91	16.5
			26	270.0	8.16	16.8
1-4	Damp	4.92	4	235.3	16.43	29.5
			8	235.3	15.05	27.0
			26	232.7	13.61	24.2
1-4	Quaking	9.70	4	246.0	11.87	22.9
			8	250.3	9.95	19.0
			26	254.8	9.42	18.3
1-6	Damp	4.75	4	235.8	14.25	25.6
			8	233.2	14.51	25.8
			26	232.9	13.40	23.8
1-6	Quaking	9.25	4	249.4	9.98	19.0
			8	249.8	9.79	18.7
			26	250.6	9.90	18.9
1-8	Damp	3.80	4	233.3	15.15	27.0
			8	230.0	14.64	25.7
			26	239.8	13.09	23.9
1-8	Quaking	8.00	4	249.8	9.16	17.5
			8	247.9	10.46	19.8
			26	248.3	11.28	21.4

TABLE 10.—Absorption of Portland Cement Mortars

SLAG SAND NO. 3

[Results are averages of 3 test pieces for each set]

Proportion of cement to sand	Consistency	Per cent water used	Age of test pieces in weeks	Dry weight in grams	Percentage of absorption	
					Weight	Volume
1-2	Damp	8.80	4	207.8	20.54	32.6
			8	214.6	20.54	33.6
			26	217.5	16.38	27.2
1-2	Quaking	13.8	4	236.8	12.17	22.0
			10	231.2	14.86	26.2
			26	238.3	10.99	19.9
1-4	Damp	8.00	4	201.9	20.45	31.5
			10	207.1	22.41	35.4
			26	204.4	20.10	31.3
1-4	Quaking	15.00	4	216.2	14.96	24.7
			10	217.3	15.41	25.6
			26	224.6	13.42	23.0
1-6	Damp	8.00	4	198.5	23.82	36.0
			10	199.6	24.21	36.9
			26	198.5	23.19	35.1
1-6	Quaking	15.00	4	200.7	18.64	28.5
			10	205.0	18.30	28.6
			26	204.7	17.41	27.2
1-8	Damp	9.00	4	196.4	25.13	37.6
			10	195.3	25.17	37.5
			26	204.6	18.75	29.3
1-8	Quaking	15.00	4	200.3	21.05	32.2
			10	199.5	23.19	35.3
			26	198.7	19.14	29.0

TABLE 11.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 4 Parts Sand

No. of compound [26]	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given [m=moist]											
		Age 2 weeks			Age 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
0	1	158	237	158	m	55	55	16	16	16	16	16	8
	2	m	118	118	m	m	16	16	24	16	16	24	16
	3	237	237	158	m	24	24	16	24	24	24	24	24
Average	.....	132	197	145	m	26	32	16	21	19	19	21	16
32	1	174	142	142	0	0	m	m	m	m	8	8	8
	2	142	142	95	0	0	0	m	m	m	8	8	8
	3	237	197	158	8	8	16	24	16	32	24	24	16
Average	.....	184	160	132	3	3	5	8	5	11	13	13	11
31	1	474	434	316	0	m	32	24	24	24	24	24	24
	2	158	158	158	0	m	71	63	55	55	55	47	47
	3	316	237	197	0	71	39	39	39	32	24	24	24
Average	.....	316	276	224	0	24	47	42	39	37	34	32	32
33	1	0	m	39	m	m	m	16	16	8	8	8	8
	2	m	134	63	m	m	m	m	16	8	8	8	8
	3	205	142	103	m	m	8	16	16	16	8	8	8
Average	.....	68	92	68	m	m	3	11	16	11	8	8	8
30	1	284	221	158	m	79	55	47	39	39	32	24	.....
	2	316	229	213	142	142	103	103	71	71	47	39	.....
	3	355	229	221	8	47	47	39	32	24	24	24	.....
Average	.....	318	226	197	50	89	68	63	47	45	34	29	.....
29	1	24	87	63	0	0	m	8	8	8	8	8	8
	2	16	47	47	0	0	m	m	8	8	8	8	8
	3	213	213	190	m	8	8	8	8	16	16	16	16
Average	.....	84	116	100	m	3	3	5	8	11	11	11	11
28	1	m	150	118	0	0	m	m	m	8	8	8	m [27]
	2	0	m	32	0	0	0	m	m	m	m	m	m [27]
	3	0	0	16	0	0	0	m	m	m	m	m	m [27]
Average	.....	m	50	55	0	0	m	m	m	3	3	3	3
27a	1	237	197	197	95	111	95	63	55	47	47	47	32
	2	316	316	237	m	39	39	39	24	24	24	24	24
	3	237	197	158	47	103	63	71	63	55	47	55	47
Average	.....	263	237	197	47	84	66	58	47	42	39	42	34
27b	1	0	0	m	0	0	0	0	0	0	0	m	8
	2	0	0	m	0	0	0	0	0	0	0	m	8
	3	0	0	m	0	0	0	0	0	0	0	0	m
Average	.....	0	0	m	0	0	0	0	0	0	0	m	5

[26] See Table 23 for quantity and manner of incorporating each compound.
[27] After 24 hours all 3 test pieces were moist.

TABLE 11.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given [m=moist]											
		Age 2 weeks			Age 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
37	1	166	111	71	m	39	47	24	24	16	16	8	8
	2	24	63	47	8	8	16	8	8	8	8	8	8
	3	m	32	47	0	0	0	0	0	0	0	0	0
Average		63	69	55	3	16	21	11	11	8	8	5	5
40 [28]	1	0	0	m	0	0	0	0	0	0	0	0	0
	2	0	0	m	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
Average		0	0	0	0	0	0	0	0	0	0	0	0
39	1	513	474	355	m	71	39	39	39	32	32	24	24
	2	513	474	395	m	55	39	32	32	32	32	24	24
	3	513	513	395	m	16	32	16	16	16	16	16	16
Average		513	487	382	m	47	37	29	29	27	27	21	21
38	1	474	395	237	32	79	71	47	32	24	24	24	24
	2	395	237	237	8	79	63	39	32	32	24	24	24
	3	395	237	237	47	63	55	32	32	32	32	32	32
Average		421	290	237	29	74	63	39	32	39	27	27	27
34	1	8	103	103	m	8	47	39	39	39	32	24	16
	2	m	8	63	m	m	8	32	32	32	24	24	24
	3	m	16	79	8	m	16	32	39	32	24	24	16
Average		3	42	82	3	3	24	34	37	34	27	24	19
35	1	276	205	150	8	24	47	55	47	47	47	47	39
	2	292	229	182	m	m	63	55	47	47	47	47	47
	3	348	261	126	m	m	24	39	32	32	32	32	24
Average		305	232	153	3	8	45	50	42	42	42	42	37
36	1	8	103	47	m	m	m	16	24	24	24	8	16
	2	47	63	79	m	m	m	8	m	8	8	m	8
	3	103	118	134	m	47	55	47	47	32	24	24	16
Average		53	95	87	m	16	18	24	24	21	19	11	13
23	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
Average		0	0	0	0	0	0	0	0	0	0	0	0

[28] Value unchanged up to 24 hours.

TABLE 11.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]										
		Age 13 weeks (retest)										
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours	48 hours
0	1	m	8	m	m	8	m	m	m	m	m	.....
	2	m	m	m	m	m	m	0	0	0	0	.....
	3	m	m	m	m	m	m	m	m	m	m	.....
Average	.....	m	3	m	m	3	m	m	m	m	m	.....
32	1	0	0	0	0	0	0	0	0	0	0	.....
	2	0	0	0	0	0	0	0	0	0	0	.....
	3	0	0	0	0	0	0	0	0	0	8	.....
Average	.....	0	0	0	0	0	0	0	0	0	3	.....
31	1	m	m	m	m	m	m	m	m	m	.....	.....
	2	m	m	0	0	0	0	0	0	0	.....	.....
	3	m	0	0	0	0	0	0	0	0	.....	.....
Average	.....	m	m	m	m	m	m	m	m	m	.....	.....
33	1	8	m	0	0	0	0	0	0	0	0	.....
	2	8	8	8	8	8	8	8	8	8	8	.....
	3	8	m	0	0	0	0	0	0	0	0	.....
Average	.....	8	3	3	3	3	3	3	3	3	3	.....
30	1	m	m	0	0	0	0	0	0	0	.....	.....
	2	m	m	0	0	0	0	0	0	0	.....	.....
	3	m	m	0	0	0	0	0	0	0	.....	.....
Average	.....	m	m	0	0	0	0	0	0	0	.....	.....
29	1	m	m	m	m	0	0	0	0	0	.....	.....
	2	m	m	8	m	m	m	m	m	0	.....	.....
	3	m	m	m	m	m	m	m	m	m	.....	.....
Average	.....	m	m	3	m	m	m	m	m	m	.....	.....
28	1	m	m	m	m	0	0	0	0	0	0	.....
	2	m	m	m	m	0	0	0	0	0	0	.....
	3	m	m	m	m	0	0	0	0	0	0	.....
Average	.....	m	m	m	m	0	0	0	0	0	0	.....
27a	1	m	m	m	8	8	8	8	8	8	.....	.....
	2	m	m	m	8	8	8	8	8	8	.....	.....
	3	m	m	m	8	8	8	8	8	8	.....	.....
Average	.....	m	m	m	8	8	8	8	8	8	.....	.....
27b	1	0	0	0	0	0	0	0	0	0	[29] 0	.....
	2	0	0	0	0	0	0	0	0	0	[29] 0	.....
	3	0	0	0	0	0	0	0	0	0	[29] 0	.....
Average	.....	0	0	0	0	0	0	0	0	0	[29] 0	.....

[29] Hydrostatic pressure raised to 2.8 at twenty-fourth hour and 4.2 at forty-eighth hour. All specimens still dry after 72 hours.

TABLE 11.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]										
		Age 13 weeks (retest)										
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours	48 hours
37	1	m	m	m	m	m	0	0	0	0	0	.....
	2	m	m	m	m	m	0	0	0	0	0	.....
	3	m	m	m	m	m	0	0	0	0	0	.....
Average	.....	m	m	m	m	m	0	0	0	0	0	.....
40	1	m	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	m	m	m	m	.....
	3	m	m	m	m	m	m	m	m	m	m	.....
Average	.....	m	m	m	m	m	m	m	m	m	m	.....
39	1	m	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	8	8	m	8	.....
	3	m	m	m	m	m	m	m	m	m	m	.....
Average	.....	m	m	m	m	m	m	3	3	m	3	.....
38	1	m	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	m	m	m	m	.....
	3	m	8	8	8	8	8	m	m	m	m	.....
Average	.....	m	3	3	3	3	3	m	m	m	m	.....
34	1	24 hrs. pressure 1.4 kg.	0	24 hrs. pressure 2.8 kg.	m	24 hrs. pressure 4.2 kg.	m	24 hrs. pressure 5.6 kg.	m	.....	.....	.....
	2		0		0		0		m	.....	.....	.....
	3		0		0		0		0	.....	.....	.....
Average	.....	.....	0	.....	m	.....	m	.....	m	.....	.....	.....
35	1	24 hrs. pressure 1.4 kg.	0	24 hrs. pressure 2.8 kg.	0	24 hrs. pressure 4.2 kg.	m	.....	.....	.....	.....	.....
	2		0		0		m	.....	.....	.....	.....	.....
	3		0		0		m	.....	.....	.....	.....	.....
Average	.....	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....
36	1	m	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	m	m	m	m	.....
	3	8	8	8	m	m	m	m	m	m	m	.....
Average	.....	3	3	3	m	m	m	m	m	m	m	.....
23 [30]	1	m	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	m	m	m	m	.....
	3	m	m	m	m	m	m	m	m	m	0	.....
Average	.....	m	m	m	m	m	m	m	m	m	m	.....

[30] For this and succeeding tests in this set, pressure equals 2.8 kilograms.

TABLE 12.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 4 Parts Sand

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface under designated pressure. [m = moist.]															
		26 weeks (retest)								52 weeks (retest)							
		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms	
		Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow
0	1	.....	.....	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
	2	.....	.....	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....
	3	.....	.....	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
Average	.....	.....	.....	24	m	.....	.....	.....	.....	.....	.....	7	m	48	m	.....	.....
32	1	.....	0	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	0	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	0	.....	.....	.....	.....	.....	m	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	3	0	.....	.....	.....	.....	24	m	.....	.....	.....	.....	.....	.....	24	0
31	1	.....	.....	.....	0	.....	0	.....	0	.....	m	.....	m	.....	m	.....	m
	2	.....	.....	.....	16	.....	8	.....	8	.....	0	.....	0	.....	0	.....	0
	3	.....	.....	.....	0	.....	0	.....	m	.....	m	.....	m	.....	m	.....	m
Average	.....	.....	.....	7	5	24	3	24	3	24	m	4	m	7	m	7	m
33	1	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	m
	2	.....	0	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	m
	3	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	m
Average	.....	24	0	24	0	24	0	24	m	.....	.....	.....	.....	.....	.....	24	m
30	1	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	0	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	24	0	24	0	24	0	24	m	.....	.....	.....	.....	.....	.....	7	0
29	1	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	24	0	24	0	48	0	24	0	.....	.....	.....	.....	.....	.....	24	0
28	1	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	0	.....	0	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	24	0	24	0	24	0	24	0	.....	.....	.....	.....	.....	.....	24	0
27a	1	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
	2	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
	3	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
Average	.....	24	m	24	m	.....	.....	.....	.....	.....	.....	7	m	48	m	.....	.....

TABLE 12.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface under designated pressure. [m = moist.]															
		26 weeks (retest)								52 weeks (retest)							
		1.4 Kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms	
		Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow
27b	1	.....	....	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	....
	2	.....	....	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	....
	3	.....	....	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	....
Average	.....	.....	....	24	0	48	0	48	0	.....	....	.....	....	.....	....	.....	....
37	1	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	0
	2	.....	0	.....	0	.....	m	.....	m	.....	....	.....	....	.....	....	.....	m
	3	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	0
Average	.....	24	0	24	0	24	m	24	m	.....	....	.....	....	.....	....	6	m
40	1	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	8
	2	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	m
	3	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	0
Average	.....	24	0	24	0	24	0	24	0	.....	....	.....	....	.....	....	6	3
39	1	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	24
	2	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	47
	3	.....	0	.....	0	.....	m	.....	m	.....	....	.....	....	.....	....	.....	m
Average	.....	24	0	24	0	24	m	24	m	.....	....	.....	....	.....	....	6	24
38	1	.....	0	.....	0	.....	m	.....	m	.....	....	.....	....	.....	....	.....	m
	2	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	m
	3	.....	0	.....	0	.....	0	.....	0	.....	....	.....	....	.....	....	.....	m
Average	.....	24	0	24	0	24	m	24	m	.....	....	.....	....	.....	....	48	m
34	1	.....	24	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
	2	.....	0	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
	3	.....	47	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
Average	.....	7	24	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
35	1	.....	....	.....	....	.....	0	.....	0	.....	....	.....	....	.....	....	.....	....
	2	.....	....	.....	....	.....	0	.....	0	.....	....	.....	....	.....	....	.....	....
	3	.....	....	.....	....	.....	0	.....	m	.....	....	.....	....	.....	....	.....	....
Average	.....	.....	....	.....	....	1	0	24	m	.....	....	.....	....	.....	....	.....	....
36	1	.....	0	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
	2	.....	0	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
	3	.....	16	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
Average	.....	7	5	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....
23	1	.....	....	.....	....	.....	....	.....	0	.....	....	.....	....	.....	....	.....	0
	2	.....	....	.....	....	.....	....	.....	0	.....	....	.....	....	.....	....	.....	0
	3	.....	....	.....	....	.....	....	.....	0	.....	....	.....	....	.....	....	.....	0
Average	.....	.....	....	.....	....	.....	....	72	0	.....	....	.....	....	.....	....	48	0

TABLE 13.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 6 Parts Sand

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist]											
		Age 2 weeks			Age 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
0	1	2130	1820	1580	434	379	355	316	284	292	276	237	213
	2	1820	1580	1420	316	237	197	174	158	166	158	150	134
	3	948	869	790	237	197	197	158	126	142	126	118	111
Average		1633	1423	1263	329	271	250	216	189	200	187	168	153
32	1	2530	1820	1420	592	434	340	276	253	237	197	158	118
	2	1660	1300	1030	316	316	237	237	158	158	118	95	79
	3	1740	1420	1110	355	316	253	237	197	158	118	95	79
Average		1980	1510	1190	421	355	277	250	203	184	144	116	92
31	1	1820	1660	1420	553	395	395	316	197	142	150	126	103
	2	1180	1030	948	237	197	182	142	126	79	71	63	55
	3	1180	1030	1030	474	284	213	205	197	158	166	150	134
Average		1390	1240	1130	421	292	263	221	173	126	129	113	97
33	1	632	553	474	158	197	197	197	118	79	55	47	32
	2	1030	869	790	276	276	276	197	158	158	134	118	134
	3	790	671	592	237	237	237	197	158	158	118	95	118
Average		817	698	619	224	237	237	197	145	132	102	87	95
30	1	632	632	553	142	118	95	79	79	79	71	71	63
	2	395	355	316	134	95	79	71	63	55	55	55	55
	3	553	529	474	142	103	103	87	87	87	87	87	87
Average		527	505	448	139	105	92	79	76	74	71	71	68
29	1	1260	1030	869	197	158	142	134	134	126	118	118	118
	2	711	632	553	213	158	126	134	126	111	111	103	103
	3	1180	869	790	197	158	142	142	126	126	126	118	126
Average		1050	844	737	202	158	137	137	129	121	118	113	116
28	1	553	513	395	m	118	111	87	79	79	71	71	63
	2	395	316	316	111	111	95	87	71	87	79	71	63
	3	395	316	237	m	55	39	39	32	24	24	24	24
Average		448	382	316	37	95	82	71	61	63	58	55	50
27a	1	790	711	711	316	316	316	237	237	197	118	118	118
	2	790	711	711	276	276	237	158	197	118	79	79	79
	3	948	869	869	434	395	316	276	237	197	158	158	158
Average		843	764	764	342	329	290	224	224	171	118	118	118
27b	1	276	276	237	0	103	87	71	63	55	55	55	55
	2	237	237	237	0	111	103	79	79	95	87	79	71
	3	276	197	197	0	103	87	55	55	79	55	39	39
Average		263	237	224	0	106	92	68	66	76	66	58	55

TABLE 13.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 6 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]											
		Age 2 weeks			Age 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
37	1	632	395	355	16	71	39	24	24	24	32	24	24
	2	395	395	355	m	95	63	63	63	55	55	47	47
	3	395	395	355	0	24	71	39	39	39	32	24	24
Average		474	395	355	5	63	58	42	42	39	40	32	32
40	1	158	142	111	m	8	32	32	16	16	16	16	16
	2	276	276	213	8	39	79	79	55	55	55	55	55
	3	118	87	71	m	m	8	8	8	8	8	8	8
Average		184	168	132	3	16	40	40	26	26	26	26	26
39	1	3240	2530	2210	355	395	316	237	197	197	197	158	158
	2	4500	3000	2370	355	434	395	316	276	276	276	237	197
	3	3160	2530	2130	474	513	434	355	316	316	316	276	237
Average		3630	2690	2240	395	447	382	303	263	263	263	224	197
38	1	2690	2130	1580	553	474	395	355	316	276	276	276	276
	2	1820	1500	1110	395	355	276	276	237	237	237	237	237
	3	2370	2050	1580	474	434	316	316	276	237	237	276	237
Average		2290	1890	1420	474	421	329	316	276	250	250	263	250
34	1	600	521	490	395	332	261	221	190	158	142	134	111
	2	395	348	324	150	134	126	103	118	103	95	95	87
	3	774	664	553	118	79	79	55	55	55	39	47	39
Average		590	511	456	221	182	155	126	121	105	92	92	79
35	1	711	592	442	m	103	87	95	87	79	87	95	95
	2	466	316	237	m	24	71	71	63	63	47	47	47
	3	924	727	585	m	142	126	95	87	118	118	111	111
Average		700	545	421	m	90	95	87	79	87	84	84	84
36	1	521	427	348	16	79	63	55	39	39	24	32	24
	2	466	355	340	182	150	87	71	63	47	24	47	32
	3	490	419	379	71	63	55	24	24	24	16	24	24
Average		492	400	356	90	97	68	50	42	37	21	34	27

TABLE 13.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 6 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m = moist.]									
		Age 13 weeks (retest)									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
0	1	24	95	71	47	47	47	32	32	32	.....
	2	8	m	8	16	16	16	16	16	16	.....
	3	0	m	8	16	16	16	8	8	8	.....
Average	.....	11	32	29	26	26	26	19	19	19	.....
32	1	m	m	m	24	16	16	16	16	16	.....
	2	m	m	m	8	16	24	16	16	16	.....
	3	0	m	m	m	m	m	8	16	16	.....
Average	.....	m	m	m	11	11	13	13	16	16	.....
31	1	m	m	8	8	16	8	16	8	8	.....
	2	m	m	m	0	0	0	0	0	0	.....
	3	m	m	8	8	8	8	8	8	8	.....
Average	.....	m	m	5	5	8	5	8	5	5	.....
33	1	0	m	m	m	m	m	m	m	8	.....
	2	0	m	m	m	8	8	8	8	8	.....
	3	0	m	m	m	8	8	8	16	8	.....
Average	.....	0	m	m	m	5	5	5	8	8	.....
30	1	m	m	8	8	8	8	16	16	16	.....
	2	m	m	8	8	m	8	24	24	24	.....
	3	m	m	8	m	8	8	m	8	8	.....
Average	.....	m	m	8	5	5	8	13	16	16	.....
29	1	m	8	8	8	24	8	8	8	8	.....
	2	m	m	8	24	24	16	16	16	16	.....
	3	m	m	8	16	16	16	16	24	8	.....
Average	.....	m	3	8	16	21	13	13	16	11	.....
28	1	m	m	m	8	8	8	8	8	m	8
	2	m	m	m	m	8	8	m	8	m	m
	3	8	m	m	m	8	m	m	m	m	m
Average	.....	3	m	m	3	8	5	3	5	m	3
27a	1	m	m	m	8	8	m	8	m	8	.....
	2	m	m	m	8	8	8	8	8	8	.....
	3	m	m	m	8	8	8	8	8	8	.....
Average	.....	m	m	m	8	8	5	8	5	8	.....
27b	1	0	0	0	0	0	0	0	m	m	.....
	2	0	0	0	0	0	0	0	m	m	.....
	3	0	0	0	0	m	4	8	8	8	.....
Average	.....	0	0	0	0	m	1	3	3	3	.....

TABLE 13.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 6 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]									
		Age 13 weeks (retest)									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
37	1	m	m	m	m	m	m	m	m	m	m
	2	m	m	16	16	24	24	16	8	16	m
	3	m	m	m	m	m	m	m	8	m	m
Average		m	m	5	5	8	8	5	5	5	m
40	1	m	0	0	0	0	0	0	0	0	[31] 0
	2	m	8	8	24	24	16	8	16	16	[31] 8
	3	8	m	0	0	0	0	0	0	0	[31] 0
Average		3	3	3	8	8	5	3	5	5	[31] 3
39	1	m	55	32	24	39	24	39	24	16	.....
	2	m	m	m	m	8	8	24	16	8	.....
	3	m	m	m	m	m	m	8	8	m	.....
Average		m	18	11	8	16	11	24	16	8	.....
38	1	m	8	m	8	8	8	8	8	8	.....
	2	16	8	m	8	16	8	8	8	8	.....
	3	m	8	8	16	16	16	8	8	8	.....
Average		5	8	3	11	13	11	8	8	8	.....
34	1	m	m	m	8	32	16	16	24	16	.....
	2	m	m	m	8	8	8	8	8	16	.....
	3	m	m	m	m	m	m	8	8	8	.....
Average		m	m	m	5	13	8	11	13	13	.....
35	1	m	m	m	m	m	8	16	8	8	.....
	2	m	m	m	m	m	m	m	m	m	.....
	3	m	8	8	m	m	8	m	m	8	.....
Average		m	3	3	m	m	5	5	3	5	.....
36	1	m	m	m	m	m	m	m	m	m	.....
	2	m	m	m	m	m	m	m	m	m	.....
	3	m	m	m	m	m	m	m	m	m	.....
Average		m	m	m	m	m	m	m	m	m	.....

[31] Hydrostatic pressure raised to 2.8 kilograms at twenty-fourth hour. At thirty-second hour Nos. 1 and 3 were "Moist" and No. 2 passed 24 tenths cubic millimeters.

TABLE 14.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 6 Parts Sand

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface under designated pressure. [m=moist.]															
		26 weeks (retest)								52 weeks (retest)							
		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms	
		Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow
0	1	.....	8	.....	.....	.....	.....	.....	.....	.....	8	.....	.....	.....	.....	.....	.....
	2	.....	8	.....	.....	.....	.....	.....	.....	.....	m	.....	.....	.....	.....	.....	.....
	3	.....	24	.....	.....	.....	.....	.....	.....	.....	m	.....	.....	.....	.....	.....	.....
Average	.....	7	13	.....	.....	.....	.....	.....	.....	24	3	.....	.....	.....	.....	.....	.....
32	1	.....	16	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	2	.....	16	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	4	.....	8	.....	4	.....	4
Average	.....	7	11	.....	.....	.....	.....	.....	.....	24	1	24	3	24	1	7	1
31	1	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	m
	2	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	24	m	24	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7	m
33	1	.....	24	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	m	.....	m
	2	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	m	.....	m
Average	.....	12	8	.....	.....	.....	.....	.....	.....	24	m	24	m	24	m	7	m
30	1	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	m	.....	m
	2	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	m	.....	8	.....	8
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
Average	.....	24	m	.....	.....	.....	.....	.....	.....	3	0	20	m	24	3	7	3
29	1	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	m	.....	.....
	2	.....	0	.....	0	.....	.....	.....	.....	.....	.....	.....	m	.....	8	.....	.....
	3	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	m	.....	8	.....	.....
Average	.....	24	0	48	m	.....	.....	.....	.....	.....	.....	24	m	7	5	.....	.....
28	1	.....	m	.....	m	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	0	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	47
	3	.....	0	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	16
Average	.....	24	m	24	m	24	m	24	m	.....	.....	.....	.....	.....	.....	6	21
27a	1	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	2	.....	0	.....	.....	.....	.....	.....	.....	.....	0	.....	m	.....	m	.....	m
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
Average	.....	24	m	.....	.....	.....	.....	.....	.....	24	0	24	m	7	m	7	m
27b	1	.....	.....	.....	0	.....	m	.....	0	.....	.....	.....	.....	.....	.....	.....	0
	2	.....	.....	.....	0	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	0
	3	.....	.....	.....	0	.....	m	.....	0	.....	.....	.....	.....	.....	.....	.....	0
Average	.....	.....	.....	24	0	48	m	48	m	.....	.....	.....	.....	.....	.....	7	0

TABLE 14.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 6 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface under designated pressure. [m=moist.]															
		26 weeks (retest)								52 weeks (retest)							
		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms		1.4 kilograms		2.8 kilograms		4.2 kilograms		5.6 kilograms	
		Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow	Hours	Flow
37	1	.....	0	.....	0	.....	0	.....	m	.....	.....	.....	.....	.....	.....	.....	m
	2	.....	0	.....	0	.....	m	.....	0	.....	.....	.....	.....	.....	.....	.....	16
	3	.....	0	.....	0	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	m
Average	.....	24	0	24	0	24	m	24	m	.....	.....	.....	.....	.....	.....	30	5
40	1	.....	0	.....	0	.....	m	.....	0	.....	0	.....	m	.....	m	.....	m
	2	.....	0	.....	m	.....	m	.....	m	.....	m	.....	.....	.....	32	.....	8
	3	.....	0	.....	0	.....	0	.....	0	.....	0	.....	m	.....	m	.....	m
Average	.....	24	0	24	m	24	m	24	m	24	m	24	m	24	11	48	3
39	1	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	2	.....	m	.....	.....	.....	.....	.....	.....	.....	0	.....	0	.....	0	.....	0
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	16	.....	24	.....	47	.....	32
Average	.....	24	m	.....	.....	.....	.....	.....	.....	24	5	24	8	4	16	6	11
38	1	.....	0	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	32	.....	.....
	2	.....	m	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	8	.....	.....
	3	.....	m	.....	m	.....	m	.....	.....	.....	.....	.....	.....	.....	8	.....	.....
Average	.....	24	m	24	m	24	m	.....	.....	.....	.....	.....	.....	24	16	.....	.....
34	1	.....	16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	.....	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	.....	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	7	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
35	1	.....	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	.....	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	.....	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	24	m	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
36	1	.....	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	.....	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	.....	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....	24	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 15.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 8 Parts Sand

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given.											
		Age, 2 weeks			Age, 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
0	1	5530	4420	3790	2760	1820	1420	1260	1260	1030	1030	908	790
	2	3320	2840	2450	869	790	632	513	513	474	434	434	395
	3	4980	4110	3790	1580	1420	948	869	869	790	753	711	711
Average		4610	3790	3343	1736	1343	1000	881	881	765	739	684	632
32	1	1970	1820	1580	474	474	355	355	316	276	237	237	237
	2	2840	2610	2290	711	632	553	513	513	474	474	474	395
	3	3950	3550	3000	1030	948	790	711	671	592	474	434	474
Average		2920	2660	2290	738	685	566	526	500	447	395	382	369
31	1	3790	3480	3000	1110	869	711	671	592	474	474	434	395
	2	3480	3240	2760	632	553	513	434	395	316	316	316	276
	3	3480	3160	2610	869	711	671	592	513	474	474	395	316
Average		3580	3290	2790	870	711	632	566	500	421	421	382	329
33	1	3710	2920	2610	1110	948	869	711	632	632	592	434	.....
	2	3320	2690	2690	948	790	671	553	553	513	474	474	.....
	3	2210	1820	1500	632	553	474	474	355	316	316	316	.....
Average		3080	2480	2270	897	764	671	579	513	487	461	408	.....
30	1	2920	2840	2210	948	869	711	671	632	632	553	553	513
	2	3160	2840	2290	790	750	711	632	592	592	553	553	474
	3	1340	1340	1180	474	434	395	355	395	355	355	355	316
Average		2470	2340	1890	737	684	606	553	540	526	487	487	434
29	1	2130	1970	1580	474	513	395	395	395	395	355	395	355
	2	1900	1740	1500	513	434	434	395	355	395	395	395	355
	3	2530	2290	1970	553	790	671	632	553	592	553	553	553
Average		2190	2000	1680	513	579	500	474	434	461	434	448	421
28	1	2450	1740	1420	1150	987	987	908	790	750	750	671	632
	2	1660	1340	1180	869	790	711	711	632	632	592	632	632
	3	2840	2130	1970	1420	1260	1260	1180	1110	987	1030	987	948
Average		2320	1740	1520	1146	1012	986	933	844	790	791	763	737
27a	1	3550	3080	2920	1260	1180	1150	987	948	829	790	869	750
	2	3710	3160	3000	1260	1110	1030	948	869	790	790	790	711
	3	3710	3400	3160	1260	1220	1110	987	869	948	869	869	869
Average		3657	3213	3027	1260	1170	1097	974	895	856	816	843	777
27b	1	1180	869	790	529	308	269	174	174	166	150	150	142
	2	1110	790	711	513	316	276	221	205	190	174	150	166
	3	948	869	711	482	379	363	316	300	276	276	269	253
Average		1079	843	737	508	334	303	204	226	211	200	190	187

TABLE 15.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given.											
		Age, 2 weeks			Age, 4 weeks (retest)								
		10 minutes	30 minutes	1 hour	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
37	1	2370	2210	2050	790	750	592	513	513	513	434	395	395
	2	2210	2050	1740	829	790	711	671	671	632	553	553	553
	3	1970	2130	1580	513	395	395	355	316	316	276	316	276
Average		2180	2130	1790	711	645	566	513	500	487	421	421	408
40	1	790	632	474	118	118	103	87	71	55	71	71	71
	2	1030	869	790	395	355	316	261	221	221	221	197	197
	3	553	395	316	158	95	86	86	71	71	71	71	71
Average		791	632	527	224	189	168	145	121	116	121	113	113
39	1	1.3000	1.1800	0.9480	3160	3240	2920	2210	2290	2210	2130	1820	1420
	2	1.6200	1.3800	1.0700	3550	3550	2920	2130	2210	2130	2130	1900	1340
	3	8690	7900	7110	1420	1740	1500	1420	1420	1340	1340	1260	1110
Average		1.2630	1.1170	9100	2710	2840	2450	1920	1970	1890	1870	1660	1290
38	1	5920	3950	3790	1900	1660	1340	790	790	790	790	790	790
	2	5530	4180	3790	2130	1740	1260	790	750	790	790	790	790
	3	6320	4740	4190	2450	1970	1260	790	711	750	750	790	790
Average		5920	4290	3920	2160	1790	1290	790	750	780	780	790	790
34	1	4818	3870	3002	806	687	648	490	411	585	474	395	348
	2	3712	3317	2844	553	553	498	363	284	419	316	269	213
	3	3317	2765	2765	592	529	498	371	316	474	371	276	221
Average		3949	3317	2870	650	590	548	408	337	493	387	313	261
35	1	3049	2528	2409	687	671	506	253	205	174	142	126	118
	2	1998	1698	1769	387	340	308	197	158	118	95	87	79
	3	2930	2457	2117	869	687	474	276	245	213	166	182	134
Average		2659	2228	2098	648	566	429	242	203	168	134	132	110
36	1	2148	1777	1817	332	229	213	150	142	118	118	111	103
	2	2377	2077	1959	379	261	190	158	142	118	103	95	95
	3	2014	1777	1777	324	213	190	166	118	103	111	103	95
Average		2180	1877	1851	345	234	198	158	134	113	111	103	98

TABLE 15.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]								
		Age, 13 weeks (retest)								
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
0	1	142	118	118	126	103	87	87	79	71
	2	24	87	79	63	55	71	55	63	39
	3	79	79	63	55	47	55	39	55	24
Average		82	95	87	81	68	71	60	66	45
32	1	m	m	32	39	24	39	32	55	16
	2	m	39	47	39	47	47	55	55	39
	3	m	47	71	55	47	47	39	39	47
Average		m	29	50	44	39	44	42	50	34
1	1	m	87	79	55	55	55	55	55	55
	2	m	79	71	63	55	55	47	63	63
	3	m	63	55	55	39	39	39	39	32
Average		m	76	68	58	50	50	47	52	50
33	1	8	197	79	71	63	55	55	55	47
	2	39	126	103	87	87	79	63	87	47
	3	m	8	32	8	8	8	32	16	8
Average		16	110	71	55	53	47	50	53	34
30	1	m	103	87	55	95	87	87	79	71
	2	m	87	111	55	103	87	87	63	55
	3	m	190	87	47	79	79	79	63	63
Average		m	127	95	52	92	84	84	68	63
29	1	m	95	126	79	79	71	63	79	63
	2	m	11	158	150	158	150	142	134	111
	3	8	142	158	142	142	134	134	126	118
Average		3	83	147	124	126	118	113	113	97
28	1	m	79	87	87	79	103	87	87	71
	2	m	m	79	55	63	87	71	71	71
	3	71	103	103	87	103	103	95	95	79
Average		24	61	90	76	82	98	94	94	74
27a	1	m	87	79	71	71	71	71	63	63
	2	m	103	103	95	87	95	71	71	63
	3	m	95	103	95	87	103	79	71	71
Average		m	95	95	87	82	90	74	68	66
27b	1	m	m	32	39	39	32	32	32	24
	2	m	m	24	47	39	32	32	32	24
	3	m	m	55	63	39	32	32	32	32
Average		m	m	37	50	39	32	32	32	27

TABLE 15.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece No.	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the periods given. [m=moist.]								
		Age, 13 weeks (retest)								
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours
37	1	142	134	111	103	103	95	95	95	79
	2	m	m	32	63	24	24	24	32	24
	3	m	m	m	24	8	8	8	8	16
Average		47	45	48	63	45	42	42	45	40
40	1	m	134	55	55	47	47	55	47	24
	2	m	m	63	55	47	47	47	39	24
	3	m	m	32	39	39	24	16	32	24
Average		m	45	50	50	44	39	39	39	24
39	1	221	158	134	126	95	87	79	87	87
	2	284	190	197	182	158	150	134	126	95
	3	182	95	103	111	111	103	87	87	71
Average		229	148	145	140	121	113	100	100	84
38	1	118	71	55	47	32	32	32	24	16
	2	m	16	39	32	16	16	16	8	16
	3	142	95	79	55	47	55	39	39	24
Average		87	61	58	45	32	34	29	24	19
34	1	m	111	111	87	79	63	55	55	63
	2	m	87	111	95	87	79	79	79	79
	3	m	m	118	39	39	32	32	32	24
Average		m	66	113	74	68	58	55	55	55
35	1	m	m	55	47	39	32	32	32	24
	2	m	m	16	32	24	32	24	32	16
	3	m	m	95	39	32	32	32	32	24
Average		m	m	55	39	32	32	29	32	21
36	1	m	m	m	m	16	16	16	16	16
	2	m	m	m	m	16	16	16	16	16
	3	m	m	m	m	16	16	16	16	16
Average		m	m	m	m	16	16	16	16	16

TABLE 16.—Permeability of Waterproofed Mortars

1 Part Portland Cement to 8 Parts Sand

No. of compound	Test piece number	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of periods given. [m=moist.]									
		26 weeks (Retest)									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
0	1	32	87	79	79	79	71	71	63	55	.....
	2	m	87	79	24	24	24	24	8	16	.....
	3	8	8	8	24	24	24	24	8	16	.....
Average	.....	13	61	55	42	42	40	40	26	29	.....
32	1	m	m	m	m	16	8	m	8	8	m
	2	m	m	m	m	8	71	8	8	8	m
	3	m	m	47	24	32	24	16	16	16	8
Average	.....	m	m	16	8	19	34	8	11	11	3
31	1	m	39	55	47	39	39	39	39	47	.....
	2	m	m	m	47	32	16	16	24	16	.....
	3	m	m	55	47	47	39	39	39	47	.....
Average	.....	m	13	37	47	39	31	31	34	37	.....
33	1	m	8	8	8	16	16	8	8	16	.....
	2	m	16	24	32	32	24	32	32	24	.....
	3	m	8	m	m	8	8	8	8	16	.....
Average	.....	m	11	11	13	19	16	16	16	19	.....
30	1	m	m	m	32	24	24	16	16	16	.....
	2	m	m	m	16	24	24	16	32	24	.....
	3	m	m	8	24	16	8	8	m	8	.....
Average	.....	m	m	3	24	21	19	13	16	16	.....
29	1	m	8	8	16	16	16	8	8	16	.....
	2	m	m	m	m	8	8	8	8	8	.....
	3	m	8	m	8	16	16	16	8	16	.....
Average	.....	m	5	3	8	13	13	11	8	13	.....
28	1	m	m	39	32	32	39	47	32	24	.....
	2	m	m	47	55	47	39	47	39	32	.....
	3	m	m	63	63	55	55	47	55	32	.....
Average	.....	m	m	50	50	45	44	47	42	29	.....
27a	1	m	8	8	24	24	16	16	16	8	.....
	2	m	8	24	24	32	32	24	24	24	.....
	3	m	m	16	16	24	24	8	24	16	.....
Average	.....	m	5	16	21	27	24	16	21	16	.....
27b	1	m	m	8	16	16	16	16	16	16	.....
	2	m	8	m	8	m	m	m	m	m	.....
	3	m	m	m	m	m	m	8	8	8	.....
Average	.....	m	3	3	8	5	5	8	8	8	.....

TABLE 16.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece number	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of periods given. [m=moist.]									
		26 weeks (Retest)									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
37	1	m	m	m	m	24	16	16	16	m	m
	2	m	m	m	8	8	24	16	8	8	m
	3	m	m	m	m	m	m	m	m	m	m
Average		m	m	m	3	11	13	11	8	3	m
40	1	8	8	m	8	8	16	8	16	16	.....
	2	m	m	m	8	16	16	16	16	8	.....
	3	m	m	m	m	8	m	m	16	m	.....
Average		3	3	m	5	11	11	8	16	8	.....
39	1	316	95	87	79	63	55	39	39	32	.....
	2	340	229	190	158	126	95	95	95	79	.....
	3	355	63	55	47	47	39	32	32	32	.....
Average		337	129	111	95	79	63	55	55	48	.....
38	1	m	m	24	24	16	16	8	16	16	.....
	2	8	111	32	39	24	24	16	24	16	.....
	3	m	16	24	16	16	16	16	16	16	.....
Average		3	42	27	26	19	19	13	19	16	.....
34	1	m	m	95	55	63	71	55	71	79	.....
	2	m	m	71	95	39	39	32	32	32	.....
	3	m	m	m	m	m	m	m	16	8	.....
Average		m	m	55	50	34	37	29	40	40	.....
35	1	.....	m	m	39	47	47	32	39	39	.....
	2	.....	m	m	55	39	55	47	47	47	.....
	3	.....	237	237	253	213	190	182	174	166	.....
Average		.....	79	79	116	100	97	87	87	84	.....
36	1	0	0	0	0	0	m	m	m	m	8
	2	0	0	0	0	0	m	39	20	16	16
	3	0	0	0	m	m	m	32	m	16	16
Average		0	0	0	m	m	m	24	7	11	13

TABLE 16.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece number	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of periods given. [m=moist.]									
		52 weeks									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
0	1	m	m	m	m	8	16	32	24	8	.....
	2	0	0	0	0	0	0	m	m	m	.....
	3	0	0	0	0	0	0	0	0	0	.....
Average	.....	m	m	m	m	3	5	11	8	3	.....
32	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	m	m	m	m
	3	0	0	0	0	0	0	0	0	0	0
Average	.....	0	0	0	0	0	0	m	m	m	m
31	1	0	m	m	m	32	39	39	39	39	32
	2	0	0	0	0	m	m	m	m	m	8
	3	0	0	0	0	m	m	m	m	m	m
Average	.....	0	m	m	m	11	13	13	13	13	13
33	1	0	0	0	m	m	m	m	m	m	m
	2	0	0	m	m	m	24	16	8	16	8
	3	0	0	0	0	0	m	m	m	m	m
Average	.....	0	0	m	m	m	8	5	3	5	3
30	1	m	m	m	m	m	16	8	.....	.....	8
	2	m	m	m	m	m	m	m	.....	.....	m
	3	0	0	0	m	m	m	m	.....	.....	8
Average	.....	m	m	m	m	m	5	3	.....	.....	5
29	1	0	0	0	0	0	0	0	.....	.....	m
	2	m	m	m	0	0	0	0	.....	.....	16
	3	0	0	m	m	16	16	16	.....	.....	32
Average	.....	m	m	m	m	5	5	5	.....	.....	16
28	1	0	0	0	m	m	m	.....	.....	.....	16
	2	m	87	111	126	126	118	.....	.....	.....	47
	3	0	m	m	m	8	8	.....	.....	.....	8
Average	.....	m	29	37	42	45	42	.....	.....	.....	24
27a	1	0	m	m	m	m	8	16	8	8	8
	2	0	m	m	m	32	32	32	32	32	16
	3	m	39	95	95	95	87	79	79	79	32
Average	.....	m	13	32	32	42	42	43	40	40	19
27b	1	m	m	0	0	0	0	0	0	0	.....
	2	m	m	m	0	0	0	0	0	0	.....
	3	m	m	m	24	32	24	24	16	16	.....
Average	.....	m	m	m	8	11	8	8	5	5	.....

TABLE 16.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece number	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of periods given. [m=moist.]									
		52 weeks									
		10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
37	1	0	8	16	32	24	32	8	.....	8	8
	2	0	0	0	0	0	0	0	.....	0	8
	3	m	m	m	m	m	m	m	.....	m	m
Average	.....	m	3	5	11	8	11	3	.....	3	5
40	1	0	0	0	m	m	16	8	8	8	16
	2	0	0	m	m	m	m	m	8	8	8
	3	0	0	0	0	m	m	m	m	m	m
Average	.....	0	0	m	m	m	5	3	5	5	8
39	1	0	0	0	0	m	m	.....	m	.....	.....
	2	0	0	0	m	32	32	.....	32	.....	24
	3	0	0	0	m	m	m	.....	8	.....	4
Average	.....	0	0	0	m	11	11	.....	13	.....	14
38	1	0	0	0	m	32	39	.....	39	.....	8
	2	0	0	0	m	32	39	.....	39	.....	8
	3	0	0	0	m	m	m	.....	0	.....	0
Average	.....	0	0	0	m	21	26	.....	26	.....	5

TABLE 16.—Permeability of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand—Continued

No. of compound	Test piece number	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of periods given. [m=moist.]										
		52 weeks (Retest)										
		Pressure raised to—	10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
0	1	2.8 kilograms	m	8	24	32	32	32	.....	.....	.....	.....
	2		m	m	m	m	m	m	.....	.....	.....	.....
	3		0	0	0	0	0	0	.....	.....	.....	.....
Average	.....		m	3	8	11	11	11	.....	.....	.....	.....
32	1	5.6 kilograms	m	m	m	m	m	m	m	m	m	.....
	2		m	m	m	8	24	16	8	16	16	.....
	3		m	m	m	m	m	8	8	8	m	.....
Average	.....		m	m	m	3	8	8	5	8	5	.....
33	1	2.8 kilograms	m	16	16	24	63	39	24	32	32	.....
	2		16	32	55	63	63	63	47	47	71	.....
	3		m	8	16	16	8	8	32	16	32	.....
Average	.....		5	19	29	34	45	37	34	32	45	.....
30	1	2.8 kilograms	24	47	.....	.....	.....	.....	.....	.....	.....	.....
	2		24	32	.....	.....	.....	.....	.....	.....	.....	.....
	3		16	16	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....		21	32	.....	.....	.....	.....	.....	.....	.....	.....
29	1	2 8 kilograms	m	24	.....	.....	.....	.....	.....	.....	.....	.....
	2		16	24	.....	.....	.....	.....	.....	.....	.....	.....
	3		87	87	.....	.....	.....	.....	.....	.....	.....	.....
Average	.....		34	45	.....	.....	.....	.....	.....	.....	.....	.....
37	1	2.8 kilograms	m	24	39	32	24	24	.....	16	32	24
	2		8	m	8	8	8	8	.....	8	8	8
	3		m	16	8	8	m	m	.....	m	m	m
Average	.....		3	13	18	16	11	11	.....	8	13	11
40	1	2.8 kilograms	16	24	16	32	24	32	24	24	32	24
	2		8	16	16	16	16	16	16	8	16	16
	3		m	m	16	8	8	m	8	8	8	m
Average	.....		8	13	16	19	16	16	16	13	19	13
39	1	2.8 kilograms	m	m	m	m	m	16	8	8	8	m
	2		95	63	71	79	95	71	71	63	63	47
	3		8	16	16	16	24	16	16	16	16	47
Average	.....		34	26	29	32	40	34	32	29	29	31
38	1	2.8 kilograms	8	16	16	16	24	24	24	16	24	16
	2		8	16	16	32	39	32	16	32	24	16
	3		0	0	0	0	0	m	m	m	m	32
Average	.....		5	11	11	16	21	19	13	16	16	21

TABLE 17.—Effect of "Retesting" on Permeability

1 Part Portland Cement to 4 Parts Sand

No. of test piece	Age in weeks when tested	Test or retest	Tenths of a cubic millimeter of water passed per minute per square centimeter of surface subjected to 1.4 kilograms hydrostatic pressure. One-minute readings taken at the end of the following periods. [m=moist.]									
			10 minutes	30 minutes	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	24 hours
1	2	Test	87	103	87	.....	.....	.....	.....	.....	.....	.....
2	2	...do	245	182	150	.....	.....	.....	.....	.....	.....	.....
3	2	...do	221	134	111	.....	.....	.....	.....	.....	.....	.....
Average	.....	.....	184	140	116	.....	.....	.....	.....	.....	.....	.....
4	4	Test	m	m	8	16	24	16	16	16	8	m
5	4	...do	m	m	47	40	32	24	24	24	24	8
6	4	...do	m	79	47	55	32	32	24	32	24	8
Average	.....	.....	m	26	34	37	29	24	21	24	19	5
1	4	Retest	m	8	m	m	8	m	8	8	8	m
2	4	...do	16	8	m	m	8	m	16	8	8	m
3	4	...do	m	16	16	32	16	16	24	16	16	8
Average	.....	.....	5	11	5	11	11	5	16	11	11	3
7	13	Test	m	m	m	m	m	m	m	m	m	m
8	13	...do	m	m	m	m	m	m	m	m	m	m
9	13	...do	m	m	m	m	0	0	0	0	0	m
Average	.....	.....	m	m	m	m	m	m	m	m	m	m
1	13	Retest	m	m	m	m	m	m	m	m	.....	.....
2	13	...do	8	8	m	m	m	m	0	0	.....	.....
3	13	...do	m	m	m	m	0	0	0	0	.....	.....
Average	.....	.....	3	3	m	m	m	m	m	m	.....	.....
4	13	Retest	m	m	m	m	m	m	m	0	.....	.....
5	13	...do	m	m	m	m	m	m	m	0	.....	.....
6	13	...do	m	m	m	m	m	m	m	0	.....	.....
Average	.....	.....	m	m	m	m	m	m	m	0	.....	.....
10	26	Test	0	0	0	0	0	0	0	0	0	0
11	26	...do	0	m	m	m	m	m	m	24	16	8
12	26	...do	0	m	m	m	m	m	m	m	m	m
Average	.....	.....	0	m	m	m	m	m	m	8	5	3
1 [32]	26	Retest	m	0	0	0	0	[33] 0	[33] m	.....	.....	[33] m
2	26	...do	0	0	0	0	0	[33] 0	[33] 0	.....	.....	[33] 0
3	26	...do	m	0	0	0	0	[33] 0	[33] 0	.....	.....	[33] 0
Average	.....	.....	m	0	0	0	0	[33] 0	[33] m	.....	.....	[33] m
4	26	Retest	0	0	0	0	0	[33] 0	[33] 0	.....	.....	[33] 0
5	26	...do	0	0	0	0	0	[33] 0	m	.....	.....	[33] m
6	26	...do	0	0	0	0	0	[33] 0	m	.....	.....	[33] m
Average	.....	.....	0	0	0	0	0	[33] 0	m	.....	.....	[33] m
7	26	Retest	0	0	0	0	m	m	m	m	m	m
8	26	...do	0	0	0	0	0	0	0	0	0	m
9	26	...do	0	0	0	0	0	0	0	0	m	m
Average	.....	.....	0	0	0	0	m	m	m	m	m	m

[32] Test pieces 1 to 6, inclusive, were retested at the 26-week period under 4.2 and 5.6 kg. per sq. cm. hydrostatic pressure, with the following results:

Pressure, 4.2 kg.; time, 24 hours: Test piece number—1 moist, 2 dry, 3 dry, average moist; 4 dry, 5 moist, 6 moist, average moist. Pressure, 5.6 kg.; time, 24 hours: Test piece number—1 moist, 2 dry, 3 dry, average moist; 4 dry, 5 moist, 6 moist, average moist.

[33] Pressure was raised to 2.8 kg. per sq. cm.

TABLE 18.—Permeability of Mortars Containing Inert Fillers

1 Part Portland Cement to 4 Parts Sand

[All of the materials were dried and ground to pass a 200-mesh sieve before adding to the mortars. Assuming the weight of cement at 100 pounds per cubic foot (1.60 grams per cubic centimeter), 20 per cent by volume of each of the materials was added to the mixture.]

No. of compound	Test piece No.	Age, 26 weeks [34]			Age, 52 weeks		
		Pressure in kilograms	Hours under pressure	Flow in cubic centimeters	Pressure in kilograms	Hours under pressure	Flow in cubic centimeters
45 (sand)	1	5.6	24	0	5.6	96	m
	2	5.6	24	0	5.6	96	m
	3	5.6	24	m	5.6	96	0
Average				m			m
43 (Missouri clay)	1	5.6	24	0	5.6	96	m
	2	5.6	24	0	5.6	96	m
	3	5.6	24	0	5.6	96	0
Average				0			m
41 (New York clay)	1	5.6	24	0	5.6	72	0
	2	5.6	24	m	5.6	72	0
	3	5.6	24	0	5.6	72	0
Average				m			0
42 (fire clay)	1	5.6	24	m	5.6	72	0
	2	5.6	24	m	5.6	72	0
	3	5.6	24	0	5.6	72	0
Average				m			0
44 [35] (feldspar)	1	2.8	24	0	4.2	48	m
	2	2.8	24	0	4.2	48	m
	3	2.8	24	0	4.2	48	0
Average				0			m

[34] For the 4-week period all test pieces were tested under 1.4 kilograms pressure for 24 hours without flow or becoming "moist." Original records were lost in transit and details can not be given. For the 13-week period all original records were lost in transit, except for compound No. 44 (feldspar), which (at 2.8 kilograms pressure for 7 hours) shows moist for test piece No. 1, dry for No. 2, and moist for No. 3 and average.

[35] At 5.6 kilograms all three test pieces were cracked after 24 hours.

TABLE 19.—Damp-proof Qualities of Treated Mortars

1 Part Portland Cement to 4 Parts Sand

No. of compound	Amount incorporated and manner of incorporation	Behavior of 3 test pieces in ½ inch of water	Behavior of 3 test pieces in 1 inch of water	Remarks
0	No compound incorporated.	Sound after 34 days' exposure.	Sound after 108 days' exposure.	Placed in 1½ inches of water and failed in 58 days.
32	2% based on the weight of dry cement, or 2 gms. compound for 100 gms. cement. Mixed with dry cement before mixing with sand and water.	Sound after 24 days' exposure.	do	Placed in 1½ inches of water, 1 failed 66 days, 2 sound after 4 months 22 days' exposure.
31	do	Sound after 35 days' exposure.	Sound after 82 days' exposure.	Placed in 1½ inches of water for 6 months 18 days without failing.
33	do	Sound after 34 days' exposure.	do	Placed in 1½ inches of water for 6 months without failing.
30	do	Sound after 27 days' exposure.	Sound after 83 days' exposure.	Do.
29	do	Sound after 28 days' exposure.	do	Placed in 1½ inches of water for 6 months 6 days without failing.

TABLE 19.—Damp-proof Qualities of Treated Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

No. of compound	Amount incorporated and manner of incorporation	Behavior of 3 test pieces in ½ inch of water	Behavior of 3 test pieces in 1 inch of water	Remarks
28.....	5% based on the weight of dry cement, or 5 gms. to 100 gms. of cement. Mixed with dry cement before mixing with sand and water.	Sound after 28 days' exposure,	Sound after 83 days' exposure,	Placed in 1½ inches of water for 6 months 6 days without failing.
27.....	2% based on the weight of dry cement, or 2 gms. of compound to 100 gms. cement. Mixed with dry cement before mixing with sand and water.	Two failed in 2 days and 1 in 19 days.	.....	On repeating test all 3 specimens failed in 1 day. (Test was repeated on the same 3 specimens)
27b.....	10% based on the weight of dry cement, or 10 gms. of compound to 100 gms. cement. Mixed with dry cement before mixing with sand and water.	Sound after 35 days' exposure.	Sound after 109 days' exposure.	Placed in 1½ inches of water for 6 months 7 days without failing.
37.....	This is a "waterproofed" cement, and it was substituted in place of all the Portland cement.	Sound after 28 days' exposure.	Sound after 83 days' exposure.	Placed in 1½ inches of water for 6 months 6 days without failing.
40.....	10% added to the mixing water; that is, 10 c c of compound to 100 c c of water. This mixture was made before adding water to sand and cement.	One failed in 19 days, another in 25 days. Third sound after 28 days.	Sound and remained sound after 83 days' exposure.	Sound and remained sound after 6 months 6 days' exposure in 1½ inches of water.
39.....	4.16% added to the mixing water; that is, 416 c c of compound to 10000 c c of water. This mixture was made before adding water to sand and cement.	Sound after 28 days' exposure.	Sound after 83 days' exposure.	Placed in 1½ inches of water for 6 months 6 days without failing.
38.....	5% based on the weight of dry cement, or 5 gms. of compound to 100 gms. of cement. Incorporated after mixing dry sand and cement together.	.....do.....	.....do.....	Placed in 1½ inches of water and failed in 2 days. Repeating this test they failed in 3 days.
34.....	2½% based on the weight of dry cement, or 25 gms. of compound to 1000 gms. of cement. Mixed with dry cement before mixing with sand and water.	Sound after 95 days' exposure.	Sound after 136 days' exposure.	
35.....	1% based on the weight of dry cement, or 1 gm. of compound to 100 gms of cement. Mixed with dry cement before mixing with sand and water.	Sound after 35 days' exposure.	Sound after 164 days' exposure.	
36.....	2% based on the weight of dry cement, or 2 gm . of compound to 100 gms. of cement. Mixed w th dry cement before mixing with sand and water.	Sound after 125 days' exposure.	Sound after 64 days' exposure.	
23.....	This material was not incorporated in mortar but tested by itself. (See Analysis.) 12% water added.	Sound after 28 days' exposure.	Sound after 110 days' exposure.	

TABLE 19.—Damp-proof Qualities of Treated Mortars—Continued

1 Part Portland Cement to 6 Parts Sand

No. of compound	Behavior of 3 test pieces in ½ inch of water	Behavior of 3 test pieces in 1 inch of water	Remarks
0	Sound for 28 days' exposure	Sound for 7 days' exposure.	Placed in 1½ inches of water, 2 specimens failed in 6 days, and the third in 133 days.
32	Sound for 22 days' exposure	Sound for 108 days' exposure.	Placed in 1½ inches of water for 5 months 21 days without failing.
31	Two failed in 2 days, third in 2 days 4 hours.		On repeating test all three specimens failed in 24 hours.
33	Sound for 34 days' exposure	Sound for 82 days' exposure.	Placed in 1½ inches of water; failed in 51 days.
30	Failed in 3 days		On repeating test all three specimens failed in 24 hours.
29	Failed in 6 days		
28	One failed in 8 days; two sound for 28 days' exposure.	Sound for 83 days' exposure.	Two sound specimens placed in 1½ inches of water. One failed in 29 days, other in 8 months 6 days.
27(a)	Failed in 2 days		On repeating test all failed in 22 hours.
27(b)	Sound for 34 days' exposure	Sound for 108 days' exposure.	Placed in 1½ inches of water, 2 failed in 77 days, and one in 92 days.
37	Sound for 28 days' exposure	Sound for 83 days' exposure.	Placed in 1½ inches of water all 3 failed in 43 days.
40	One failed in 1 day, another in 1 day 3 hours, third in 2 days.		On repeating test all failed in 1 day.
39	Sound for 28 days' exposure	Sound for 83 days' exposure.	Placed in 1½ inches of water one of the three specimens failed after 6 months 6 days' exposure.
38	Failed in 21 hours		On repeating test all failed in 24 hours.
34	Failed in 24 days		
35	Failed in 1 day and 8 hours		
36	One failed in 38 days; two sound for 5 months 11 days' exposure.	Two sound for 64 days' exposure.	

1 Part Portland Cement to 8 Parts Sand

0	One failed in 4 hours, other 2 failed in 24 hours.		On repeating test all failed in 4 hours.
32	Sound for 34 days' exposure	Sound for 82 days' exposure.	Placed in 1½ inches of water all failed in 4 months.
31	Two failed in 1 day; third specimen failed in 2 days.		On repeating test all three failed in 6 hours.
3	One failed in 2 days, other 2 failed in 5 days.		On repeating test two failed in 3 hours and one in 1 day (24 hours).
30	Two failed in 18 hours, other in 27 hours.		On repeating test all failed in 1 day (24 hours).
29	Failed in 18 hours		On repeating test all failed in 1 day.
28	Failed in 18 hours		On repeating test all failed in 7 hours.
27(a)	One failed in 2 days, other two failed in 28 days.		On repeating test one failed in 2 hours, one in 3 hours, and one in 4 hours.
27(b)	Failed in 3 days		All failed in 4 hours on repeating test.
37	Sound for 28 days' exposure	Sound for 83 days' exposure.	Placed in 1½ inches of water all failed in 5 months 6 days.
40	Sound for 28 days' exposure	Sound for 83 days' exposure.	Placed in 1½ inches of water all failed in 3 days.
39	Sound for 28 days' exposure	Sound for 83 days' exposure.	Placed in 1½ inches of water all failed in 5 months and 6 days.
38	Failed in 21 hours		On repeating test all failed in 3 hours.
34	Failed in 22 hours		
35	Failed in 24 hours		
36	Sound for 125 days' exposure.	Sound for 36 days' exposure.	

TABLE 20.—Absorption of Waterproofed Mortars

1 Part Typical Portland Cement to 4 Parts Sand

[Results are averages of 3 test pieces for each set.]

In damp room 4 weeks; immersed 4 weeks

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
0	1, 2, 3	261.79	9.93	19.83	.....	.....	8.13	16.22	8.37	16.70	8.48	16.93	9.02	18.00
32	1, 2, 3	264.63	8.59	17.34	.....	.....	3.75	7.58	4.69	9.47	5.76	11.62	7.52	15.18
31	1. 2. 3	256.79	10.24	20.04	.....	.....	7.86	15.39	[1] 8.45	[1] 16.55	8.60	16.84	9.07	17.79
33	1, 2, 3	263.52	9.30	18.70	.....	.....	6.49	13.04	6.98	14.02	7.20	14.47	8.05	16.17
30	1, 2, 3	254.47	9.41	18.27	.....	.....	7.20	13.96	7.72	14.98	7.96	15.46	9.09	17.64
29	1, 2, 3	262.20	10.31	20.61	.....	.....	6.38	12.75	.....	.....	8.29	16.57	8.82	17.64
28	1, 2, 3	255.60	10.30	20.06	.....	.....	[2] 8.20	[2] 15.97	8.28	16.13	8.47	16.50	8.96	17.46
27a	1, 2, 3	255.93	9.99	19.53	.....	.....	[2] 7.79	[2] 15.20	8.01	15.62	8.60	16.79	9.32	18.19
27b	1, 2, 3	268.32	[3] 8.78	[3] 17.98	.....	.....	[2] 6.72	[2] 13.75	7.00	14.33	7.66	15.67	[4] 8.18	[4] 16.74
37	1, 2, 3	251.29	10.58	20.28	.....	.....	4.87	9.32	7.01	13.43	7.59	14.55	8.41	16.12
40	1, 2, 3	253.54	10.41	20.13	.....	.....	7.14	13.81	8.52	16.49	8.59	16.62	9.26	17.91
39	1, 2, 3	265.77	10.38	21.04	.....	.....	3.17	6.42	[1] 4.03	[1] 8.18	4.77	9.67	6.38	12.93
38	1, 2, 3	264.23	9.80	19.75	.....	.....	7.44	15.00	7.97	16.07	[5] 8.19	[5] 16.50	8.47	17.06
34	1, 2, 3	261.83	[6] 8.51	. 17.00	3.27	6.50	6.32	12.62	6.84	13.65	7.19	14.36	8.11	16.20
35	1, 2, 3	251.40	[6] 10.13	. 19.37	4.00	7.63	7.97	15.30	.....	.....	8.57	16.40	9.47	18.17
36	1, 2, 3	254.83	[6] 7.83	. 15.27	2.13	4.10	3.30	6.43	4.00	7.80	5.10	9.90	6.47	12.57

In damp room 13 weeks; immersed 1 week

0	4, 5, 6	261.61	7.63	15.30	.....	.....	7.37	14.70	[1] 7.60	[1] 15.17	[5] 7.70	[5] 15.37	[7] 8.33	[7] 16.57
32	4, 5, 6	263.65	8.57	17.27	.....	.....	4.00	8.13	5.30	10.67	5.73	11.50	6.47	13.00
31	4, 5, 6	260.52	7.40	14.70	.....	.....	[2] 7.23	[2] 14.37	.....	.....	7.57	15.07	8.10	16.10
33	4, 5, 6	262.98	6.70	13.43	.....	.....	5.90	11.80	6.53	13.07	6.83	13.70	7.57	15.17
30	4, 5, 6	256.81	7.83	15.30	.....	.....	7.63	15.00	8.00	15.63	8.13	16.00	9.07	17.73
29	4, 5, 6	255.01	8.53	16.57	.....	.....	7.83	15.23	8.27	16.00	8.70	16.90	9.70	18.83
28	4, 5, 6	252.52	8.90	17.10	.....	.....	8.43	16.23	8.73	16.80	9.00	17.37	9.83	18.93
27a	4, 5, 6	262.29	7.97	15.93	.....	.....	7.50	15.03	[1] 7.67	[1] 15.37	[5] 7.73	[5] 15.53	[7] 8.40	[7] 16.77
27b	4, 5, 6	265.75	9.63	19.53	.....	.....	8.07	16.33	8.37	17.00	8.67	17.50	.....	.....
37	4, 5, 6	251.19	6.93	13.20	.....	.....	6.50	12.47	7.10	13.57	7.63	14.60	8.67	16.60
40	4, 5, 6	251.94	8.73	16.73	.....	.....	8.57	16.53	8.83	16.93	8.97	17.10	9.60	18.47
39	4, 5, 6	259.13	7.40	14.57	.....	.....	3.20	6.30	3.90	7.67	4.53	9.00	5.87	11.57
38	4, 5, 6	259.00	7.73	15.30	.....	.....	7.10	14.10	7.83	15.60	8.10	16.10	8.53	16.90
34	4, 5, 6	260.46	8.83	17.57	3.07	6.13	6.50	12.90	7.10	14.07	7.47	14.83	8.37	16.53
35	4, 5, 6	252.72	9.53	18.40	3.23	6.23	7.30	14.00	7.57	14.68	7.63	14.70	9.27	17.80
36	4, 5, 6	255.01	8.57	16.73	.....	.....	.....	.....	[1] 5.65	[1] 10.95	6.33	12.30	[8] 7.57	14.67

NOTE.—Results indicated by the reference figures show the following variations in days immersed: [1] 4, [2] 2, [3] 25, [4] 19, [5] 8, [6] 7, [7] 29, [8] 30.

TABLE 20.—Absorption of Waterproofed Mortars—Continued

1 Part Typical Portland Cement to 4 Parts Sand—Continued

[Results are averages of 3 test pieces for each set.]

In damp room 26 weeks; immersed 1 week

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
0	7, 8, 9	266.12	8.33	16.93	2.43	4.93	7.33	14.90	7.80	15.83	8.00	16.27	8.47	17.17
32	7, 8, 9	262.62	8.10	16.17	1.43	2.87	3.33	6.70	4.40	8.83	4.77	9.57	5.90	11.87
31	7, 8, 9	259.70	8.17	16.30	2.70	5.37	6.97	13.93	7.37	14.60	7.57	15.13	8.10	16.17
33	7, 8, 9	266.84	8.23	16.77	3.27	6.20	5.97	12.20	6.33	12.83	6.90	14.13	7.40	15.03
30	7, 8, 9	254.35	8.60	16.67	3.10	6.03	7.67	14.93	8.10	15.67	8.30	16.10	8.87	17.20
29	7, 8, 9	265.99	7.93	16.10	2.95	5.90	6.83	13.87	7.23	14.63	7.37	14.97	7.97	16.17
28	7, 8, 9	251.15	7.20	13.83	2.07	3.93	5.93	11.33	6.83	13.07	7.07	13.50	7.80	14.97
27a	7, 8, 9	259.79	7.80	15.43	2.27	4.50	5.37	10.63	7.00	13.83	7.37	14.67	8.03	15.93
27b	7, 8, 9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
37	7, 8, 9	251.18	8.60	16.47	2.07	3.90	4.47	8.57	5.43	10.53	5.90	11.30	6.70	12.80
40	7, 8, 9	255.23	9.63	18.67	4.50	8.73	7.90	15.43	8.17	15.80	8.27	16.00	8.93	17.30
39	7, 8, 9	263.70	10.70	21.50	1.03	2.07	2.03	4.13	3.03	6.00	3.80	7.63	5.87	11.77
38	7, 8, 9	266.50	8.17	16.60	1.50	3.10	5.63	11.53	7.00	14.23	7.20	14.70	7.83	15.97
34	7, 8, 9	261.82	8.77	17.53	.....	.....	6.23	12.50	7.20	14.40	7.40	14.77	7.87	15.73
35	7, 8, 9	255.10	7.47	14.50	.....	.....	7.17	14.00	7.53	14.73	7.93	15.40	8.80	17.13
36	7, 8, 9	258.70	6.17	12.17	.....	.....	2.67	5.23	3.53	6.97	4.33	8.57	5.47	10.80
23	7, 8, 9	287.38	6.80	14.90	.....	.....	3.17	6.93	4.30	9.40	4.60	10.10	5.23	11.43

In damp room 52 weeks; immersed 1 week

0	10, 11, 12	263.45	5.70	11.43	.....	.....	5.27	10.50	5.93	12.00	6.47	13.00	7.20	14.50
32	10, 11, 12	265.28	6.10	12.37	.....	.....	[2] 2.37	[2] 4.77	[1] 3.80	[1] 7.67	[5] 4.53	[5] 9.17	[7] 5.43	[7] 11.07
31	10, 11, 12	261.72	6.37	12.70	.....	.....	[2] 6.40	[2] 12.77	6.50	12.93	6.70	13.37	7.17	14.30
33	10, 11, 12	263.83	6.50	13.00	.....	.....	5.57	11.20	6.40	12.83	6.70	13.50	7.20	14.40
30	10, 11, 12	260.30	6.67	13.27	.....	.....	6.47	12.83	6.77	13.47	6.93	13.80	7.33	14.50
29	10, 11, 12	263.67	7.17	14.40	.....	.....	4.97	10.00	6.97	14.03	.....	.....	7.77	15.63
28	10, 11, 12	252.27	7.37	14.13	.....	.....	6.43	12.40	7.23	13.90	.....	.....	7.90	15.17
27a	10, 11, 12	265.92	7.33	14.83	.....	.....	6.80	13.83	7.40	15.07	7.63	15.50	7.97	16.17
27b	10, 11, 12	269.20	6.87	14.07	.....	.....	4.87	10.03	6.70	13.80	7.13	14.67	7.73	15.87
37	10, 11, 12	254.02	5.90	11.43	.....	.....	4.60	8.97	5.70	11.10	.....	.....	6.53	12.67
40	10, 11, 12	259.08	8.20	16.20	.....	.....	7.77	15.37	7.93	15.70	8.13	16.03	8.50	16.77
39	10, 11, 12	264.53	6.53	13.17	.....	.....	2.50	5.03	4.17	8.37	5.10	10.33	6.27	12.63
38	10, 11, 12	267.53	6.80	13.93	.....	.....	5.47	11.17	6.97	14.23	7 30	14.87	7.77	15.77
23	10, 11, 12	287.98	5.67	12.47	.....	.....	2.33	5.10	3.07	6.73	3.67	8.07	4.37	9.70

TABLE 21.—Absorption of Waterproofed Mortars

1 Part Typical Portland Cement to 6 Parts Sand

[Results are averages of 3 test pieces for each set.]

In damp room 4 weeks; immersed 4 weeks

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
0	1, 2, 3	251.05	10.08	21.22	.....	.....	[1] 8.48	[1] 16.24	8.61	16.48	9.19	17.60	9.85	18.86
32	1, 2, 3	255.83	9.69	18.92	.....	.....	4.46	8.70	5.55	10.82	6.74	13.16	8.68	16.93
31	1, 2, 3	252.88	[2] 10.72	[2] 20.67	.....	.....	7.95	15.34	8.55	16.50	8.87	17.12	9.37	18.07
33	1, 2, 3	249.29	9.82	18.68	.....	.....	6.66	12.68	7.38	14.04	7.73	14.69	9.36	17.82
30	1, 2, 3	247.04	11.24	21.17	.....	.....	7.51	14.14	8.65	16.29	8.93	16.83	9.72	18.32
29	1, 2, 3	250.11	11.43	21.81	.....	.....	6.36	12.14	.....	.....	8.78	16.74	9.54	18.20
28	1, 2, 3	237.37	11.81	21.39	.....	.....	7.15	12.94	8.61	15.60	9.09	16.46	9.91	17.94
27a	1, 2, 3	252.46	11.63	22.41	.....	.....	8.65	16.66	9.38	18.06	9.69	18.65	10.18	19.62
27b	1, 2, 3	251.84	[2] 9.98	[2] 19.18	.....	.....	[1] 8.40	[1] 16.13	8.88	17.07	9.62	18.47	[3] 10.54	[3] 20.26
37	1, 2, 3	243.51	10.25	19.04	.....	.....	5.05	9.38	6.91	12.84	7.64	14.19	8.90	16.53
40	1, 2, 3	244.03	12.30	22.90	.....	.....	8.68	16.16	9.55	17.77	9.88	18.40	10.39	19.35
39	1, 2, 3	254.33	12.34	23.94	.....	.....	3.04	5.90	[1] 4.19	[1] 8.12	5.49	10.65	9.59	18.59
38	1, 2, 3	249.09	12.30	23.37	.....	.....	9.13	17.33	9.68	18.38	9.85	18.70	10.84	20.59
34	1, 2, 3	245.26	10.74	20.09	4.40	8.23	7.51	14.05	8.68	16.24	8.96	16.76	10.50	19.64
35	1, 2, 3	243.17	[4] 11.10	[4] 20.40	5.47	10.13	8.83	16.43	9.53	17.70	9.80	18.13	11.07	20.50
36	1, 2, 3	245.05	[4] 10.00	[4] 18.70	2.43	4.53	4.07	7.57	4.90	9.17	6.07	11.33	[5] 7.47	[5] 14.00

In damp room 13 weeks; immersed 1 week

0	4, 5, 6	246.29	8.47	15.91	.....	.....	8.10	15.21	[6] 8.34	[6] 15.67	8.46	15.88	9.18	17.23
32	4, 5, 6	256.24	[7] 10.07	[7] 19.74	.....	.....	4.49	8.76	[6] 5.85	[6] 11.43	[8] 6.35	[8] 12.41	7.48	14.63
31	4, 5, 6	246.76	8.53	16.03	.....	.....	[1] 8.13	[1] 15.33	.....	.....	8.73	16.40	9.40	17.70
33	4, 5, 6	252.28	7.21	13.88	.....	.....	6.09	11.72	7.01	13.51	7.40	14.24	8.51	16.37
30	4, 5, 6	244.89	7.91	14.78	.....	.....	7.83	14.63	8.27	15.45	8.63	16.11	9.72	18.16
29	4, 5, 6	247.33	9.13	17.23	.....	.....	8.40	15.84	8.83	16.65	9.37	17.67	10.39	19.61
28	4, 5, 6	240.55	9.06	16.63	.....	.....	8.48	15.56	8.79	16.14	9.25	16.98	10.34	18.98
27a	4, 5, 6	248.43	8.75	16.59	.....	.....	8.40	15.91	8.59	16.28	[8] 8.75	[8] 16.58	[9] 9.52	[9] 18.04
27b	4, 5, 6	254.97	9.50	18.47	.....	.....	7.78	15.14	8.13	15.82	8.42	16.37	.....	.....
37	4, 5, 6	237.80	6.95	12.61	.....	.....	6.94	12.59	7.60	13.79	8.26	14.99	9.76	17.71
40	4, 5, 6	242.28	10.32	19.05	.....	.....	9.28	17.15	9.51	17.57	9.82	18.15	10.61	19.69
39	4, 5, 6	249.02	8.14	15.50	.....	.....	3.30	6.28	4.15	7.89	4.80	9.12	6.37	12.09
38	4, 5, 6	249.13	9.28	17.62	.....	.....	8.64	16.40	9.12	17.33	9.50	18.05	10.24	19.45
34	4, 5, 6	248.21	11.08	20.98	3.17	5.99	6.95	13.15	7.83	14.82	8.45	16.00	9.61	18.20
35	4, 5. 6	244.05	11.07	20.61	4.28	7.99	8.62	16.05	8.99	16.73	9.05	16.85	9.50	17.68
36	4, 5, 6	244.28	11.47	21.37	.....	.....	.....	.....	[6] 7.09	[6] 13.20	7.57	14.10	[10] 8.63	[10] 16.02

NOTE.—Results indicated by the reference figures show the following variations in days immersed: 2, [2] 20, [3] 25, [4] 7, [5] 21, [6] 4, [7] 28, [8] 8, [9] 29, [10] 30, [11] 6, [12] 31.

TABLE 21.—Absorption of Waterproofed Mortars—Continued

1 Part Typical Portland Cement to 6 Parts Sand—Continued

[Results are averages of 3 test pieces for each set.]

In damp room 26 weeks; immersed 1 week

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
0	7, 8, 9	252.96	8.57	16.57	2.57	4.93	7.37	14.27	8.00	15.50	8.17	15.77	8.80	16.93
32	7, 8, 9	255.67	8.83	17.27	1.27	2.47	3.63	7.07	5.03	9.80	5.47	10.63	7.07	13.83
31	7, 8, 9	252.66	9.33	17.90	2.33	4.53	6.77	13.00	7.30	14.10	7.60	14.57	8.47	16.30
33	7, 8, 9	249.84	9.63	18.33	2.67	5.10	7.23	13.77	7.63	14.50	8.33	15.87	9.00	17.13
30	7, 8, 9	252.32	9.77	18.80	4.27	8.23	7.97	15.33	8.33	16.00	8.60	16.57	9.07	17.43
29	7, 8, 9	252.19	8.70	16.77	2.80	5.37	6.10	11.73	8.27	15.93	8.37	16.17	9.10	17.50
28	7, 8, 9	244.57	10.37	19.30	3.40	6.43	7.73	14.50	.....	.....	[11] 8.17	[11] 15.27	[12] 9.13	[12] 17.03
27a	7, 8, 9	251.12	6.90	13.27	2.83	5.43	6.47	12.40	6.77	12.97	7.37	14.10	8.47	16.17
27b	7, 8, 9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
37	7, 8, 9	243.72	10.17	18.97	2.50	4.67	6.17	11.50	.....	.....	[11] 7.07	[11] 13.17	[12] 8.57	[12] 15.97
40	7, 8. 9	247.25	11.03	20.80	5.20	9.80	8.63	16.23	8.70	16.43	9.07	17.10	9.63	18.20
39	7, 8, 9	249.34	12.43	23.57	1.97	3.67	3.63	6.87	4.50	8.50	5.90	11.10	8.20	15.53
38	7, 8, 9	252.95	11.40	21.93	2.23	4.33	7.97	15.27	8.53	16.43	8.70	16.73	9.67	18.57
34	7, 8, 9	247.09	8.60	16.17	.....	.....	7.10	13.37	7.70	14.53	8.13	15.37	9.50	17.93
35	7, 8, 9	244.48	8.07	15.17	.....	.....	7.40	13.93	8.30	15.63	8.53	16.10	9.63	18.20
36	7, 8, 9	247.12	6.67	12.57	.....	.....	4.37	8.27	4.80	9.00	5.47	10.30	6.60	12.47
23	7, 8, 9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

In damp room 52 weeks; immersed 1 week

0	10, 11, 12	251.28	7.03	13.47	.....	.....	6.70	12.87	7.03	13.57	7.43	14.30	7.97	15.23
32	10, 11, 12	257.98	7.13	14.03	.....	.....	[1] 2.77	[1] 5.40	[6] 4.93	[6] 9.73	5.80	11.40	6.97	13.77
31	10, 11‘ 12	252.88	7.63	14.70	.....	.....	6.90	13.30	7.40	14.23	8.13	15.63	8.40	16.27
33	10, 11, 12	255.38	5.53	10.80	.....	.....	3.17	6.20	5.50	10.70	5.90	10.57	6.73	13.10
30	10, 11, 12	247.72	7.70	14.57	.....	.....	7.43	14.07	7.80	14.77	8.07	15.17	8.50	16.07
29	10, 11, 12	255.27	8.13	15.80	.....	.....	7.00	13.57	8.20	15.90	.....	.....	8.83	17.20
28	10. 11, 12	245.68	7.07	13.23	.....	.....	6.20	11.60	6.80	12.80	.....	.....	7.98	14.90
27a	10, 11, 12	251.62	6.23	12.00	.....	.....	5.50	10.57	6.03	11.67	6.63	13.00	7.50	14.30
27b	10, 11, 12	259.51	7.27	14.43	.....	.....	5.83	11.67	[6] 6.57	[6] 13.07	7.03	13.87	8.20	16.23
37	10, 11, 12	247.30	6.90	13.07	.....	.....	6.53	12.23	6.93	13.07	7.30	13.77	7.70	14.53
40	10, 11, 12	247.93	8.63	16.30	.....	.....	8.10	15.27	8.20	15.53	8.50	16.03	8.97	16.90
39	10, 11, 12	254.07	5.80	11.23	.....	.....	2.67	5.10	4.23	8.23	5.23	10.10	6.63	12.83
38	10, 11. 12	254.78	7.50	14.53	.....	.....	5.23	10.13	7.27	14.10	7.77	15.13	8.27	16.13

TABLE 22.—Absorption of Waterproofed Mortars

1 Part Typical Portland Cement to 8 Parts Sand

[Results are averages of 3 test pieces for each set.]

In damp room 4 weeks; immersed 4 weeks

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
0	1, 2, 3	241.25	11.21	20.63	.....	.....	[1] 9.06	[1] 16.67	9.14	16.82	9.78	18.00	10.84	19.95
32	1, 2, 3	251.40	9.89	18.97	.....	.....	5.41	10.37	[2] 5.77	[2] 11.07	6.48	12.42	8.09	15.51
31	1, 2, 3	247.24	[3] 11.21	[3] 21.15	.....	.....	[1] 8.61	[1] 16.24	8.80	16.60	9.34	17.61	10.12	19.09
33	1, 2, 3	242.51	12.21	22.58	.....	.....	8.33	15.41	9.39	17.37	10.43	19.31	12.00	22.19
30	1, 2, 3	241.88	12.11	22.34	.....	.....	8.42	15.54	9.08	16.75	9.42	17.38	10.48	19.33
29	1, 2, 3	244.12	11.41	21.24	.....	.....	[1] 8.82	[1] 16.43	8.85	16.48	9.34	17.40	10.20	19.00
28	1, 2, 3	236.08	11.92	21.46	.....	.....	7.42	13.35	8.55	15.40	8.93	16.08	9.70	17.47
27a	1, 2, 3	247.57	11.76	22.20	.....	.....	8.55	16.16	9.00	17.00	9.29	17.54	10.08	19.03
27b	1, 2, 3	250.89	[4] 10.92	[4] 20.89	.....	.....	[1] 8.60	[1] 16.46	8.83	16.90	9.37	17.92	[5] 9.94	[5] 19.03
37	1, 2, 3	241.21	11.28	20.75	.....	.....	6.04	11.12	8.06	14.83	8.56	15.75	9.53	17.53
40	1, 2, 3	243.60	12.56	23.34	.....	.....	9.34	17.36	[2] 9.70	[2] 18.02	9.84	18.28	10.50	19.52
39	1, 2, 3	245.37	12.38	23.17	.....	.....	[1] 6.28	[1] 11.74	6.62	12.39	7.83	14.64	10.08	18.88
38	1, 2, 3	249.76	11.63	22.16	.....	.....	7.08	13.48	[2] 8.93	[2] 17.02	9.23	17.57	10.06	19.17
34	1, 2, 3	248.84	[4] 10.60	[4] 19.47	4.77	8.73	7.44	13.67	8.53	15.67	8.86	16.27	11.04	20.29
35	1, 2, 3	239.80	[4] 10.73	[4] 19.67	8.13	14.90	9.23	16.90	9.50	17.37	9.90	18.10	11.60	21.23
36	1, 2, 3	241.34	[4] 11.00	[4] 20.23	2.23	4.20	3.97	7.23	4.67	8.63	6.10	11.20	8.60	15.87

In damp room 13 weeks; immersed 1 week

0	4, 5, 6	243.11	9.23	17.10	.....	.....	8.80	16.33	[2] 9.03	[2] 16.73	[6] 9.27	[6] 17.20	[7] 10.20	[7] 18.93
32	4, 5, 6	246.45	8.50	16.10	.....	.....	[1] 5.80	[1] 10.86	.....	.....	6.80	12.70	8.10	15.30
31	4, 5, 6	245.60	8.30	15.53	.....	.....	8.20	15.37	8.47	15.87	8.80	16.47	9.87	18.49
33	4, 5, 6	241.43	8.67	15.97	.....	.....	7.17	13.20	7.93	14.57	8.53	15.77	10.00	18.40
30	4, 5, 6	238.85	8.75	16.00	.....	.....	8.35	15.15	8.80	16.05	9.40	17.15	10.55	19.25
29	4, 5, 6	238.97	9.77	17.80	.....	.....	8.60	15.63	9.13	16.73	9.90	18.03	11.10	20.27
28	4, 5, 6	237.78	8.83	16.00	.....	.....	8.53	15.47	8.80	15.97	9.23	16.73	10.03	18.23
27a	4, 5, 6	246.45	[8] 11.63	[8] 21.87	.....	.....	8.80	16.57	9.23	17.43	9.43	17.80	.....	.....
27b	4, 5, 6	250.73	10.80	20.70	.....	.....	8.50	16.20	8.90	17.03	9.43	18.00	.....	.....
37	4, 5, 6	235.57	6.57	11.82	.....	.....	6.83	12.27	7.47	13.43	8.03	14.43	9.73	17.53
40	4, 5, 6	237.25	10.03	18.13	.....	.....	9.33	16.90	9.53	17.20	9.63	17.43	10.73	19.40
39	4, 5, 6	241.43	8.10	14.90	.....	.....	3.90	7.20	4.90	9.05	5.65	10.45	7.05	13.00
38	4, 5, 6	247.45	[8] 11.00	[8] 20.70	.....	.....	6.97	13.17	.....	.....	.....	.....	.....	.....
34	4, 5, 6	244.76	11.63	21.70	.....	.....	8.10	15.13	[2] 8.80	[2] 16.43	9.47	17.73	10.67	19.90
35	4, 5, 6	239.42	11.00	20.06	.....	.....	.....	.....	9.10	16.60	9.63	17.60	[9] 10.80	[9] 19.70
36	4, 5, 6	245.45	11.87	21.97	.....	.....	.....	.....	[2] 6.13	[2] 11.33	6.73	12.47	[9] 7.80	[9] 14.50

NOTE.—Results indicated by the reference figures show the following variations in days immersed: [1] 2, [2] 4, [3] 20, [4] 7, [5] 25, [6] 8, [7] 29, [8] 28, [9] 30.

TABLE 22.—Absorption of Waterproofed Mortars—Continued

1 Part Typical Portland Cement to 8 Parts Sand—Continued

In damp room 26 weeks; immersed 1 week

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption											
			Previous to drying		Subsequent to drying									
					Immersed 30 minutes		Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Volume	Volume	Weight	Volume
0	7, 8, 9	246.38	8.80	16.57	3.10	5.77	6.00	11.33	6.73	12.63	7.47	14.00	9.33	17.10
32	7, 8, 9	252.05	8.83	16.97	1.93	3.70	4.33	8.30	5.63	10.77	6.13	11.83	7.57	14.53
31	7, 8, 9	247.32	8.33	15.70	2.60	4.93	7.03	13.27	7.53	14.17	7.70	14.47	8.47	15.97
33	7, 8, 9	247.64	11.07	20.90	3.10	5.80	8.00	15.10	9.00	17.00	9.40	17.80	10.20	19.22
30	7, 8, 9	243.50	9.57	17.73	3.53	6.63	7.80	14.50	8.27	15.33	8.63	16.03	9.23	17.17
29	7, 8, 9	247.67	10.00	18.90	3.03	5.73	8.23	15.53	8.70	16.37	9.03	17.07	9.67	18.23
28	7, 8, 9	238.17	11.60	21.13	3.40	6.13	7.93	14.47	8.23	14.92	8.50	15.40	9.37	17.00
27a	7, 8, 9	246.81	9.93	18.73	2.83	5.30	8.07	15.17	8.37	15.77	8.67	16.37	9.47	17.80
37	7, 8, 9	240.91	10.43	19.13	2.83	5.23	6.53	12.07	7.20	13.30	7.80	14.33	9.10	16.77
40	7, 8, 9	239.67	10.73	19.57	3.67	6.67	7.70	14.07	7.83	14.33	8.27	15.07	8.93	16.37
39	7, 8, 9	244.96	13.10	24.43	1.23	2.27	2.20	4.17	3.27	6.07	5.00	9.33	8.33	15.57
38	7, 8, 9	252.07	11.47	22.03	2.90	5.53	7.57	14.50	8.27	15.90	8.40	16.17	9.73	18.73
34	7, 8, 9	242.64	8.37	15.47	.....	.....	7.03	13.03	7.73	14.33	8.17	15.07	9.57	17.73
35	7, 8, 9	240.65	8.83	16.23	.....	.....	8.73	16.03	9.13	16.77	9.80	18.00	10.60	19.43
36	7, 8, 9	244.63	6.37	11.87	.....	.....	4.77	8.93	5.10	9.57	5.90	11.00	7.17	13.43

In damp room 52 weeks; immersed 1 week

0	10, 11, 12	248.73	7.73	14.67	.....	.....	6.93	13.17	7.40	14.07	7.87	14.90	8.97	16.97
32	10, 11, 12	252.25	6.07	11.70	.....	.....	[1] 4.47	[1] 8.57	4.83	9.23	5.67	10.93	6.83	13.13
31	10, 11, 12	248.57	7.10	13.43	.....	.....	6.40	12.13	6.97	13.13	7.33	13.90	8.37	15.83
33	10, 11, 12	248.85	7.83	14.87	.....	.....	5.47	10.40	7.87	14.97	8.20	15.57	8.73	16.60
30	10, 11, 12	241.65	7.95	14.60	.....	.....	7.20	13.30	7.95	14.60	.....	.....	8.55	15.85
29	10, 11, 12	245.67	8.60	16.13	.....	.....	7.60	14.20	8.20	15.40	.....	.....	9.13	17.10
28	10, 11, 12	239.55	8.37	15.30	.....	.....	7.33	13.43	7.97	14.57	.....	.....	8.40	15.37
27a	10, 11, 12	249.28	8.97	17.00	.....	.....	8.39	15.93	8.70	16.57	8.97	17.07	9.47	18.03
27b	10, 11, 12	254.57	8.43	16.33	.....	.....	7.50	14.57	7.83	15.20	8.37	16.27	9.13	17.77
37	10, 11, 12	242.03	6.93	12.77	.....	.....	6.60	12.13	6.87	12.67	7.20	13.23	7.60	14.00
40	10, 11, 12	239.42	8.00	14.60	.....	.....	7.67	13.87	7.83	14.33	7.90	14.40	8.23	15.07
39	10, 11, 12	245.02	6.10	11.45	.....	.....	2.75	5.20	4.10	7.75	5.05	9.40	6.15	11.45
38	10, 11, 12	249.23	8.07	15.30	.....	.....	5.73	10.90	7.93	15.07	8.37	15.87	8.83	16.80

TABLE 23.—Absorption of Mortars Containing Inert Fillers

1 Part Typical Portland Cement to 4 Parts Sand

[Results are averages of 3 test pieces for each set.]

No. of compound	No. of test piece	Dry weight in grams	Percentage of absorption									
			Previous to drying		Subsequent to drying							
					Immersed 24 hours		Immersed 72 hours		Immersed 7 days		Immersed 28 days	
			Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight	Volume
In damp room 13 weeks; immersed 1 week												
45	1, 2, 3	268.03	9.52	19.46	7.65	15.63	7.93	16.22	8.02	16.40	8.45	17.30
43	1, 2, 3	271.66	9.40	19.50	7.91	16.40	8.15	16.88	8.28	16.98	8.59	17.80
41	1, 2, 3	267.53	9.80	20.01	8.05	16.38	8.30	16.85	8.41	17.15	8.87	18.07
44	1, 2, 3	265.47	8.00	16.19	7.52	15.22	7.81	15.80	7.97	16.10	8.35	16.88
42	1, 2, 3	270.97	9.82	20.23	8.00	16.53	8.50	17.68	8.62	17.83	9.00	18.63
In damp room 26 weeks; immersed 1 week												
45	1, 2, 3	262.79	7.15	14.30	5.62	11.24	6.11	12.22	6.38	12.75	6.93	13.87
43	1, 2, 3	270.51	7.77	16.02	6.79	14.00	6.85	14.10	7.12	14.70	7.51	15.50
41	1, 2, 3	266.77	7.36	14.96	4.97	10.10	6.18	12.58	6.47	13.14	6.91	14.07
44	1, 2, 3	264.88	7.92	15.98	7.19	14.50	[36] 7.50	[36] 15.13	[37] 7.73	[37] 15.60	[38] 8.35	[38] 16.88
42	1, 2, 3	272.59	8.44	17.52	7.42	15.40	7.60	15.80	7.84	16.27	8.17	16.98
In damp room 52 weeks; immersed 1 week												
45	1, 2, 3	265 80	6.27	12.70	6.00	12.16	6.31	12.77	6.47	13.12	6.76	13.70
43	1, 2, 3	267.93	6.94	14.19	6.53	13.30	6.78	13.80	6.98	14.22	7.19	14.63
41	1, 2, 3	269.87	7.38	15.18	7.19	14.80	7.37	15.17	7.57	15.58	7.74	15.94
44	1, 2, 3	261.58	8.08	16.10	7.44	14.84	7.63	15.22	7.88	15.72	8.59	17.13
42	1, 2, 3	270.03	7.01	14.44	6.32	13.02	6.86	14.12	7.12	14.67	7.38	15.21

TABLE 24.—Tensile and Compressive Strength of Waterproofed Mortars

1 Part Portland Cement to 4 Parts Sand

Number of compound	Number of test pieces	Compressive strength (pounds per square inch)						Tensile strength (pounds per square inch)					
		Age in weeks when tested						Age in weeks when tested					
		1	2	4	13	26	52	1	2	4	13	26	52
0	1, 2, 3	750	1141	1493	2354	3158	3558	131	196	286	326	377	527
	Range [39]	72	49	173	97	250	450	6	28	62	6	39	76
32	1, 2, 3	1096	1357	2123	2908	3250	3850	154	229	295	345	409	475
	Range	86	289	84	250	1300	525	13	20	24	37	34	41
31	1, 2, 3	881	1335	1720	2274	2742	3569	172	204	256	311	370	418
	Range	185	107	85	282	975	438	21	36	48	66	38	65
33	1, 2, 3	993	1697	1837	2597	2933	3633	174	252	278	357	350	420
	Range	40	271	153	298	400	275	7	14	87	26	27	27
30	1, 2, 3	920	1244	1537	1794	2210	2642	156	215	254	302	334	420
	Range	90	231	97	272	330	525	18	27	47	26	54	72

[36] Immersed 96 hours. [37] Immersed 8 days. [38] Immersed 29 days.

[39] Range is the difference between maximum and minimum values for three test pieces.

TABLE 24.—Tensile and Compressive Strength of Waterproofed Mortars—Continued

1 Part Portland Cement to 4 Parts Sand—Continued

Number of compound	Number of test pieces	Compressive strength (pounds per square inch)						Tensile strength (pounds per square inch)					
		Age in weeks when tested						Age in weeks when tested					
		1	2	4	13	26	52	1	2	4	13	26	52
29	1, 2, 3	882	1324	1662	2069	2900	3567	206	246	312	347	405	492
	Range	43	137	76	452	100	500	49	4	25	13	23	21
28	1, 2, 3	1023	1211	1227	1727	2458	2883	185	227	235	309	375	322
	Range	190	406	161	140	75	400	6	20	47	37	36	86
27a	1, 2, 3	873	1472	1408	1868	2122	3025	153	211	238	295	320	429
	Range	60	362	70	198	229	175	14	18	61	89	37	19
27b	1, 2, 3	1292	1652	1934	3088	3142	3633	185	215	275	334	374	396
	Range	97	60	98	238	250	700	14	42	34	45	35	25
37	1, 2, 3	979	1409	1481	2244	2683	3967	226	234	266	358	385	507
	Range	85	52	154	105	925	350	24	21	27	36	16	30
40	1, 2, 3	1070	1130	1319	1725	2264	3267	174	193	241	300	318	469
	Range	22	58	81	319	237	500	10	13	20	34	4	22
39	1, 2, 3	823	1309	1328	1945	2342	3392	180	219	259	299	368	444
	Range	30	107	196	596	78	125	9	15	31	68	19	105
38	1, 2, 3	888	926	1907	2163	2758	3171	189	272	288	359	392	537
	Range	44	58	226	450	125	475	30	48	32	46	27	75
34	1, 2, 3	628	1320	1695	2244	2896	.....	124	209	289	353	427	.....
	Range	37	25	110	68	583	.....	34	12	36	74	39	.....
35	1, 2, 3	597	844	1226	1836	2151	.....	131	177	225	340	379	.....
	Range	3	106	33	114	126	.....	10	8	13	41	42	.....
36	1, 2, 3	1009	1115	1684	2190	2983	.....	176	226	289	346	551	.....
	Range	10	28	25	347	325	.....	42	24	21	18	83	.....
23	1, 2, 3	3325	3675	4417	5713	5867	7600	367	393	490	546	582	658
	Range	200	750	525	275	300	350	46	46	31	33	58	62

1 Part Portland Cement to 6 Parts Sand

0	1, 2, 3	559	612	733	1056	1326	1673	96	115	183	207	248	259
	Range	27	49	117	45	65	55	8	20	4	28	9	94
32	1, 2, 3	458	572	813	1126	1330	1950	80	129	164	200	243	275
	Range	52	53	148	109	68	150	4	15	22	38	8	16
31	1, 2, 3	511	516	748	1023	1253	1653	113	108	142	210	242	310
	Range	82	95	22	51	101	783	9	24	29	21	13	26
33	1, 2, 3	498	654	845	1498	1387	1796	112	148	197	211	263	265
	Range	21	14	125	78	28	12	9	43	10	33	21	24
30	1, 2, 3	467	597	646	1127	1314	1683	96	124	160	223	244	285
	Range	30	42	98	151	90	450	5	10	19	66	12	100
29	1, 2, 3	419	577	639	930	1277	1583	70	114	179	182	225	334
	Range	128	48	86	91	217	250	30	4	11	5	17	38
28	1, 2, 3	353	552	596	1021	1210	1775	78	113	140	187	229	287
	Range	38	97	67	99	285	138	29	15	16	25	14	60
27a	1, 2, 3	477	608	673	1026	1450	2108	92	122	148	206	225	311
	Range	24	87	52	25	110	275	6	9	21	28	16	35
27b	1, 2, 3	601	694	1051	1667	1714	2109	98	133	150	212	214	294
	Range	64	55	27	72	289	197	10	16	11	22	13	41
37	1, 2, 3	664	628	956	1132	1488	2092	148	148	163	218	239	321
	Range	74	147	349	135	38	250	10	37	25	19	18	40
40	1, 2, 3	521	624	735	1195	1100	1542	85	118	139	175	197	289
	Range	33	71	30	120	45	1100	11	15	21	9	18	52
39	1, 2, 3	323	474	567	826	1308	1892	78	105	146	187	202	339
	Range	25	8	57	62	626	575	5	6	8	11	93	78
38	1, 2, 3	498	621	764	1074	1172	1804	86	122	190	223	267	312
	Range	66	30	129	21	35	650	16	60	14	42	28	20
34	1, 2, 3	242	559	723	1240	1335	.....	77	115	159	229	275	.....
	Range	17	78	70	96	214	.....	5	20	20	18	16	.....
35	1, 2, 3	339	397	637	1009	1323	.....	91	133	141	246	275	.....
	Range	32	21	27	31	99	.....	7	5	3	38	30	.....
36	1, 2, 3	425	536	688	1141	1496	.....	91	132	166	244	317	.....
	Range	38	17	57	80	12	.....	8	7	13	27	35	.....

TABLE 24.—Tensile and Compressive Strength of Waterproofed Mortars—Continued

1 Part Portland Cement to 8 Parts Sand

Number of compound	Number of test pieces	Compressive strength (pounds per square inch)						Tensile strength (pounds per square inch)					
		Age in weeks when tested						Age in weeks when tested					
		1	2	4	13	26	52	1	2	4	13	26	52
0	1, 2, 3	207	378	364	741	1064	1084	63	71	90	128	148	247
	Range	14	45	39	46	26	138	7	6	16	7	12	63
32	1, 2, 3	245	343	589	626	752	1227	55	83	121	155	186	.....
	Range	20	22	50	20	253	83	8	11	5	23	27	.....
31	1, 2, 3	273	440	508	663	894	1947	60	88	117	160	194	268
	Range	15	11	80	57	8	245	11	2	30	32	16	44
33	1, 2, 3	260	330	425	604	854	972	67	78	104	153	193	199
	Range	42	16	77	83	36	108	10	1	8	26	18	44
30	1, 2, 3	246	359	553	561	798	1005	65	91	126	139	184	324
	Range	24	67	75	70	30	285	8	29	24	16	35	161
29	1, 2, 3	261	386	418	518	871	1329	65	83	139	169	189	281
	Range	53	29	70	81	40	517	9	5	13	16	6	10
28	1, 2, 3	216	366	442	558	805	879	54	70	88	144	170	207
	Range	18	23	95	35	33	37	1	6	10	27	16	72
27a	1, 2, 3	284	421	509	622	760	1642	63	86	115	148	172	228
	Range	42	20	38	19	21	125	8	12	4	31	10	11
27b	1, 2, 3	298	411	554	905	849	1288	62	79	112	153	158	237
	Range	12	73	52	83	77	240	11	11	18	7	12	41
37	1, 2, 3	311	480	647	749	1029	1650	71	90	129	155	186	281
	Range	47	26	44	44	123	325	3	40	18	22	21	8
40	1, 2, 3	227	339	441	713	938	975	69	76	106	128	148	200
	Range	40	30	53	33	30	100	0	6	11	15	20	55
39	1, 2, 3	190	155	317	597	792	917	43	63	82	131	167	216
	Range	66	23	36	223	94	100	6	1	11	50	74	26
38	1, 2, 3	217	298	376	851	685	667	59	104	160	141	174	235
	Range	14	40	63	40	40	100	1	53	23	20	13	10
34	1, 2, 3	118	280	397	643	929	.....	43	62	94	192	217	.....
	Range	8	25	34	31	107	.....	6	10	6	27	7	.....
35	1, 2, 3	201	310	436	665	925	.....	52	70	103	153	223	.....
	Range	7	24	13	69	50	.....	0	6	10	15	70	.....
36	1, 2, 3	261	349	410	716	968	.....	57	86	108	161	208	.....
	Range	25	20	20	22	105	.....	4	7	10	12	18	.....

TABLE 25.—Tensile and Compressive Strength of Mortars Containing Inert Fillers

1 Part Portland Cement to 4 Parts Sand

Number of compound	Number of test pieces	Compressive strength (pounds per square inch)						Tensile strength (pounds per square inch)					
		Age in weeks when tested						Age in weeks when tested					
		1	2	4	13	26	52	1	2	4	13	26	52
0	1, 2, 3	750	1141	1493	2354	3158	3558	131	196	286	326	377	527
	Range [40]	72	49	173	96	250	450	4	28	62	6	39	76
45	1, 2, 3	1140	1529	1674	3105	3750	4517	209	253	272	380	432	436
	Range	55	26	48	91	825	300	10	34	22	42	23	64
43	1, 2, 3	958	1383	1627	2244	3092	5175	196	253	278	370	436	473
	Range	244	103	62	122	300	475	16	29	28	13	10	178
41	1, 2, 3	1373	1253	1631	2435	3575	4450	191	226	340	375	408	473
	Range	142	91	260	132	400	550	9	13	57	63	51	11
42	1, 2, 3	1281	1500	1542	2195	2900	4583	197	232	294	369	380	470
	Range	186	29	41	95	125	600	29	12	14	24	25	25
44	1, 2, 3	625	930	1561	2633	2968	3417	152	200	266	389	422	460
	Range	13	42	108	200	404	350	7	27	30	21	27	65

[40] Range is the difference between maximum and minimum values for three test pieces.