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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000621
Building Research Note, 1973-02

CANADA

Building Research Note

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OF TYPES S AND N MORTARS

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February 1973

DIVISION OF BUILDING RESEARCH · NATIONAL RESEARCH COUNCIL · OTTAWA · CANADA

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TYPE S MORTAR

The construction of an 11-storey load-bearing masonry wall apartment building in Halifax during the fall of 1971 provided an opportunity for field tests on a Type S mortar not commonly used in the area. The compression testing of cubes of mortar for load-bearing masonry is described in the Canadian Structural Design Manual, Supplement No. 4 to the National Building Code of Canada 1970. The objectives of the proposed testing program were to investigate the test procedures outlined in the Manual and to obtain statistical data on the relationship between compression values for field and laboratory mortar. The structural engineer on the site agreed to allow some testing; in return he was to receive a copy of the compression values for cubes of field mortar. The first cubes were molded 20 September 1971 and compression tests were completed 4 January 1972. A total of 240 cubes of field mortar were molded and tested.

REQUIREMENTS

The Canadian Structural Design Manual permits the design of masonry structures based on an engineering analysis. An alternative method for determining the value of the compressive strength of the masonry is based on tests of the masonry units and mortar. The mortar values are established from tests on laboratory-prepared mortar containing the same materials and in the same proportions as those used in the masonry. This method also includes field control tests designed to ensure that the mortar being used on the site develops strength values comparable to those obtained for the laboratory design mix, on which the structural calculations were based.

The following are the provisions in the Design Manual for Field Control Tests on Mortar:

4.4.3.8(1) ... at least five 2" mortar cube specimens shall be made for each 5000 square feet, or portion thereof, of wall but not less than five test specimens for each storey height, and not less than five test specimens for any building.
4.4.3.8(4) For tests of mortar cubes referred to in Sentence (1): (a) the mortar shall be taken at random from the mortar boards currently in use but care shall be taken that no old mortar from the edges of the boards is included; (b) mortar test cubes shall be made, cured and tested in accordance with CSA A179-1967, Mortar for Unit Masonry; (c) except as provided in (d), compression strength tests of mortar cubes shall be made at an age of 28 days; and (d) tests may be made after seven days on mortar test cubes provided that the relationship between 7- and 28-day strength of the mortar has been established by previous tests, or the compression strengths obtained from 7-day test results may be assumed to be 90 per cent of the 28-day value.
4.4.3.8(5) The average compression strength of mortar cubes obtained from any five consecutive 28-day field control tests or from the 28-day strengths predicted from 7-day tests in accordance with Clause (d) referred to in Sentence (4) shall be at least 0.80 of the compressive strength determined in accordance with 4.4.3.3 for the type of mortar used and no individual test result shall have a value less than 0.67 of that strength.

MORTAR

The job specification called for a Type S mortar to contain 1 part Portland cement to $\frac{1}{2}$ part hydrated lime, but this had been changed by agreement and the mortar used on-site contained $\frac{1}{2}$ part Portland cement and 1 part 1:1:6 masonry mortar mix. This mixture is also classified as a Type S mortar in CSA A179-1967. The latter specification, and the Design Manual, require a minimum average compressive strength of 1800 psi at 28 days for a Type S mortar.

MATERIALS

Both the Portland cement and the masonry mortar mix used on-site were produced by reputable manufacturers. They meet the requirements of the respective CSA specifications and are used extensively with good results in masonry mortars in the area. The masonry mortar mix is known to be a blended mixture of Portland cement and hydrated lime, an air-entraining material, and possibly other additives. Information on the bag indicates that, when the contents are mixed with 18 No. 2 shovelsful of sand, the resulting mortar will meet the requirements for a Type N mortar as defined in CSA A179-1967.

It is interesting to note that since the mortar mix contained equal parts Portland cement and hydrated lime, the mortar used ($\frac{1}{2}$ part

Portland cement + 1 part mortar mix) becomes 1 part Portland cement and $\frac{1}{2}$ part hydrated lime because the mortar mix contains $\frac{1}{2}$ part Portland cement and $\frac{1}{2}$ part hydrated lime. In effect the mortar used was the mortar specified.

The aggregate was a pit sand with a particle size grading within the limits defined in CSA A82.56 (Figure 1).

CUBES OF FIELD MORTAR

The mortar was mixed in a rotary paddle mechanical mixer. A "batch" consisted of 1 bag of mortar mix and 3/4 to 1 bucket of Portland cement (2 buckets = 1 bag). The sand was measured with a shovel and limited observations indicated that 15 to 18 shovelsful were used per batch. The amount of water used varied from 1 to $1\frac{1}{2}$ buckets (1 bucket = $3\frac{1}{2}$ gal.). The order of charging the mixer was as follows - water (usually put in the mixer immediately after the previous batch of mortar was discharged), then half the sand, Portland cement, masonry mortar mix, the remaining sand and more water as required. Charging and mixing time totalled about 3 min. As it took at least half this time to charge the machine, it can be seen that mixing time was minimal. It should be noted however, that observations of mixing procedures were usually made at the start of operations in the morning or after lunch. Mixing time could be expected to be below average during these periods when the masons were waiting for mortar in order to start operations.

As directed in the Design Manual, mortar samples were taken at random from the mason's mortar boards at the wall. There was no set pattern as to the time samples were taken thus preventing the possibility of a special mortar being prepared for anticipated tests. Cubes were molded in brass molds as described in CSA A.8. Twelve cubes were molded at each sampling; there were usually two samplings for each storey (12 cubes only for storeys 3 and 8, 24 for each of the other 9 - making the total 240).

After the brass molds were filled they were placed in polyethylene bags, left in the construction shack overnight, then moved into the laboratory at 20 to 24 hours, when the molds were stripped and the cubes immersed in water for the duration of the curing period.

LABORATORY CONTROL CUBES

Laboratory mortar was mixed as directed in CSA A179-1967. The Type S mortar, containing $\frac{1}{2}$ part Portland cement, 1 part masonry mortar mix and 2 1/4 to 3 parts sand by volume, was batched by weight using the following values as indicated in the Specification -

Portland cement	- $87\frac{1}{2}$ lb/cu ft
Masonry mortar mix	- wt on bag (55 lb/cu ft)
Sand, damp, loose	- 80 lb/cu ft

The materials were obtained from the job site. It should be noted that a bag of Portland cement contains only 80 lb rather than the $87\frac{1}{2}$ lb/cu ft figure listed in the Specification. Since the specified design mix had not been checked out by laboratory investigation prior to the start of masonry construction it was decided that the initial control mortar should contain the maximum amount of sand (3 parts by volume). When early compressive strength values for field mortar were much higher than those for control mortar, the latter was adjusted in two ways: Portland cement content was reduced in line with the use (at that time) of 3/4 bucket on the site, i.e., the control mortar proportions became 3/8 Portland cement to 1 masonry mortar mix; and sand was reduced to the minimum, 2 1/4 instead of 3 parts. Late in the study the Portland cement content was again reduced to bring it in line with the 80 lb/bag figure used in field mortar. As directed in CSA A179, sufficient water was used in the control mortar to produce a flow value between 100 and 115. Each time cubes were molded on the site an equal number were prepared with control mortar in the laboratory.

COMPRESSION TESTS

Half the cubes (6) from each sampling were tested at 7 days, and the remainder at 28 days. Upon completion of the respective curing periods, cubes were removed from the water, wiped surface dry and tested in a "wet" condition. The values are listed in Table I and are summarized as follows -

Field Mortar

	7-Day	28-Day
Average (120 values)	2077 psi	2916 psi
High	2859 "	3775 "
Low	1380 "	2220 "

Control Mortar - maximum sand

Average (24 values)	1377 psi	1926 psi
High	1563 "	2188 "
Low	1170 "	1540 "

Control Mortar - minimum sand - reduced Portland cement

	7-Day	28-Day
Average (78 cubes)	1921 psi	2651 psi
High	2350 "	3065 "
Low	1700 "	2213 "

Control Mortar - minimum sand - Portland cement 80 lb/bag

	7-Day	28-Day
Average (12 cubes)	1882 psi	2324 psi
High	1960 "	2575 "
Low	1800 "	2125 "

The over-all average value (114 cubes) for control mortar at 7 days was 1802 psi vs 2421 psi at 28 days. The 7-day average for field mortar was 70.1 per cent of the 28-day value (vs 74.4 per cent for control mortar), and the 28-day value exceeded the 1800 psi requirement by 62 per cent. Field mortar values were also higher than those for control mortar, 51 per cent (maximum sand), 10 per cent (minimum sand - reduced Portland cement) and 25 per cent (minimum sand - cement at 80 lb/bag).

DISCUSSION

(a) Field Test Method

The directions in the Design Manual do not specify where the cubes are to be molded so three alternatives are possible:

(1) After on-site sampling the mortar could be taken to the laboratory and cubes molded there, permitting proper curing procedure from the outset. The effectiveness of this method would depend on the distance of the site from the lab, and the method of packaging the mortar during transit;

(2) After sampling the mortar, cubes could be molded on-site, and the molds containing the fresh mortar moved directly into the laboratory for curing. There is danger, in this method, of disturbing the plastic mortar in the molds during transit; and

(3) After sampling the mortar, cubes could be molded on-site, allowed to remain in a sheltered spot overnight, and removed to the lab after hardening (20 to 24 hrs). Reservations re this method concern the lack of control over curing conditions during the initial on-site storage period.

All three methods have been used in previous studies and the third one found to give the highest and the most consistent results. Accordingly, it was selected for this study and the effect of variations in the initial on-site curing environment was minimized by putting the molds in polyethylene bags.

(b) Comparison of Values

It is generally recognized that a control mortar prepared in the laboratory will have higher strength values than the same mortar mixed on a construction site, because the laboratory mortar is mixed to a stiffer consistency (contains less water) than the field mortar. This is reflected in the requirements of the Design Manual where the average value for 5 tests must be 80 per cent of the value of the type of mortar used, with no individual value less than 67 per cent of that strength.

The results of this study do not support this reasoning because the control mortar did not accurately represent the field mortar. Observations suggest that the field mortar was undersanded, a common practice among masons in this area. The directions on the masonry mortar mix bag, 18 No. 2 shovelsful of sand per bag, would mean 27 shovelsful for $1\frac{1}{2}$ bags of cementitious material instead of the 15 to 18 shovelsful actually used. There was also evidence that the amount of cementitious material was varied at the discretion of the masonry foreman. It is evident from these observations, and the variation in compressive strength values, that the control mortars were not really representative of the mortar used on-site.

To provide a better comparison a series of 60 two-in. cubes of Type S mortar was prepared in the laboratory. The difference between this series and previous control mortars is that only the sand quantities were varied, while in the previous series both sand and cement quantities were varied. Thirty of these cubes contained the maximum amount of sand permitted under the property specification (3 times the sum of the volumes of cementitious materials), while the remaining thirty contained the minimum (2 1/4 times the total volume of cementitious materials). All materials were obtained from the construction site. Results of 7- and 28-day compressive strength tests are listed in Table II and the average values compared with field values in the following summary.

Compressive Strength of Control and Field Mortar

	7-Day Values	28-Day Values
Control - maximum aggregate	1417 psi	2201 psi
Control - minimum aggregate	2123 "	3122 "
Field	2077 "	2916 "

The comparison indicates that the field values are slightly less than values for the laboratory mortar containing the minimum amount of aggregate. This concurs with our field observations.

The use of an air-entrained mortar mix, permitted in the National Building Code, is not recommended by authorities such as the Canadian Structural Clay Association and the Structural Clay Products Institute because of the danger that air content might have a detrimental effect on strength values. A limited number of air content determinations on the construction site mortar produced values between 12.5 and 13.5 per cent, and the high compressive strength values indicate that air content was not detrimental in this instance.

CONCLUSIONS

(1) Satisfactory curing results are obtained when mortar cubes are molded on the construction site, stored there overnight in polyethylene bags, and taken into the laboratory at 20 to 24 hours for normal curing.

(2) Field values substantially higher (62 per cent) than the 1800 psi requirement for Type S mortar are attributed to the use of minimum amounts of sand in the mix.

(3) Field values closer to the design requirements could have been obtained with a design mix established by a pre-construction laboratory evaluation.

(4) The presence of an air-entraining material in the masonry mortar mix did not have any noticeable effect on strength values.

(5) A 9 per cent reduction in the weight per bag of Portland cement (80 lb as compared with 87.5 lb/cu ft used in laboratory tests) was not significantly reflected in reduced strength values.

(6) Twenty-eight day tests were of no practical value on this project where 1 storey (8000 sq ft) was completed every $4\frac{1}{2}$ days. Seven-day tests were also of questionable value; values at three days would have been much more practical.

TYPE N MORTAR

During the construction of the apartment building the interior load-bearing wythe of concrete block and Type S mortar was laid up first and the exterior wythe of clay brick and Type N mortar followed. This procedure made it possible to do some field studies on the Type N mortar following the Type S study. The tests essentially included analysis of plastic mortar to establish cementitious material, aggregate ratio, and compression strength tests on 2-in. cubes. First tests were conducted 16 November 1971 and the last cubes were molded on 2 February 1972. A total of 156 cubes were molded with field mortar using the procedures described previously for the Type S mortar. There was a companion set of control cubes of laboratory mortar for each set with the following exceptions: on 6 January laboratory control cubes were molded with field mortar, and on 24 January and 2 February no control cubes were molded. The method of determining the cementitious material:aggregate ratio has been drafted in ASTM Committee C-12 and is currently being evaluated in a co-operative test program. Briefly the ratio is established by washing the cementitious material from the mortar on a No. 100 sieve. The residue is primarily aggregate after washing and the ratio is easily established. A moisture content test on the mortar is an essential part of this procedure. Mortar cubes were cured in a fog room, maintained at a relative humidity in excess of 90 per cent.

MORTAR

The mortar contained 1 part masonry mortar mix to 3 parts sand. Both materials were the same as used in the Type S mortar. On the site the proportions were generally 1 bag mortar mix and 15 shovelsful of sand (18 shovelsful were recommended in the directions on the bag). A limited number of observations indicated a mixing time that rarely exceeded 1 minute after the machine was fully charged.

RESULTS

Compressive strength values are listed in Table III and are summarized as follows:

7-Day Values

Control mortar	- Avg.	737 psi (60)*	Range	594-1070 psi
Field "	- "	884 " (78)	"	450-1340 "

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* Number of specimens tested.

28-Day Values

Control mortar	- Avg.	1035 psi (60)	Range	800-1385 psi
Field "	- "	1262 " (78)	"	750-1655 "

Cubes Molded in the Lab with Mortar from the Field

7-Day Value	- Avg.	910 psi (6)	Range	883- 940 psi
28-Day Value	- "	1322 " (6)	"	1260-1380 ".

Average values for field mortars exceed those for control mortars by 20 per cent at 7 days and 22 per cent at 28 days. The average 7-day values are 71 per cent of 28-day values for control mortar and 70 per cent for field mortar.

DISCUSSION

As in the Type S study the values for field mortars exceed those for control laboratory mortars, and again this is thought to relate to short sanding on the site, where 15 shovelsful of sand were used instead of the 18 shovelsful recommended by the mortar mix manufacturer. All values for field mortar satisfy the 750 psi requirement for Type N mortar in CSA Specification A179-67. The minimum value at 28 days was 750 psi, but this was the only one of 78 values that was under 800 psi. The average value, 1262 psi, exceeded the 750 psi requirement by 68 per cent, slightly higher than the excess over requirement for the Type S mortar.

There was considerable variation in individual values for both control and field mortars and the observations in Table III indicate some of the contributing factors. For example, Series A and B control mortars contained less water per mix (230 vs 240 ml) than remaining control mortars and this contributed to their higher values (Avg 1260 vs over-all avg of 1035 psi). Cubes of field mortar in Series D, E, F and G were frozen during the initial on-site storage. During the period when they were molded, 22 December to 6 January, the fire in the construction shack, where the cubes were stored, was not kept going during the night. When these cubes were brought into the lab the crow's foot pattern characteristic of freezing was evident, and the cubes were generally soft. The compressive strength values were below average indicating some damage from freezing, e.g., the low 7-day value (475 psi) and the low 28-day value (750 psi) occurred in Series D cubes. Series E cubes appeared somewhat different than the other cubes in which freezing was detected. The 7-day values were higher, but there was a below average increase in strength at 28 days (16 per cent vs average increase of 30 per cent). It is possible that these cubes had attained an initial set before freezing occurred and that freezing retarded subsequent curing, whereas freezing occurred in the other cubes before initial set occurred. Normal curing resumed when they thawed in the lab. This is supported by the fact that 7-day values for frozen cubes were 69 per cent (vs 70 per cent over-all) of 28-day values.

The damage from freezing was, however, not nearly as severe as might be anticipated in fresh mortar in non-absorbent metal molds wrapped in polyethylene, conditions designed for maximum retention of water in mortar. Two explanations offered for the minimum damage are that the temperature drop below 32°F may not have been sufficient to cause more than a surface freezing, and the entrained air in the mortar may have been beneficial in relieving stresses caused by an expansion of water frozen in the mortar. Tests on mortars used in Series J and L cubes produced air content levels in the 12 to 12.5 per cent range.

It will also be noted that values for Series K cubes were substantially below average both at 7 and 28 days. On-site observations indicated that it received an abnormal amount of handling during the transfer from the mixer at ground level to the working face on the eleventh floor. The tower crane was inoperative at the time and the mortar was raised to the eighth floor by a small crane and then carried in buckets to the working face. An above-average water content for samples of this mortar suggests that it was probably retempered by the mason before he could use it. A third factor, namely an above-average aggregate content may have also contributed to the lower compressive strength values for these cubes.

Observations of the miximg operation during the sampling of mortar for Series L, M and N cubes revealed that the operator was varying the amount of aggregate. Twelve, fourteen and seventeen shovelsful of sand were used respectively in the three batches. The reduction to 12 shovelsful in Series L mortar was said to be an attempt to eliminate lumps in the mortar. The variations, ordered by the foreman, may have related to the demand of the masons or weather variations in mid-winter (late January to early February).

Moisture content values and cementitious material to aggregate ratio in the plastic mortar and average compressive strength values for 2-in. cubes at 28 days, for each of the thirteen batches of mortar samples are listed in Table IV, and the compressive strength is plotted against the properties of the plastic mortar in Figures II and III.

The pattern between these values is not consistent and there is not enough data to draw firm conclusions. The limited data does, however, suggest that water content (Figure II) has a greater influence on compressive strength than the aggregate content (Figure III). The results indicate the potential value of analysis of the plastic mortar. The time required to obtain meaningful compressive strength results distracts from its practical value as a control test for regulating mortar mixes, especially in load-bearing masonry construction which moves at a fast pace. The results of moisture content and cementitious material to aggregate ratio tests can be available within 24 hours, and could be useful as field control tests for correcting the mortar mix as the work proceeds.

CONCLUSIONS

(1) There are wide variations among individual compressive strength values for cubes of Type N mortar from the field.

(2) The variations in values are caused by a number of factors or combinations of factors.

(3) Field tests for moisture content and cementitious material to aggregate ratio in plastic mortar show some promise as quality control tests for on-site use.

TABLE I

COMPRESSIVE STRENGTH VALUES (PSI) TYPE S MORTAR

(for each cube No. there is a control sample and a field sample)

	7-Day Curing			28-Day Curing		
Date Molded	Cube No.	Control	Field	Cube No.	Control	Field
20/9/71	1	1200	2185	2	1810	2540
	3	1185	2120	4	2008	2640
	5	1300	2280	6	2025	2555
	7	1185	2195	8	2010	2555
	9	1230	2190	10	2020	2440
	11	1235	2175	12	2018	2700
22/9/71	13	1200	2420	14	2005	3145
	15	1170	2427	16	1895	3205
	17	1500	2200	18	2000	3550
	19	1450	2385	20	1920	3325
	21	1508	2425	22	2030	3188
	23	1375	2400	24	2000	3206
27/9/71	25	1475	2553	26	1623	3450
	27	1450	2390	28	1805	3063
	29	1450	2725	30	1705	3125
	31	1438	2535	32	1600	3500
	33	1563	2850	34	1540	3775
	35	1495	2663	36	1605	2900
30/9/71	37	1450	2163	38	2120	3105
	39	1540	2163	40	2188	3065
	41	1400	2138	42	2150	3313
	43	1370	2150	44	2000	3300
	45	1440	2150	46	2120	3200
	47	1450	2169	48	2025	3250
5/10/71	49		2140	50	No	2899
	51		2105	52	Control	2925
	53		2010	54	Cubes	2938
	55		2088	56	for	2938
	57		2050	58	This	2875
	59		2100	60	set	2925
12/10/71	61	1780	1575	62	2470	2310
	63	1770	1380	64	2560	2325
	65	1850	1425	66	2510	2400
	67	1845	1468	68	2600	2440

TABLE I (Cont'd)

13/10/71	73	1960	1780	74	2575	2620
	75	1775	1820	76	2650	2590
	77	1750	1825	78	2630	2545
	79	1803	1800	80	2650	2450
	81	1760	1790	82	2575	2350
	83	1750	1760	84	2500	2400
18/10/71	85	1700	1865	86	2688	2935
	87	1825	1820	88	2788	2950
	89	1730	1840	90	2705	2988
	91	1715	1930	92	2700	3138
	93	1765	1780	94	2913	3100
	95	1715	1820	96	2900	2875
19/10/71	97	1920	2015	98	2794	3375
	99	1865	1980	100	2863	3263
	101	1780	1975	102	2713	3150
	103	1780	2025	104	2700	3050
	105	1825	2025	106	2750	3200
	107	1810	1965	108	2838	3063
21/10/71	109	1950	2100	110	2675	2963
	111	2145	2165	112	2825	3013
	113	2000	2110	114	2950	3000
	115	1900	1980	116	2750	2950
	117	2000	2018	118	2850	2900
	119	1805	2050	120	3000	2950
25/10/71	121	1800	1535	122	2831	2720
	123	1790	1563	124	2825	2795
	125	1825	1565	126	2825	2850
	127	1810	1655	128	2800	2805
	129	1785	1570	130	2825	2685
	131	1800	1550	132	2838	2830
28/10/71	133	1835	2070	134	2700	3225
	135	1960	2075	136	2750	2900
	137	2010	2060	138	2900	3163
	139	2025	2140	140	3065	3075
	141	1950	2215	142	2850	3150
	143	1955	2075	144	2820	3225
1/11/71	145	2075	2405	146	2563	2644
	147	2000	2300	148	2363	2800
	149	1950	2295	150	2700	2800
	151	2055	2370	152	3000	2956
	153	2095	2220	154	2563	2750
	155	2100	2400	156	2700	2750

TABLE I (Cont'd)

3/11/71	157	1970	2660	158	2338	3300
	159	1965	2645	160	2475	3625
	161	2000	2580	162	2575	3325
	163	2015	2700	164	2375	3538
	165	1975	2663	166	2250	2938
	167	1995	2660	168	2550	2750
17/11/71	169	2290	1875	170	2875	2625
	171	2300	1810	172	2950	2738
	173	2350	1775	174	2700	2825
	175	2150	1790	176	2250	2763
	177	2250	1725	178	2213	2725
	179	2300	1765	180	2500	2750
18/11/71	181	1900	1838	182	2400	2900
	183	2000	1815	184	2370	2900
	185	1830	1790	186	2425	2900
	187	1820	1900	188	2400	2913
	189	1935	1845	190	2400	2925
	191	1800	1765	192	2365	2888
23/11/71	193	2000	1980	194	2575	3225
	195	1990	1890	196	2588	3075
	197	1950	1835	198	2638	3175
	199	2010	1870	200	2613	3200
	201	1920	1875	202	2600	2875
	203	1950	1920	204	2750	3050
24/11/71	205	1775	1650	206	2500	2963
	207	1875	1725	208	2513	2825
	209	1975	1500	210	2750	3000
	211	1870	1540	212	2450	3050
	213	1920	1585	214	2563	2950
	215	1980	1540	216	2750	2813
29/11/71	217	1900	1720	218	2250	2638
	219	1800	1720	220	2525	2775
	221	1845	1620	222	2575	2663
	223	1900	1650	224	2400	2688
	225	1905	1775	226	2300	2500
	227	1895	1620	228	2425	2625
6/12/71	229	1800	2595	230	2125	3050
	231	1825	2470	232	2200	2775
	233	1905	2465	234	2250	2813
	235	1960	2475	236	2215	2700
	237	1920	2320	238	2400	2800
	239	1930	2500	240	2220	2738

TABLE II

COMPRESSIVE STRENGTH VALUES (PSI) TYPE S MORTAR

MINIMUM AGGREGATE					MAXIMUM AGGREGATE				
Date Molded	Cube No.	7-Day Curing	Cube No.	28-Day Curing	Date Molded	Cube No.	7-Day Curing	Cube No.	28-Day Curing
9/2/72	SI	2120	S2	3144	10/2/72	S31	1470	S32	2225
"	S3	2150	S4	3125	"	S33	1440	S34	2250
"	S5	2075	S6	3100	"	S35	1450	S36	2200
"	S7	2063	S8	3100	"	S37	1455	S38	2190
"	S9	2125	S10	3063	"	S39	1435	S40	2185
"	S11	2063	S12	3150	"	S41	1410	S42	2203
"	S13	2100	S14	3000	"	S43	1475	S44	2190
"	S15	2150	S16	3000	"	S45	1410	S46	2180
"	S17	2145	S18	3213	"	S47	1400	S48	2205
"	S19	2000	S20	3190	"	S49	1350	S50	2175
"	S21	2150	S22	3000	"	S51	1415	S52	2200
"	S23	2170	S24	3115	"	S53	1350	S54	2228
"	S25	2140	S26	3250	"	S55	1370	S56	2175
"	S27	2145	S28	3275	"	S57	1420	S58	2205
"	S29	2250	S30	3100	"	S59	1400	S60	2198
	AVG	2123		3122		AVG.	1417		2201

TABLE III

COMPRESSIVE STRENGTH VALUES (PSI) TYPE N MORTAR

(for each cube No. there is a control sample and a field sample)

Date Molded	7-Day Curing Cube No.	Control	Field	28-Day Curing Cube No.	Control	Field	
16/11/71	LA1	1020	810	LA2	1365	1410	
	LA3	1070	840	LA4	1385	1575	
	LA5	1030	975	LA6	1350	1655	
	LA7	975	855	LA8	1300	1405	
	LA9	935	865	LA10	1355	1490	
	LA11	1025	845	LA12	1325	1415	
22/11/71	LB1	930	665	LB2	1286	1148	
	LB3	888	673	LB4	1348	1295	
	LB5	880	763	LB6	1100	1273	
	LB7	665	753	LB8	1215	1275	
	LB9	629	806	LB10	1040	1135	
	LB11	594	720	LB12	1050	1228	
13/12/71	LC1	800	1145	LC2	1040	1450	Water content of control cubes raised from 230 to 240 ml.
	LC3	750	1105	LC4	1035	1365	
	LC5	720	1125	LC6	1025	1425	
	LC7	750	1160	LC8	1100	1480	
	LC9	660	1230	LC10	1055	1425	
	LC11	650	1058	LC12	1045	1380	
22/12/71	LD1	735	600	LD2	975	925	D2 cubes frozen in molds during overnight storage in construction shack.
	LD3	730	625	LD4	860	810	
	LD5	640	570	LD6	1050	840	
	LD7	745	475	LD8	1045	750	
	LD9	718	600	LD10	1055	910	
	LD11	800	525	LD12	1000	845	
29/12/71	LE1	660	1143	LE2	820	1283	Also evidence of freezing in these cubes - crow's foot pattern observed and cubes were soft when brought into the lab at 24 hours.
	LE3	675	1025	LE4	975	1070	
	LE5	750	915	LE6	965	1290	
	LE7	715	913	LE8	800	1150	
	LE9	698	1065	LE10	950	1440	
	LE11	700	1080	LE12	945	1060	

TABLE III (Cont'd)

30/12/71	LF1	700	725	LF2	870	1020	Evidence of
	LF3	665	755	LF4	900	983	freezing.
	LF5	730	675	LF6	950	920	
	LF7	710	755	LF8	918	900	
	LF9	725	655	LF10	900	910	
	LF11	725	700	LF12	905	960	
6/1/72	LG1	883	545	LG2	1260	903	Note - Control
	LG3	910	625	LG4	1380	1045	cubes of mortar
	LG5	925	565	LG6	1378	820	from site - cubes
	LG7	905	590	LG8	1313	1033	molded in lab.
	LG9	895	750	LG10	1265	1065	Evidence of
	LG11	940	733	LG12	1338	883	freezing.
11/1/72	LH1	750	1035	LH2	1000	1455	No freezing.
	LH3	800	960	LH4	1050	1325	
	LH5	675	1025	LH6	965	1320	
	LH7	700	1000	LH8	900	1355	
	LH9	730	1065	LH10	915	1430	
	LH11	720	1015	LH12	950	1450	
13/1/72	LJ1	775	1060	LJ2	1010	1448	Air content 12%
	LJ3	750	1045	LJ4	975	1448	
	LJ5	725	1030	LJ6	1010	1500	
	LJ7	785	1070	LJ8	1000	1400	
	LJ9	775	1065	LJ10	985	1450	
	LJ11	720	1050	LJ12	900	1550	
18/8/72	LK1	650	500	LK2	925	800	Big crane broken
	LK3	700	465	LK4	1000	870	mortar raised to
	LK5	690	550	LK6	1050	880	8th floor by
	LK7	703	450	LK8	950	855	mobile crane then
	LK9	725	475	LK10	1045	835	carried in
	LK11	730	475	LK12	975	835	buckets to 11th
							floor.
20/1/72	LL1	650	930	LL2	990	1565	Air content 12.5%
	LL3	675	875	LL4	1050	1600	sand content
	LL5	710	915	LL6	1000	1560	reduced from 15
	LL7	650	1050	LL8	1065	1525	to 12 shovelsful
	LL9	715	1025	LL10	1070	1570	20°F temp.
	LL11	675	1005	LL12	1050	1600	outside.
24/1/72	M1		1340	M2		1600	14 shovelsful
	M3		1320	M4		1560	sand 28°F temp.
	M5		1285	M6		1570	outside.
	M7		1330	M8		1620	
	M9		1275	M10		1650	
	M11		1275	M12		1595	

TABLE III (Cont'd)

2/2/72	N1	1040	N2	1450	17 shovelsful sand.
	N3	980	N4	1425	
	N5	1000	N6	1410	
	N7	985	N8	1415	
	N9	915	N10	1425	
	N11	1065	N12	1420	

AVERAGE VALUES

Control - 7 days - 737 psi (60) High - 1070 psi; Low - 594 psi.
28 days - 1035 " (60) " - 1385 "; " - 800 ".
7 days - 910 " (6) " - 940 "; " - 883 ". Mortar from site.
28 days - 1322 " (6) " - 1380 "; " - 1260 ". Molded in lab.

Field - 7 days - 884 " (78) " - 1340 "; " - 450 ".
28 days - 1262 " (78) " - 1655 "; " - 750 ".

TABLE IV

PROPERTIES OF TYPE N MORTAR

Date Sampled	Mortar Batch	M/C - % Dry Wt.	M.C.:S Ratio	Compressive Strength (P.S.I.)	
				7-Day	28-Day
16/11/71	A	17.1	1:3.1	865	1492
22/11/71	B	16.6	1:2.9	730	1226
13/12/71	C	18.7	1:2.75	1137	1421
22/12/71	D	19.1	1:3.25	566	847
29/12/71	E	22.1	1:3.6	1024	1216
30/12/71	F	18.1	1:3.2	713	949
6/1/72	G	18.2	1:2.75	635	958
11/1/72	H	16.7	1:3.2	1017	1389
13/1/72	J	16.7	1:2.7	1053	1466
18/1/72	K	20.4	1:3.3	486	846
20/1/72	L	20.1	1:3.4	967	1570
24/1/72	M	17.5	1:2.7	1304	1599
2/2/72	N	17.6	1:2.3	998	1424
	AVG.	18.4	1:3.01	884	1262

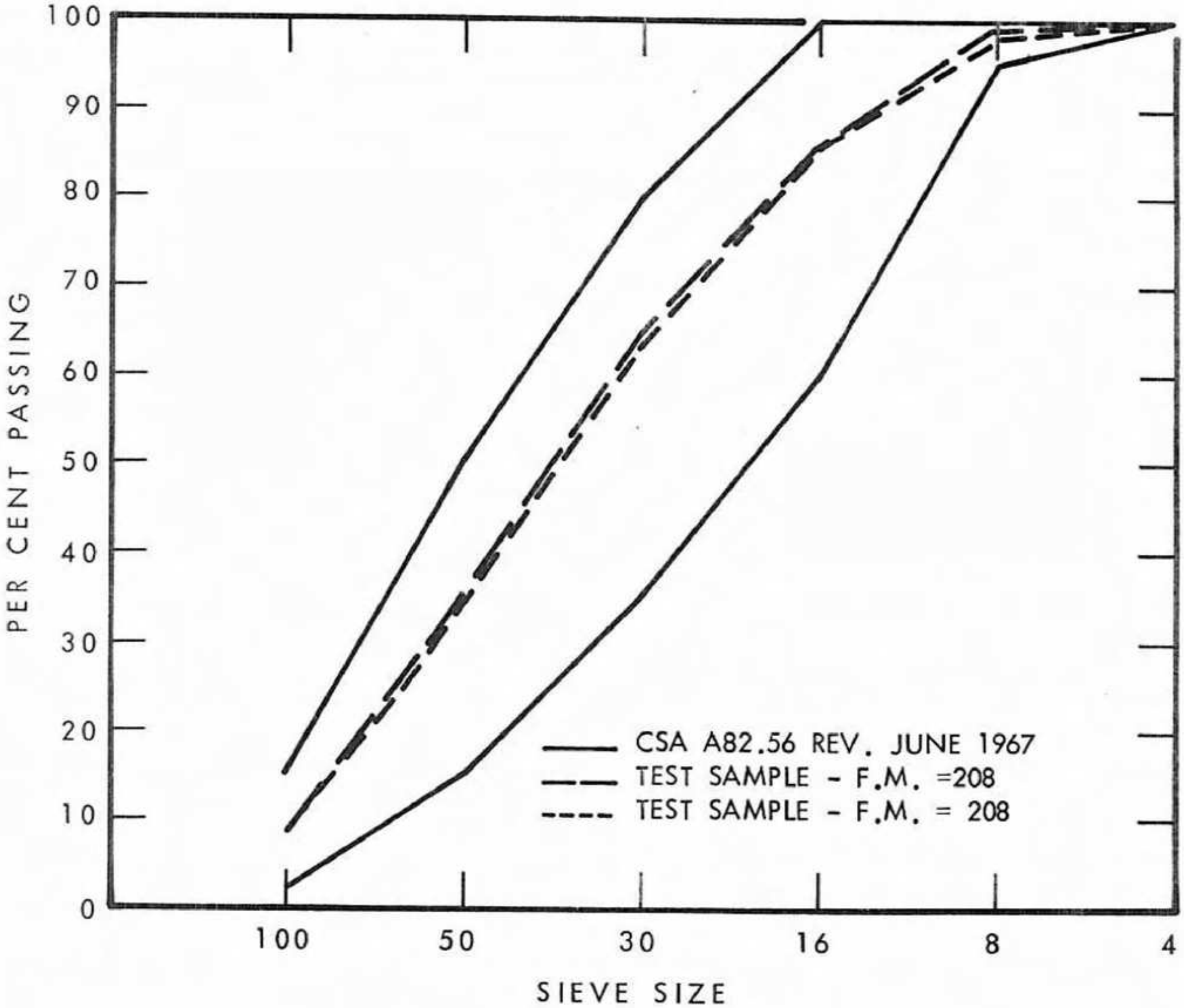

FIGURE 1

SIEVE ANALYSIS - MASONRY SAND-SEPTEMBER 1971 (TYPE S MORTAR)

BR 5042-1

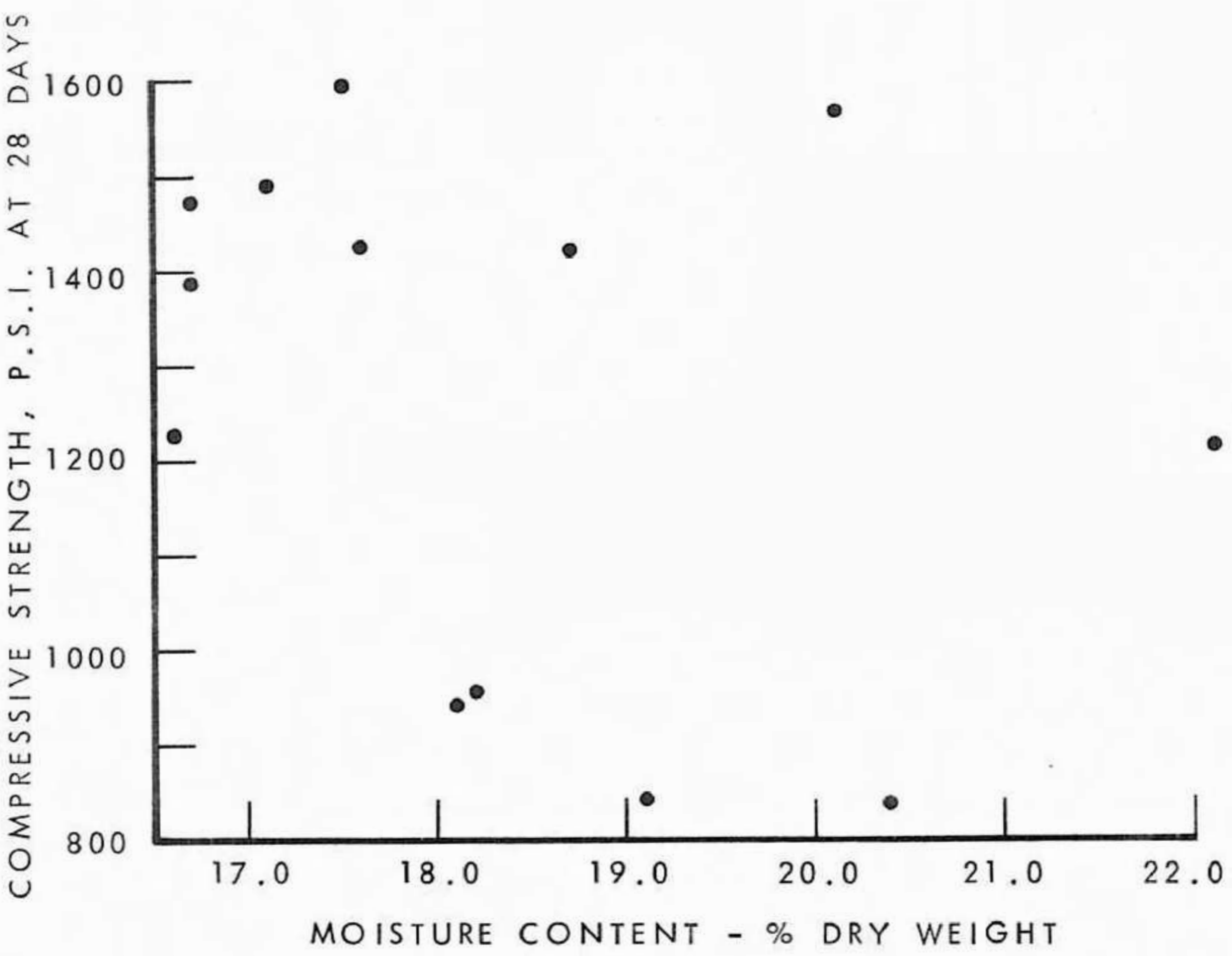

FIGURE 2

MOISTURE CONTENT VS COMPRESSIVE STRENGTH (TYPE N MORTAR)

BR 5042-2

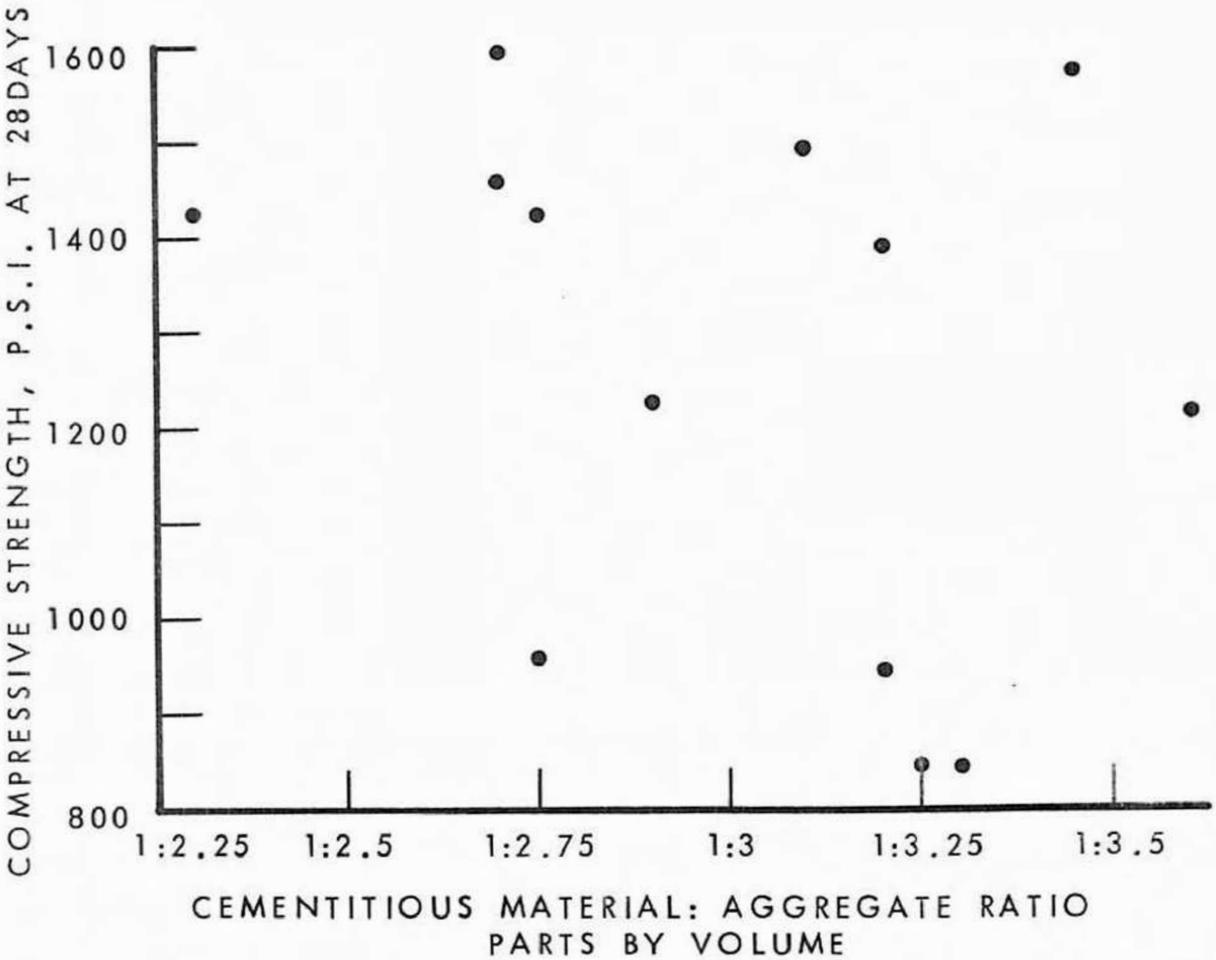

FIGURE 3

CEMENTITIOUS MATERIAL TO AGGREGATE RATIO VS COMPRESSIVE STRENGTH (TYPE N MORTAR) BR 5042-3