RESULTS OF TESTING GYPSUM PRODUCTS*

By W. E. Emley and C. F. Faxon

In an effort to write standard specifications for gypsum, many difficulties have been encountered. Probably the greatest source of confusion was the attempt to adopt verbatim the standard methods of test which were in use in the examination of other similar materials. Experience showed the futility of this procedure, and finally compelled the invention of new methods of test, designed especially for gypsum. After considerable deliberation and experiment, a number of methods of test were finally agreed upon and adopted as tentative.[1]

It then developed that no one had had enough experience with these new methods to be able to predict what numerical results they would give. For example, take the tensile strength. This property of gypsum was pretty well known when measured by any one of several different methods. The method adopted, however, introduced certain innovations, so that no one could foretell just what tensile strength a given sample of material would have when tested by this new method.

Obviously some information about these numerical results was essential, in order that specifications could be intelligently written. It would be absurd to specify a tensile strength of 300 pounds per square inch, and then discover that either all or none of the gypsum on the market met the requirement.

Accordingly the Bureau of Standards undertook to test a number of commercial samples. This article is a compilation of the results obtained. The tests were carried out on 43 samples, made by three different manufacturers. Of these, 25 were shipped to us direct from the factory, packed in air-tight glass containers; 8 came direct from the factory, in the usual commercial package; and 10 were obtained from dealers.

* Received Sept. 1, 1920.

[1] American Society for Testing Materials, C-26–19T.

While an attempt was made to follow the methods of test cited above, certain changes and additions were found advisable and were accordingly made. A brief description of the methods is as follows:

1. **Chemical Analysis.**—Lime, sulphuric anhydride, carbon dioxide, and loss on ignition, were determined by the usual methods of chemical analysis.[1] These constituents were then combined as follows: The amount of lime required to combine with the carbon dioxide was found by multiplying the per cent carbon dioxide by 56/44. The per cent lime present as carbonate was deducted from the total per cent lime. The per cent water was found by subtracting the per cent carbon dioxide from the per cent loss on ignition. From the figures for lime, sulphuric anhydride, and water, the maximum possible content of calcined gypsum ($CaSO_4.{}^1/_2H_2O$) was calculated, using the ratios 56:80:9. Usually two, and always one of these three ingredients was found to be in excess of these ratios. This was taken to indicate the presence of some foreign material, such as calcium hydroxide, magnesium sulphate, anhydrous calcium sulphate, etc.

2. **Normal Consistency.**—This is the number of cubic centimeters of water which must be added to 100 grams of dry material to produce a paste of standard "wetness." It was determined by means of the Southard viscosimeter,[2] the standard wetness being such that the final radius of the pat was 9.6 cms.

3. **Time of Set.**—This is measured by means of a Vicat needle, on material of normal consistency. It is the elapsed time from when the sample is added to the water to when the needle fails to penetrate to the bottom of the pat.

4. **Fineness.**—This is expressed as the per cent by weight of the material separated by six sieves of different meshes. The sieves used were the Nos. 8, 14, 28, 48, 100 and 200. In general, the material could be screened dry through Nos. 8 and 14, but had to be washed with kerosene in order to get clean separations on the finer sieves.

[1] Hillebrand, "Analysis of Silicate and Carbonate Rocks," U. S. Geol. Sur., *Bull.* 700.

[2] A. S. T. M., C26-19T.

5. Compressive Strength.—Three cylinders, 2 inches in diameter by 4 inches high, were made of paste of normal consistency. They were removed from the molds as soon as they were hard enough to handle (1 to 24 hours), stored in the air in the room for one week, and tested. The results are expressed as pounds square inch.

TABLE 1

Lab. No.	Trade name of material	Class
1	Unretarded gauging plaster	Calcined gypsum only
2	Molding plaster	
10	Unretarded gauging plaster	
11	Molding plaster	
19	Unretarded gauging plaster	
20	Molding plaster	
26	Stucco	
28	Molding plaster	
29	Reground stucco	
31	Stucco	
32	Stucco	
34	Plaster of Paris F	
35	Plaster of Paris FFF	
37	Windsor cement FFF	
43	Potters plaster	
Ave.		
3	Retarding gauging plaster	Calcined gypsum plus retarder
4	Cement plaster, unsanded, not fibered	
12	Retarded gauging plaster	
13	Cement plaster, unsanded, not fibered	
21	Retarded gauging plaster	
22	Cement plaster, unsanded, not fibered	
38	Ready finish	
41	Superfine Windsor cement	
Ave.		
5	Cement plaster, unsanded, fibered	Calcined gypsum plus retarder plus fiber
16	Retarded fibered cement plaster	
23	Fibered cement plaster	
27	Fibered plaster	
33	Fibered plaster	
36	Windsor cement, neat	
Ave.		

6	Wood fiber plaster to be used with sand	Calcined gypsum plus retarder plus wood fiber
7	Wood fiber plaster	
14	Wood fiber plaster to be used with sand	
15	Retarded wood fiber plaster	
24	Wood fiber plaster to be used with sand	
25	Wood fiber cement	
30	Wood fiber plaster	
39	Windsor cement for concrete	
42	Wood fiber plaster	
Ave.		
9	Ready mixed brown coat	Calcined gypsum plus retarder plus sand
18	Ready mixed brown coat	
Ave.		
8	Ready mixed scratch coat	Calcined gypsum plus retarder plus fiber plus sand
17	Ready mixed scratch coat	
40	Brown mortar	
Ave.		

TABLE 2

	Chemical analysis					
	Found				Calculated	
Lab No.	CaO	CO_2	SO_3	Loss on ignition	Calcined gypsum	Constituents in excess
1	37.60	4.21	48.73	10.40	83.50	$SO_3.H_2O$
2	37.20	4.22	49.00	10.70	82.40	$SO_3.H_2O$
10	34.80	12.53	36.80	16.20	48.77	$SO_3.H_2O$
11	35.28	11.00	38.55	16.40	55.10	$SO_3.H_2O$
19	38.12	0.56	53.50	8.00	97.02	$CaO.H_2O$
20	38.24	.74	53.64	8.00	86.60	$SO_3.H_2O$
26	38.20	.10	54.00	7.60	97.88	$CaO.H_2O$
28	37.94	.10	53.90	7.70	97.69	$CaO.H_2O$
29	35.80	2.40	47.80	9.20	84.83	$SO_3.H_2O$
31	37.44	0.60	51.90	7.90	94.07	$CaO.H_2O$
32	37.10	4.10	48.70	10.60	82.54	$SO_3.H_2O$
34	38.00	1.00	51.65	7.53	93.65	$CaO.H_2O$
35	38.26	0.62	53.70	6.91	97.10	$SO_3.H_2O$
37	38.13	.53	53.80	6.94	97.00	$SO_3.H_2O$
43	38.90	.70	53.60	7.55	97.15	$CaO.H_2O$
Ave.	37.41	2.89	49.98	9.44	87.02	
3	37.04	4.53	48.28	10.90	83.50	$SO_3.H_2O$
4	36.72	4.37	47.90	10.75	80.60	$SO_3.H_2O$
12	34.52	10.02	36.49	17.35	56.35	$SO_3.H_2O$
13	34.84	12.33	37.56	16.55	49.58	$SO_3.H_2O$
21	38.60	0.81	53.30	7.55	96.60	$CaO.H_2O$
22	38.28	.84	53.74	8.10	96.40	$SO_3.H_2O$

TABLE 2 (*Continued*)

	Chemical analysis					
	Found				Calculated	
Lab. No.	CaO	CO_2	SO_3	Loss on ignition	Calcined gypsum	Constituents in excess
38.....	39.20	2.83	15.55	14.20	28.20	$CaO.H_2O$
41.....	35.72	15.20	35.90	20.05	42.38	$SO_3.H_2O$
Ave.....	36.86	6.37	41.09	13.18	66.70	
5.....	36.96	4.73	47.83	11.15	80.20	$SO_3.H_2O$
16.....	35.00	12.16	37.90	17.15	50.56	$SO_3.H_2O$
23.....	36.88	0.68	52.30	7.35	93.30	$SO_3.H_2O$
27.....	38.24	.40	53.90	7.90	97.68	$SO_3.H_2O$
33.....	37.70	.10	53.40	7.80	96.79	$CaO.H_2O$
36.....	36.88	1.40	48.50	8.18	87.95	$CaO.H_2O$
Ave.....	36.94	3.24	48.97	9.92	84.41	$CaO.H_2O$
6.....	36.92	4.36	48.52	10.70	81.20	$SO_3.H_2O$
7.....	37.00	4.41	48.59	10.50	81.25	$SO_3.H_2O$
14.....	34.96	12.64	37.32	17.35	48.86	$SO_3.H_2O$
15.....	35.12	11.90	38.10	17.40	51.70	$SO_3.H_2O$
24.....	38.20	0.74	53.64	7.90	96.47	$SO_3.H_2O$
25.....	38.08	.82	53.06	7.95	95.95	$SO_3.H_2O$
30.....	36.14	2.50	48.40	9.40	85.34	$SO_3.H_2O$
39.....	27.41	1.64	27.70	9.25	50.22	$CaO.H_2O$
42.....	35.40	1.31	46.40	8.60	84.10	$CaO.H_2O$
Ave.....	35.47	4.48	44.64	11.01	75.01	$CaO.H_2O$
9.....	18.20	10.86	13.49	13.10	11.27	$SO_3.H_2O$
18.....	25.60	15.70	13.68	17.80	14.50	$SO_3.H_2O$
Ave.....	21.90	13.28	13.58	15.45	12.88	
8.....	18.52	10.32	14.80	12.75	13.92	$SO_3.H_2O$
17.....	24.80	13.86	15.84	16.70	18.49	$SO_3.H_2O$
40.....	8.76	0.47	10.80	3.09	19.58	$CaO.H_2O$
Ave.....	17.36	8.22	13.81	10.85	17.33	

TABLE 3

	Fineness						
Lab. No.	On 8	8–14	14.28	28–48	48–100	100–200	Through 200
1.....	...	0.1	0.1	0.9	3.9	15.4	79.6
2.....	...	...	.2	1.1	4.1	8.2	86.4
10.....	...	.1	.3	4.6	7.0	11.5	76.5
11.....	...	.1	.1	.3	0.7	6.8	92.0
19.....	...	.1	.3	3.0	24.0	26.7	45.9
20.....	...	...	.1	0.5	6.3	23.2	69.9

26	...	...	.3	4.0	15.6	29.7	50.4
28	...	...	.1	0.3	4.8	15.6	79.2
29	...	...	.7	3.8	8.5	20.3	66.7
31	...	...	.1	0.4	1.1	9.1	89.3
32	...	...	.2	1.3	3.1	8.2	87.2
34	0.3	0.7	2.5	8.8	16.4	11.1	60.2
35	...	...	...	0.2	9.3	13.4	77.1
37	...	...	...	.1	6.1	9.7	84.1
43	...	...	...	.3	4.9	13.2	81.6
Ave.	0.0	0.1	0.3	2.0	7.7	14.5	75.1
3	...	...	0.2	0.9	3.1	10.7	85.1
4	...	...	.1	1.3	4.1	12.4	82.1
12	...	0.1	.3	4.1	8.9	8.8	77.8
13	...	...	.1	0.2	1.2	4.7	93.8
21	...	...	.2	2.5	18.0	28.7	50.6
22	...	...	.3	2.2	18.6	21.5	57.4
38	...	...	...	0.2	2.6	7.7	89.5
41	...	...	...	1.7	14.1	10.3	73.9
Ave.	0.0	0.0	0.1	1.6	8.8	13.1	76.3
5	0.1	0.1	0.1	0.9	3.3	10.8	84.7
16	.1	.1	.1	.2	0.8	6.4	92.3
23	.1	.1	.2	1.7	14.8	21.9	61.2
27	...	...	.2	0.9	2.8	17.0	79.1
33	...	...	.3	1.5	4.8	28.7	64.7
36	0.1	0.4	2.3	13.5	16.8	9.6	57.4
Ave.	.1	.1	0.5	3.1	7.2	15.9	73.2
6	0.5	0.4	0.5	1.7	3.8	9.7	83.4
7	.7	.3	.3	1.7	4.0	10.7	82.3
14	.4	.2	.4	4.0	8.9	11.0	75.1
15	.4	.2	.4	3.7	8.6	9.5	77.2
24	.8	.5	.6	2.7	17.5	19.3	58.6
25	.4	.1	.4	2.6	19.5	22.6	54.4
30	.1	.2	1.2	3.5	9.7	22.4	62.9
39	1.5	4.2	7.5	16.0	17.5	6.6	46.7
42	0.3	0.6	1.1	8.5	23.5	9.4	56.6
Ave.	.6	.8	1.4	4.9	12.6	13.5	66.4
9	0.1	8.9	10.9	18.0	25.4	16.7	20.0
18	.8	21.2	21.6	10.8	11.4	3.8	30.4
Ave.	.4	15.0	16.2	14.4	18.4	10.2	25.2
8	0.2	10.3	11.3	12.8	21.2	13.7	30.5
17	3.6	30.0	12.8	6.5	10.0	4.4	32.7
40	0.5	5.3	10.2	31.4	26.0	8.0	18.6
Ave.	1.4	15.2	11.4	16.9	19.1	8.7	27.3

TABLE 4

Lab. No.	Compressive strength	Yield: Lbs. paste per cu. ft.	Yield: Lbs. dry material per cu. ft. paste	Yield: Lbs. set material per cu. ft.	Tensile strength	Normal consistency	Time of set
1	1460	106	64	76	254	66.1	21
2	1315	107	64	75	775	66.9	21
10	1700	113	77	88	333	46.6	12
11	1570	107	66	79	270	56.2	7
19	1105	101	58	68	244	73.2	11
20	1060	102	58	68	220	75.0	19
26	1550	113	74	82	413	53.0	14
28	1580	112	72	81	387	56.0	22
29	1956	114	77	89	357	48.0	16
31	1935	107	68	78	394	58.0	8
32	1875	110	72	83	444	51.8	12
34	2200	114	76	85	437	50.0	13
35	1630	111	69	79	280	60.2	9
37	2285	116	75	83	299	51.5	8:00
43	1720	92	57	78	270	61.0	9:00
Ave.	1665	108	62	80	325	58.2	13:00
3	1295	107	65	77	273	64.3	53:00
4	925	105	63	74	236	66.0	11:56
12	1420	111	76	87	290	46.2	2:54
13	630	112	74	85	218	51.9	17:23
21	1280	103	62	73	272	65.4	1.58
22	1000	103	62	73	261	65.0	13:07
38	145	93	50	54	37	85.5	1:00
41	1400	120	83	87	129	44.6	5:37
Ave.	1010	107	67	76	215	61.1	6:41
5	555	104	63	73	182	65.7	14:15
16	1100	110	73	80	254	51.2	25:24
23	1030	106	66	75	269	61.0	13:09
27	1730	107	69	81	379	55.5	6:34
33	1475	115	75	83	400	53.3	8:50
36	800	107	70	80	186	51.6	19:42
Ave.	1115	108	69	79	278	56.4	14:39
6	835	103	62	73	222	65.4	18:35
7	670	103	62	74	195	66.3	6:17
14	785	108	73	86	223	47.1	11:26
15	885	109	75	87	259	45.7	6:20
24	960	99	61	73	228	63.0	10:30
25	910	101	60	71	232	67.4	12:24

30.....	1480	104	70	85	372	48.6	9:10
39.....	275	115	75	78	73	53.0	3:10
42.....	710	107	69	81	120	53.7	4:45
Ave.....	835	106	67	79	214	56.7	9:11
9.....	195	129	101	108	52	27.0	2:19
18.....	475	131	106	111	109	23.1	2:32
Ave.....	335	130	103	109	80	25.0	2:30
8.....	200	126	98	104	53	29.0	1:52
17.....	865	130	106	112	198	22.2	4:51
40.....	180	120	95	103	37	25.8	3:27
Ave.....	415	125	100	106	96	25.7	3:23

6. Yield.—The above cylinder molds were weighed empty, and immediately after filling. The cylinders were weighed just before they were tested. The amount of dry material in a given volume of paste was calculated from the figure for normal consistency. These data were used to calculate the weight per cubic foot of paste, the weight of dry material per cubic foot of paste, and the weight per cubic foot of set material.

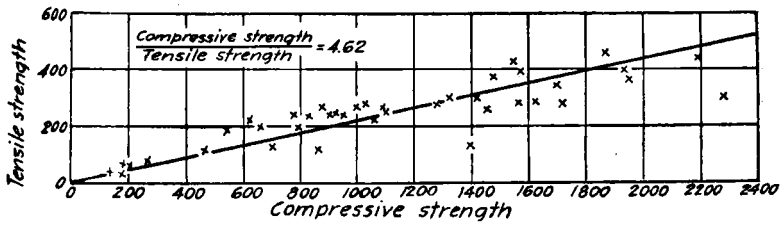

FIG. 1.—Compressive strength *vs.* tensile strength.

7. Tensile Strength.—Three briquettes of the usual form were made of paste of normal consistency, stored in the same way as the compressive strength specimens, and tested when one week old. The results are expressed in pounds per square inch.

The results of all of these tests are given in the accompanying tables. Owing to the extremely confusing nomenclature, no attempt has been made to group the samples according to their trade names. They have been classified, instead, in accordance with their actual compositions.

Primarily, these data are intended to enable us to arrive at numerical values expressing the different properties of gypsum.

These values are to be used in writing specifications for the material. Incidentally, the data may also be used in an attempt to correlate the various properties. Certain efforts along this line are indicated in figures 1 and 2, showing the relations between

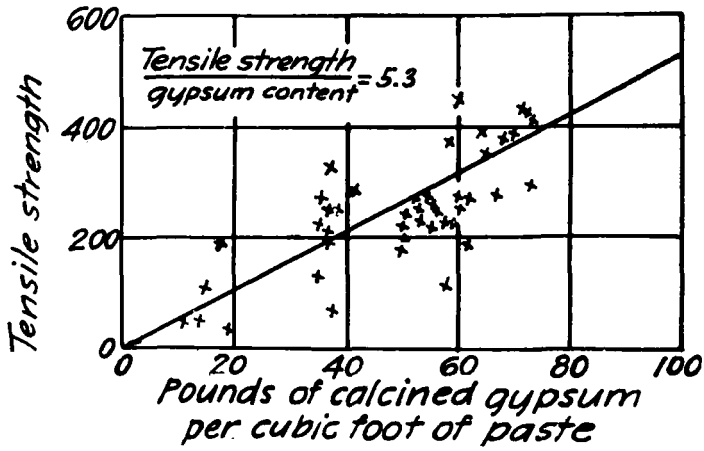

FIG. 2.—Tensile strength *vs.* gypsum content.

tensile strength and compressive strength, and tensile strength and gypsum content, respectively. Obviously the data permit and invite a great deal of this sort of calculation.

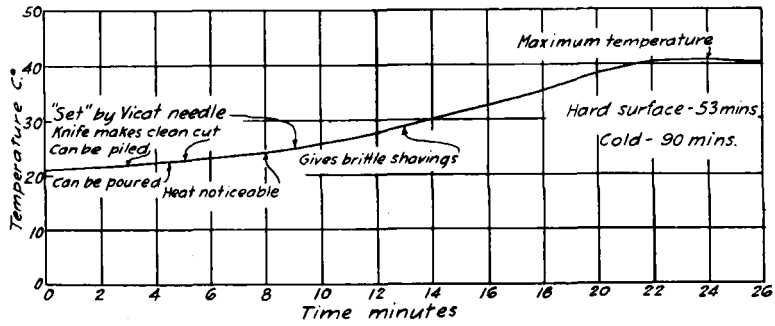

FIG. 3.—Time of set.

It seems that the present method of measuring time of set by means of the Vicat needle has been the subject of much criticism.

To get more information on this point, the times of set of ten samples were measured by means of the temperature rise, and by direct observation. The results for one of these samples are given in figure 3. All of these results confirm those previously[1] obtained: that the temperature rise method is fundamentally unsound, and is misleading. The Vicat needle is endorsed. It gives results which are definite, which can be checked, and which indicate the time during which gypsum may be worked without injury.

The use of the Southard viscosimeter to measure normal consistency has also been criticized. The results obtained by means of this instrument are probably accurate within 1 per cent, and can be readily checked by different observers. The machine is not portable, and its use is therefore confined to the laboratory. It was suggested that a cylinder mold two inches in diameter by four inches long could easily be carried in the pocket, and a "slump" test, using this mold, would measure consistency to a sufficient degree of accuracy. Accordingly, pastes of normal consistency (by the Southard viscosimeter) were made of 10 samples, and were tested by the slump method, using a two by four inch cylinder. It was found that the final diameter of the pat varied from $4^1/_4$ to $5^1/_2$ inches for the different samples. It would seem, therefore, that the slump method is hardly accurate enough for a standard method, although it will probably give satisfaction when used for plant control.

We wish to acknowledge our obligations to Mr. H. A. Bright for the analytical work, and to Mr. L. A. Balser for assistance in making physical measurements.

BUREAU OF STANDARDS
WASHINGTON, D. C.

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

[1] Emley, "Time of Set of Calcined Gypsum," *Trans. Amer. Ceram. Soc.*, **19**, p. 573 (1917).