Properties of Some Masonry Cement

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Seventeen brands of masonry cement were tested for soundness, strength, consistency, fineness, time of setting, shrinkage, water repellency, water retention, autoclave expansion, air entrainment, and resistance to freezing and thawing. Mortars were proportioned both by weight and by volume. Autoclave tests indicated potential unsoundness in some of the cements. Air entrained in the mortar was effective in increasing the ability to withstand freezing and thawing. The shrinkage of these cements differed greatly. The results of tests indicated also that the properties of these masonry cements were appreciably different from those previously reported in 1934.

1. Introduction

Masonry cements are used in building construction to a greater extent today than ever before. Possible reasons for the popularity are their general availability, the convenience of proportioning and mixing masonry mortars, and their desirable physical properties. Evidence of appreciable changes in the properties of these cements since the 1934 National Bureau of Standards survey of these materials [1]* has been presented by Watstein and Seese [2] and also has been evident in the acceptance-testing-work of the Bureau laboratories. In addition to the development of the materials, new methods and ideas of testing have been devised since the last major revision of the Federal Specification for Masonry Cements. It seemed desirable, therefore, to apply the knowledge of these new test methods and ideas of testing in making a survey of the properties of modern masonry cements before revising the specifications.

2. Scope of Investigation

Tests were made on 17 brands of masonry cement, purchased for the most part from building supply dealers east of the Mississippi River.

The following tests were made as required in Federal Specification SS–C–181b for masonry cement: Normal consistency, time of setting, soundness, strength, water retention, and water repellency.

In addition to these specified tests, determinations were also made of the fineness by the No. 325-sieve and air-permeability methods, soundness of neat cement pats in steam and of neat cement and mortar bars in the autoclave test, air entrainment, durability in freezing and thawing tests, and volume change of mortar bars and reinforced mortar bars. The freezing and thawing tests were made on mortar bars proportioned with 1 part of cement to 3 parts of blended sand, by volume. The other mortar tests were made on mortars proportioned both by volume and by weight.

3. Materials Tested

Cements. The 17 brands of masonry cement tested were purchased in 1947 at a time when cement was scarce, so these cements probably had no warehouse deterioration, and represented the product as manufactured. An attempt was made to get as many different types of cements as possible. The present selection of brands is not, however, representative of the quantities of the various types, as the authors have been informed that approximately 90 percent of the masonry cement sold at present is of the portland-cement-base type. Of the cements tested, Nos. 6 and 12 are believed to be largely natural cement; No. 7 is believed to contain some natural cement; No. 8 is believed to be a slag cement; and No. 15, a mixture of portland cement and lime. The others are believed to be mixtures of portland cement and limestone or raw mix.

Sand. The sands used were standard Ottawa silica sands, both "20–30" and "graded". The 20–30 Ottawa sand was used in the air-entrainment mortars (1 to 4) and in the mortars for compressive-strength tests (1 to 3, by weight). Mortars proportioned by volume were prepared with 1 part of cement and 3 parts of blended sand (one-half 20–30 Ottawa sand and one-half graded Ottawa sand).

4. Method of Testing

(a) Fineness on a No. 200 sieve, time of setting, soundness of pats in air and water, compressive strength of cubes (1 to 3, by weight) water retention, and water repellency were determined by the methods given in Federal Specifications SS–C–181b.

(b) The following tests were made according to the methods given in Federal Specification SS–C–158, with the exceptions as noted: Fineness on No. 325 sieve and by air-permeability method, soundness of pats in steam and of neat cement bars and mortar bars in the autoclave,[1] and air entrainment.[2]

(c) The following tests were made of the mortars proportioned by volume: Autoclave expansion at 7

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[1] Specimens were removed from the molds at 48 hr and soundness determinations were made at 48 hr rather than 24 hr.

[2] The mortar in the air-entrainment test was tamped with a 1 by ½ in. tamper instead of a rod.

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*Figures in brackets indicate the literature references at the end of this paper.

days, compressive strength, freezing and thawing. water retention, water repellency, and volume change of mortar bars and reinforced mortar bars.

The weights of the materials for the 1 to 3 by volume mortars were calculated by assuming the weight of a bag of cement to be the weight per cubic foot and assuming the dry weight of sand in 3 ft³ of loose damp sand as being 240 lb. This proportion was selected because it is the usual recommendation in mortar specifications to mix 1 sack of masonry cement with 3 ft³ of sand for masonry mortar. The sand used was a blend of one-half 20–30 and one-half graded Ottawa sand, with a fineness modulus of approximately 2.40. This sand is also the same as that required in the standard method of test for measuring mortar making properties of fine aggregate ASTM designation C87–47. This blend more nearly approximates masonry sand than does 20–30 Ottawa sand specified for the compressive strength test in Federal Specification SS–C–181b.

The mortars were mixed in a model C–10 Hobart mixer with a special paddle constructed with side strips of bronze attached to a center strip. The side strips were covered with sections of rubber tubing of such length that the ends brushed the side of the 3-qt bowl in which the mortar was mixed. The cement was added to the water in the mixing bowl and mixed for 30 sec. About half the sand was added and mixed for 30 sec. The rest of the sand was then added and mixing was continued for 60 sec. The mortar was then allowed to stand for 90 sec, with the bowl and mortar covered with a damp cloth, and then was remixed for an additional 60 sec, and the cubes were made in the regular manner.

It should be noted that the mortars used in this investigation are not the same as the mortars used in the investigation by Rogers and Blaine [1], and hence the results are not directly comparable. Of the 3 mortars used in the earlier investigation, 1 mortar was proportioned by weight, 1 part of cement to 3 parts of 20–30 Ottawa sand, the other 2 were proportioned 1 part of cement to 3 parts of mixed sand, 1 by weight and the other by rodded volume. The mixed sand was composed of 2 parts of 20–30 Ottawa sand to 1 part of pit-run Ottawa sand, the mixed sand having a fineness modulus of 2.62. The sand and cement were hand mixed in a metal vessel, water was added and the mixing continued for 5 min. After standing for 14½ min, they were again stirred for ½ min.

In the tests described herein, cubes were stored in the moist cabinet for 7 days, after which specimens for test at 28 days and 1 year were immersed in water at 70° F. Specimens to be tested after 1 year in air were stored in the laboratory air at 70° F and 50-percent relative humidity after the first 7 days. Six cubes were tested at each age after each condition of storage.

Specimens for the freezing and thawing test were mortar prisms 2 by 2 by 12 in. After 48 hr they were removed from the molds and stored in water for 12 days, then in laboratory air for 14 days. At the age of 28 days they were placed in water in 2¼ by 13-in. noncorroding metal containers and stored at 40° F for 48 hr. Then the containers holding the specimens were placed in rapidly circulating ethylene glycol at −20° F for 2 hr, then in the 40° F bath for 2 hr. Two freezing cycles were made each day. Specimens were stored at 40° F overnight and over weekends. After each five freezing cycles, each bar was weighed and sonic measurements [3, 4] were made. Measurements were continued to 100 cycles, except for bars broken prior to 100 cycles. Only 16 cements were used as there was not enough of cement 2 for this test.

(d) Two sets of mortar prisms 1 by 1 by 11 in. were made of the mortar of each cement. Reference points were placed in the ends of each of one set of prisms for length measurement, leaving an effective length of 10 in. between the inner ends of the points. Cold-rolled steel rods ¼ by 11¾ in., threaded the full length except for rounded ends, were imbedded in the other set of prisms, the rounded ends serving as reference points for length change. Molds were removed at 48 hr, and after an additional 5 days of storage in the moist closet, the prisms were placed in water at 70° F for 21 days, and then in air at 70° F and 50-percent relative humidity. Length measurements were made at 7 and 28 days and at frequent intervals thereafter until apparent equilibrium was reached. Examination of the reinforced prisms was made for evidence of cracking.

5. Results of Tests

Data on weight per bag, density, fineness in terms of percentage of weight of cement retained on No. 200 and No. 325 sieves, specific surface as determined by air permeability, normal consistency, initial time of set, and autoclave expansion of both neat cement and mortar are presented in table 1 for all 17 cements.

TABLE 1. *Weight, density, fineness, normal consistency, setting time, and linear autoclave expansion of 17 masonry cements tested*

Cement	Bag weight	Specific gravity	Weight retained on sieve No.—		Fineness (air permeability)	Normal consistency [a]	Initial setting time	Linear autoclave expansion	
			200	325				Neat cement	Mortar
	lb		%	%	*cm²/g*		*hr/min*	%	%
1	70	2.91	2.8	7.5	5,920	23.6	4:15	0.11	0.10
2	70	2.86	1.1	6.4	6,650	25.2	4:15	.16	.07
3	75	2.83	1.1	5.1	7,470	28.0	3:20	.56	.14
4	70	2.93	2.4	10.2	5,620	24.6	3:40	.01	.04
5	70	2.91	.7	2.7	6,370	29.0	4:25	.11	.05
6	65	2.87	5.8	13.8	9,490	33.2	5:10	6.2	1.60
7	70	2.90	1.3	4.8	5,550	29.6	4:20	0.64	0.18
8	80	2.78	.4	1.7	5,880	30.8	4:25	.03	.03
9	70	2.91	6.5	15.1	5,360	24.4	4:10	.08	.07
10	75	2.92	4.3	7.7	9,730	27.4	3:20	.03	.02
11	70	2.90	1.3	9.5	5,470	37.0	3:55	.12	.03
12	62.5	2.75	14.6	24.2	6,970	25.8	4:35	.16	.10
13	70	2.85	0	0	6,600	28.0	4:35	.16	.09
14	70	2.94	.5	1.9	7,110	26.2	4:35	.07	.07
15	62.5	2.72	17.5	25.0	6,850	25.2	3:45	.18	.08
16	70	2.90	4.0	11.2	6,840	27.4	7:30	.03	.03
17	70	2.93	6.3	13.4	7,470	25.2	4:25	.05	.04

[a] Ratio of weight of water to weight of dry cement times 100 required for penetration of 10 mm in the Vicat test.

TABLE 2. *Air entrainment, water retention, water repellency, 24-hour absorption and durability and weight loss in freezing and thawing*

Ce-ment	Air entrain-ment 1:4 by volume	Water retention 1:3 by weight	1:3 by volume	Water repellency 1:3 by weight	1:3 by volume	Water absorption at 24 hr 1:3 by weight	1:3 by volume	Freezing and thawing Durability factor [4]	Weight loss 100 cycles
	%	%	%	%	%	%	%		%
1	27.9	78	77	33	46	6.2	6.7	100	8.7
2	20.2	82	74	61	33	5.9	8.2	----	
3	7.3	83	76	48	54	8.8	9.0	a 14	b 17.2
4	20.1	78	68	39	41	6.8	7.5	100	8.2
5	16.7	69	74	42	37	5.0	5.3	100	4.7
6	18.2	87	86	64	76	11.1	10.7	100	4.1
7	19.0	69	68	37	34	9.0	9.3	100	10.4
8	3.7	59	60	70	34	24.0	9.1	c 9	9.4
9	15.1	68	54	43	52	7.3	7.8	100	3.9
10	23.9	86	90	33	34	4.6	5.9	100	7.6
11	14.0	66	63	33	42	6.1	6.2	94	19.3
12	15.3	74	73	26	55	10.2	9.2	100	3.3
13	19.4	73	77	30	36	6.9	7.1	97	11.6
14	29.0	67	76	36	37	6.6	6.9	100	8.6
15	4.8	76	59	30	67	10.1	9.7	d 3	(e)
16	10.8	76	78	53	55	10.1	9.3	100	15.6
17	23.5	88	87	34	32	5.2	5.5	100	9.1

a Failed at 30 cycles, disintegrated at 70 cycles.
b Weight loss at 65 cycles.
c Failed at 20 cycles.
d Failed at 5 cycles.
e Disintegrated at 10 cycles.

TABLE 3. *Compressive strengths and water requirements of mortars made with Ottawa silica sand*

Ce-ment	1:3 by weight mortar Compressive strength 7 day	28 day	Water require-ment a	1:3 by volume mortar Compressive strength at— 7 day	28 day	1 year (air)	1 year (water)	Water require-ment a	Shrink-age of neat cement bars
	psi	psi		psi	psi	psi	psi		%
1	1,220	1,530	40	1,210	1,380	1,890	1,680	39	0.102
2	1,000	1,280	43	920	1,130	1,380	1,360	42	.077
3	1,030	1,430	49	1,030	1,540	2,750	1,850	48	.089
4	1,610	2,090	42	1,340	1,810	2,530	2,180	42	.082
5	1,980	2,330	46	1,830	2,160	3,380	2,280	44	.100
6	370	800	56	310	690	1,220	1,270	50	.108
7	770	1,220	51	710	1,040	2,030	2,120	48	.098
8	1,440	2,810	48	1,690	3,160	3,730	4,480	46	.102
9	1,030	1,520	44	860	1,320	1,610	2,000	43	.075
10	1,780	2,390	47	1,610	2,190	3,050	2,600	45	.129
11	1,830	2,870	56	1,700	3,000	3,310	4,275	52	.155
12	930	1,560	51	620	1,060	2,490	2,090	44	.078
13	1,570	2,050	44	1,410	1,840	2,250	2,030	41	.073
14	1,370	1,910	42	1,040	1,450	1,760	1,740	40	.076
15	820	1,390	50	460	850	1,240	1,500	47	.138
16	1,070	2,040	50	960	1,740	1,750	2,970	49	.130
17	1,450	1,640	46	1,270	1,620	1,950	2,010	44	.116

a Ratio of weight of water to weight of dry cement times 100. (Water required for normal flow of mortars).

Values for air entrainment, water retention, water repellency, and water absorption determined on mortars proportioned by weight and volume, as well as durability factors and weight loss resulting from freezing and thawing are given in table 2 for the same cements.

Additional data comprising compressive strength at several ages for mortars proportioned 1:3 by weight and by volume, together with their water
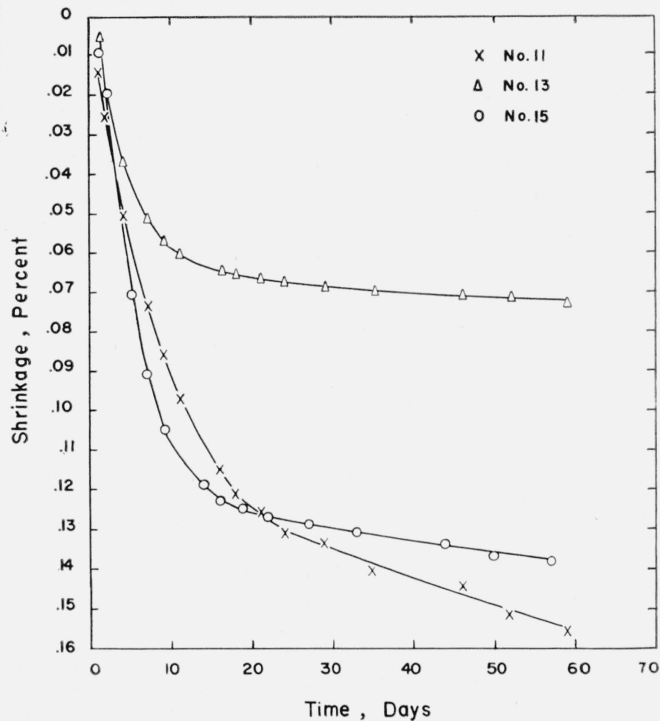

FIGURE 1. *Shrinkage of mortar bars (3:1 by volume).*

Stored in air at 70° F. and 50-percent relative humidity. Initial length measured at age of 21 days upon removal from wet storage.

requirements, are given in table 3. This table also presents data on shrinkage of neat-cement prisms, as well as the water requirement. A selection of the data on shrinkage is presented graphically in figure 1.

6. Discussion

Weight of Cements. The weight per bag ranged from 62.5 to 80 lb, and for 11 of the 17 masonry cements was 70 lb. In the investigation by Rogers and Blaine [1], the weights of 41 masonry cements, as rodded into a box, ranged from 39.7 to 89.9 lb/ft³, the mean weight being 64.7 lb. No direct comparison can be made, as the rodded weight per cubic foot was not determined in this study, and the specific gravity was not determined in the 1934 investigation.

Specific gravity. Specific gravities of the cements ranged from 2.72 to 2.94, appreciably lower than the specific gravity of portland cement, which is approximately 3.15.

Sieve fineness. Residues on the No. 200 sieve ranged from 0.0 to 25.0 percent by weight. Only two cements failed to meet the requirement of Federal Specification SS-C-181b that not more than 12 percent of the cement shall be retained on the No. 200 sieve. Three cements had residues of 15 percent or more on the No. 325 sieve. In the 1934 investigation the residue on the No. 325 sieve was reported as: 7 having less then 10 percent, 13 having 10 to 15 percent, 14 having 15 to 25 percent, 2 having more than 40 percent, and 3 not reported. Determination of the air-permeability fineness was not made in 1934,

but from a comparison of the sieve residues, it may be assumed that the present cements are finer.

Normal consistency. The water requirement for normal consistency ranged from 23.6 to 37 percent, and only 3 cements required more than 30 percent. The water requirement for normal consistency is the ratio of the weight of water to the weight of cement expressed as percentage, for the water-cement paste to produce a penetration of 10 mm by the Vicat needle.

Air entrainment. The amount of entrained air as determined by the method for portland cement, using 1 part of cement to 4 parts of 20-30 Ottawa sand by weight, ranged from 3.7 to 29.0 percent. Four of the cements had air-entrainment values of less than 12 percent, 9 from 12 to 21 percent, and 4, more than 21 percent.

Water retention. Of the mortars proportioned by weight, only 1 had a water retention of less than 65 percent, and of the mortars proportioned by volume, 4 had water retentions of less than 65 percent. A majority of the mortars proportioned by weight showed slightly higher water retention than the mortars proportioned by volume, although there were exceptions.

Air-permeability fineness. The fineness of the cements as shown by the air-permeability method ranged from 5,360 to 9,730 cm^2/g, with an average of about 6,780. Masonry cements as a group are much finer than portland cement (about 2,700 to 3,500 cm^2/g by the same method). The air-permeability fineness of the masonry cements does not appear to be related to the sieve residue or to other properties, such as strength, water requirements, water retention, or water repellancy.

Time of setting. The time of initial set varied from 3 hr 20 min to 7 hr 30 min. All cements reached final set in less than 24 hr.

Soundness. The test for soundness of pats in air, water, and steam did not indicate any evidence of unsoundness of any of the cements. However, it should be pointed out that these soundness tests for neat-cement pats are not sufficiently severe to distinguish between any of the cements tested. On the other hand, the autoclave expansion of neat-cement prisms, tested at 48 hr, ranged from 0.03 to 6.2 percent, with 3 cements having expansion greater than 0.50 percent, 7 having expansion less than 0.1 percent, and 7 having expansion between 0.1 and 0.2 percent. The autoclave expansions of the mortar bars proportioned by vloume and tested at the age of 7 days, though lower, fell for the most part in the same order as those of the corresponding neat cements.

In the investigation of white-coat plaster failure by Wells, Clarke, Newman, and Bishop [5], it was shown that the failures were caused by the delayed hydration and resulting expansion of the magnesia in the dolomitic lime. It was also shown by Wells, Clarke, and Levin [6], in their study of the expansive characteristics of hydrated limes and the development of a test for soundness, that expansion of the autoclaved bars was dependent not only on the amount of unhydrated magnesia but also on the strength of the test specimens. The limits suggested by these authors for the autoclave expansion of 1:1 cement to lime (by weight) prisms was 1 percent. In the present investigation of masonry cements only 1 of the 17 cements had an autoclave expansion of more than 1 percent.

The causes of lack of bond and appearance of spaces between the brick and mortar bed have been discussed at considerable length by Palmer [7], Davis and Troxell [8], and others. A recent paper by J. W. McBurney, "Cracking in masonry caused by expansion of mortar" [9], questions the assumption that cracking is necessarily caused by shrinkage. He shows that the openings between bricks and mortar usually ascribed to mortar shrinkage result actually from the mason's techniques in "cutting" joints. He reports damaging expansions resulting from delayed hydration of free magnesium oxide in masonry mortar.

Water repellency. The ratio of 1-hr absorption to 24-hr absorption was less than 0.9 in all cases, and ranged from 0.33 to 0.64 for mortars proportioned by weight, and from 0.32 to 0.76 for mortars proportioned by volume. The water absorbed at 24 hr ranged from 2.5 to 11.1 percent for mortars proportioned by weight, and from 5.3 to 10.7 percent for mortars proportioned by volume. The rate of absorption and total water absorbed usually was lower for mortars proportioned by weight, although there are some exceptions. The results of the water-repellency test in this investigation are in marked contrast to those reported by Rogers and Blaine. They tested cements for absorption in mortars X (1 cement to 3 parts 20-30 silica sand by weight) and mortar Y (1 part cement to 1.5 parts 20-30 silica sand and 1.5 parts pit-run silica sand). Of the mortars proportioned by weight, one crumbled when placed in water and 20 reached 90 percent of the 72-hr absorption in 1 hr or less. Of the mortars proportioned by volume, 2 crumbled when placed in water, and 26 reached 90 percent of the 72-hr absorption in 1 hr or less. This high rate of absorption was related by them to the failure in 10 cycles or less in the freezing and thawing test and resulted in the development of the water-repellency test that was included in Federal Specification SS-C-181a. They also noted that cements having water-repellent additions produced mortar having entrained air, and that most of these were resistant to freezing and thawing. It was also noted that with one exception all specimens having low strengths (less than 500 psi at 28 days) showed poor resistance to freezing and thawing, the one exception being a mortar having a high percentage of entrained air and a low rate of absorption.

Freezing and thawing. Determinations of the loss of weight and of the sonic modulus were made after each 5 cycles of freezing and thawing. Mortar prisms of cement 15 showed a failure at 5 cycles (decrease of 30 percent of the modulus of elasticity, as shown by sonic measurement) [4] and were so badly crumbled at 10 cycles that no further tests could be made. Mortar prisms of cement 8 had a

weight loss at 100 cycles of only 9.4 percent. However, the durability factor was only 9, and the sonic measurement indicated failure at 20 cycles. Mortar prisms of cement 3 had a weight loss of 17.2 percent at 65 cycles and were broken at 70 cycles, and failure was indicated at 30 cycles. The three cements that failed in the freezing and thawing test all had air-entertainment values of less than 8 percent. The tests were discontinued at 100 cycles. None of the cements used in this study had the high rate of absorption (90 percent of 24-hr absorption in 1 hr) or the low strength (less than 500 psi at 28 days) that were noted in several of the cements tested in 1934. The freezing and thawing test in this investigation shows a relation between entrained air and resistance to freezing and thawing but does not appear to show a good relation between rate of absorption or weight loss and resistance to freezing and thawing. Possibly a better relation of the tests would have been shown had the freezing and thawing tests been carried further. The freezing and thawing test is a rather severe shock test and may not have the same effect on mortar prisms cast in nonabsorbent molds that natural weathering has on mortar placed between bricks.

Compressive strength. Of the 17 cements tested, only cement 6 would be classed as a type I masonry cement (not less than 250 and 500 psi at 7 and 28 days, respectively). When the mortar cubes were proportioned by volume both cements 6 and 15 failed to meet the requirements (500 and 1,000 psi at 7 and 28 days, respectively) for type II masonry cement. For mortars proportioned by weight, the 7-day strength ranged from 370 to 1,980 psi, the 28-day strength from 800 to 2,810 psi; and the increase between 7 and 28 days ranged from 190 to 1,370 psi, or from 13 to 116 percent. The strength of the mortars proportioned by volume ranged from 310 to 1,830 psi at 7 days and from 690 to 3,160 psi at 28 days, with the increase in strength between the two ages ranging from 170 to 1,470 psi, or 14 to 122 percent. For the 12 cements that are believed to be portland cement and limestone, the mortars proportioned by weight had strengths ranging from 1,000 to 1,830 psi at 7 days and from 1,280 to 2,870 psi at 28 days, the increase in strength being from 190 to 1,040 psi, or from 13 to 90 percent. The compressive strength of specimens of 7 of the cements stored for 1 year in air appears to be appreciably higher than the corresponding specimens stored in water for 1 year. It is known that the degree of saturation of a specimen at the time of breaking affects the strength. Although the air-cured specimens were soaked before breaking it is not known whether the degree of saturation was the same in both sets. There is also the possibility that some specimens that were high in lime or limestone may have been weakened by leaching due to prolongued water storage. In the investigation in 1934, no attempt was made to bring the strength specimens stored in air and water to the same degree of saturation before breaking. The conclusion in the 1934 investigation was that air storage usually gave higher compressive strengths than water storage.

Water requirement. The water (expressed as percentage of dry weight of cement) required for a flow of 100 to 115 is shown in table 3. The mortars proportioned by volume appear to require slightly less water than the corresponding mortars proportioned by weight. The difference is not large enough to have much significance due to the wide range of flows used (from 100 to 115). The percentage of water required for normal flow of the masonry-cement mortars is about the same as that required for portland cement.

Shrinkage. The unreinforced mortar prisms had shrinkages ranging from 0.073 to 0.155 percent in 60 days. About three-fourths of this shrinkage occurred in the first week, with little change after 28 days. The change of length (shrinkage) against time is presented graphically in figure 1 for mortars made from cements, which represent the extremes of those tested. Note that cements 11 and 15 are alike in having high shrinkage but differ in rate of shrinkage at both early and late ages. Attention should be called to the probability that "The volumetric changes of a mortar cast in a non-absorbent mold and stored in air is no criterion to the volumetric changes that may be expected to occur in the same kind of mortar when used as the joint material in brickwork," a conclusion reported by Davis and Troxell (8).

The reinforced mortar prisms showed a shrinkage of 0.02 to 0.05 percent as evidenced by compression of the reinforcing rods. With the threaded rods, the cracks formed were for the most part extremely small and difficult to see. This is in contrast to the work reported by Watstein and Seese (2), who used regular reinforcing rods. Presumably, the regular rods with deformations at greater intervals caused larger and more widely spaced cracks. The study by Watstein and Seese also indicated that for masonry cements of comparable compositions, the shrinkage increased with the amount of water used. Their work also indicated that the resistance to cracking was increased with increased strength of the mortars and was lowered with increased shrinkage of the mortars. Their study included the bond between bricks and mortars and indicated that both high compressive strength and good water retention are important in producing high binding strength in brick assemblages. Adequate compressive strength are required in masonry mortars to insure load-bearing capacity, and a balance between strength and water retention is necessary to obtain a good bond between the brick and mortar.

General. Masonry cements may be made of one or more of a number of different proportions. For a cement of a given composition, the relation between different properties, such as fineness and strength, water requirement, and water retention, can be shown. For a large group of masonry cements of different materials and various amounts, the relationship becomes obscured by the properties of the different materials.

This study indicates that mortars proportioned by weight did not always have higher strength, water retention, and water repellency than the correspond-

ng mortars proportioned by volume. Both mortars made with cement 8 had the same weight of cement, and the higher strength of the mortars proportioned by volume is largely due to the difference in sand. With the other factors the same, the blended sand tends to produce stronger mortars than the 20–30 sand, as the smaller voids permit a more dense structure (1). Some of the differences between the mortars proportioned by weight and by volume are not of sufficient magnitude to be considered significant.

Some of the differences that may be noted between the masonry cements tested in 1947 and those tested in 1934 are: a marked tendency toward higher strength and slower rates of absorption, waterproofing agents have probably been largely replaced by air-entraining agents, it is probable that the majority of masonry cements now being made contain air-entraining agents, and most of the cements tested showed a good resistance to freezing and thawing.

7. Summary

Tests were made of 17 brands of masonry cements representing materials of different types. The results of tests were as follows:

1. The masonry cements tested had weight-per-bag values ranging from 62½ to 80 lb.

2. The specific gravity of the cements ranged from 2.72 to 2.94 percent.

3. The residue retained on a No. 200 sieve ranged from 0.0 to 17.5 percent, and on a No. 325 sieve the residue ranged from 0.0 to 24.2 percent. The fineness, as determined by the air-permeability apparatus, ranged from 5,470 to 9,730 cm^3/g. There was no relation between fineness and other properties of the cements.

4. All the cements attained final set within 24 hr.

5. The compressive strength of 2-in. cubes proportioned 1 to 3 by weight ranged from 310 to 1,980 psi at 7 days, and from 690 to 3,160 psi at 28 days. The 12 masonry cements of portland cement-base type had strengths ranging from 1,000 to 1,980 psi at 7 days and from 1,280 to 2,870 psi at 28 days. Strengths of mortars proportioned 1 to 3 by weight were slightly greater than those proportioned by volume. The 1-year tests indicated an appreciable increase in strength for most cements with both air and water storage.

6. The water-repellency values for the mortars proportioned by weight ranged from 0.26 to 0.70, and from 0.32 to 0.76 for mortars proportioned by volume. The requirement of Federal Specification SS–C–181b for water repellency is that the ratio of the 1- to 24-hr absorption shall not exceed 0.90.

7. Of the mortars proportioned by weight, only one had a water retention of less than 65 percent, and of mortars proportioned by volume, 4 had water-retention values less than 65 percent.

8. The air content of 1 to 4 mortars ranged from 3.7 to 29.0 percent.

9. Three of the cements having less than 10 percent of air in the 1 to 4 mortar had a very low durability factor. Only 2 of the 11 cements with more than 15 percent of air in the 1 to 4 mortar had a weight loss of more than 10 percent in 100 freezing and thawing cycles, and all had a very high durability factor.

10. Mortar bars of the different cements proportioned 1 to 3 by volume had shrinkage ranging from 0.075 to 0.16 percent in 60 days.

11. Neat pats made of these cements exhibited satisfactory soundness in both air and steam. The expansion of neat-cement bars as a result of autoclave treatment ranged from 0.03 to 6.2 percent. Fourteen of the cements had an expansion less than 0.20 percent, the expansions of the other 3 were 0.56. 0.64, and 6.2 percent.

8. References

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