PROPERTIES OF READY MIXED MORTAR

by

M. Hatzinikolas[1], J. Longworth[2], J. Warwaruk[3]

1 Director of Technical Services, Alberta Masonry Institute, Edmonton, Alberta.
2 Professor of Civil Engineering, University of Alberta, Edmonton, Canada.
3 Professor of Civil Engineering, University of Alberta, Edmonton, Canada.

ALBERTA MASONRY INSTITUTE

PROPERTIES OF READY MIXED MORTAR

by

M. Hatzinikolas[1], J. Longworth[2], J. Warwaruk[3]

INTRODUCTION

The prime functions of masonry mortar is to provide for even bearing, bond the masonry units together and provide resistance to water penetration. The properties of mortar are affected by a number of variables, one of the most important being the material proportioning at the job site. The introduction of a chemical retarder suitable for use in masonry mortars has made possible the development of ready mixed, ready to use mortar.

In this paper the properties of a ready-mixed mortar are evaluated. These properties include compressive strength, tensile bond, shear bond and resistance to freezing and thawing. The tensile and shear bond strengths were evaluated using a centrifugal force, testing machine developed by the authors (1).

PRE-MIXED MORTAR

In Canada ready mixed, ready to use mortar is mixed in accordance with CSA Standard A179-1975, "Mortar and Grout for Unit Masonry" (2). The proportions of the basic materials (cement, lime and sand)

---

[1] Director of Technical Services, Alberta Masonry Institute, Edmonton, Alberta.

[2] Professor of Civil Engineering, University of Alberta, Edmonton, Canada.

[3] Professor of Civil Engineering, University of Alberta, Edmonton, Canada.

are specified by the Standard. During the mixing process a small quantity (1% by the weight of cement) of a hydration retarding additive is added. As a result the mortar stays fresh and workable for up to 48 hours from the time of mixing. The chemical additive also acts as an air-entraining agent producing 8 to 12% entrained air. Thus the resulting product is a workable "fat" mortar.

Once the mortar is placed between the masonry units and some of the water is removed by suction, the ready mixed mortar sets the same as normal mortar; thus no special laying procedures are required. Ready mixed mortar is used in a number of cities in Canada with very encouraging results. Figures 1 and 2 show two large projects in Edmonton, Alberta, Canada where ready mixed mortar was used.

COMPRESSIVE STRENGTH OF READY MIXED MORTAR

The average compressive strength of type N mortar (1 part normal cement, 1 part lime and 6 parts sand) tested at 28 days was found to be 1130 psi, with a standard deviation of 117 psi, based on 36 2x2x2 mortar cubes. The individual results are given in Table 1. The table also indicates the time between the production of the mortar and the molding of the specimens.

The compressive strengths of type S mortar (1 part normal cement, 1/2 part lime and 4 1/2 parts sand) was found to be 1700 psi with a standard deviation was 65 psi. Test results are shown in Table 2.

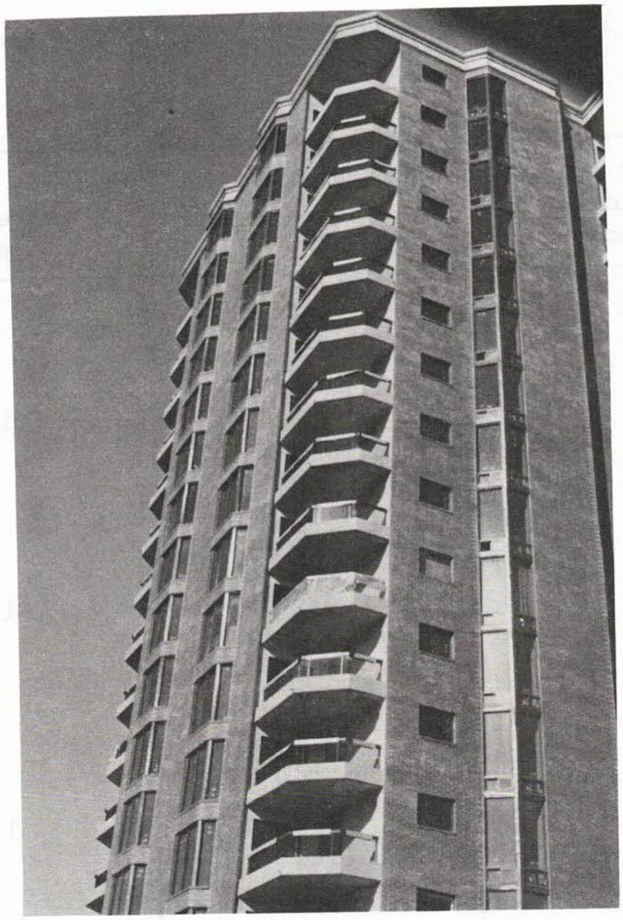

FIG. 1 Apartment building in Edmonton where ready mixed mortar was used

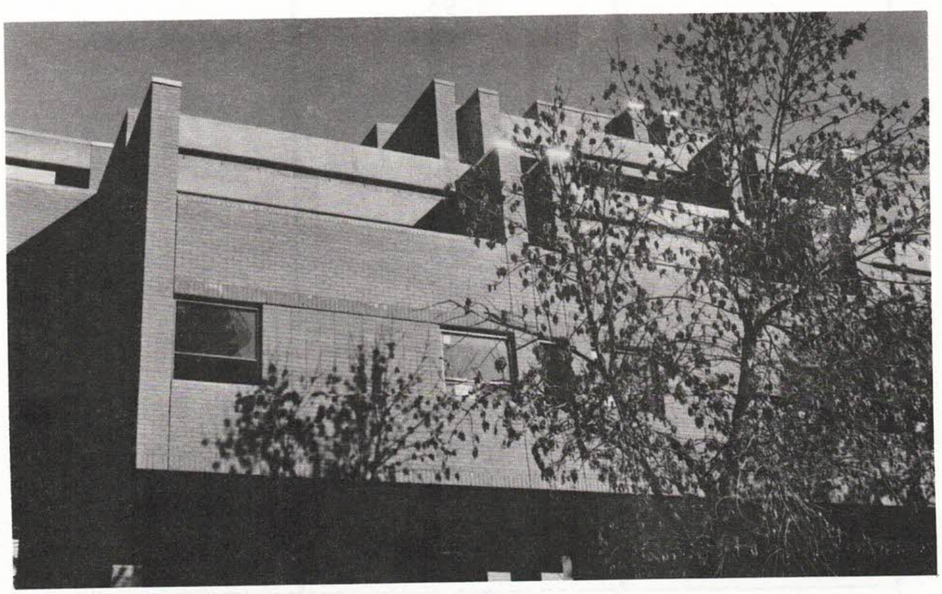

FIG. 2 Low Rise residential structure constructed using ready mixed mortar

Table 1 Compressive Strength of Type N Mortar at 28 Days

Mortar age at molding (hours)	Compressive strength psi	Average compressive strength psi
0 + 2	1300 1045 1225 1150 1040 1205	1160
0 + 6	1305 1200 970 1195 980 1000	1108
0 + 12	1215 1200 1225 1145 950	1147
0 + 24	915 1195 1195 915 1270 1240 1250	1140
0 + 28	915 1100 925 1130 1170 1130	1062
0 + 36	1195 1140 1170 1090 1130 1245	1162
Average	1130	

TENSILE AND SHEAR BOND

The tensile bond between mortar and lightweight concrete masonry units was tested using a centrifugal force testing machine. The method is based on the principle that if a mass is rotated about a fixed axis at a constant angular velocity, the mass is subjected to a force in the radial direction known as a centrifugal force. This force is a function of the mass m, the radius of rotation R and the angular velocity w. If the mass accelerates, an additional component of force, proportional to the acceleration, is introduced in the tangential direction.

If a test specimen is mounted on a rotating disc the magnitude and direction of the force acting on the specimen is dependent on the specimen shape and orientation, the angular velocity and the acceleration. By increasing the angular velocity sufficient force may be developed to cause failure of the specimen. A schematic diagram of such an apparatus is shown in Figure 3. Figure 4 shows the test specimens. The method has been used successfully in determining tensile and shear bond strength by the writers (3).

Consider the case of a tensile bond specimen mounted on a rotating disc and clamped at one end and free at the other end (Figure 3). The disc can be driven by a variable speed motor starting from rest and accelerating with a constant acceleration to an angular velocity, w. The force acting on any section of the specimen is given by the well known relation

$$F = m w^2 R \qquad (1)$$

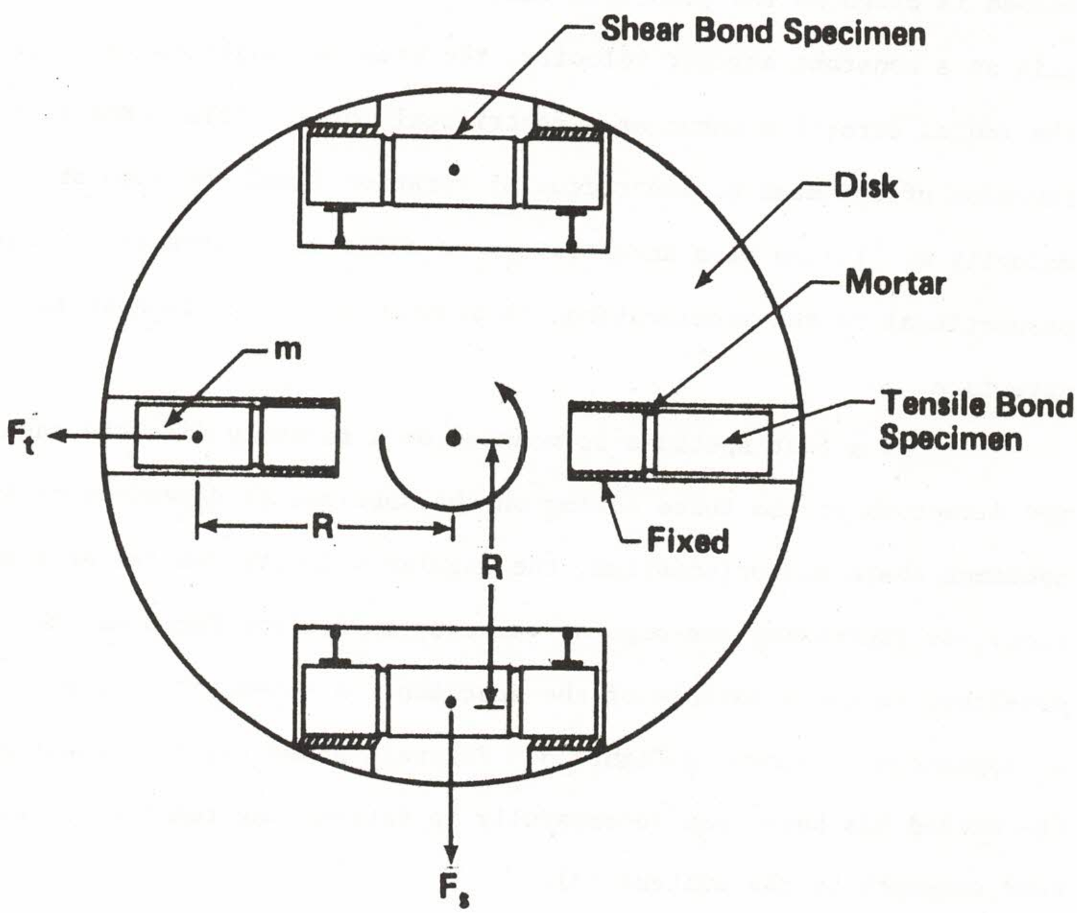

FIG. 3 Schematic diagram of centrifugal force testing machine

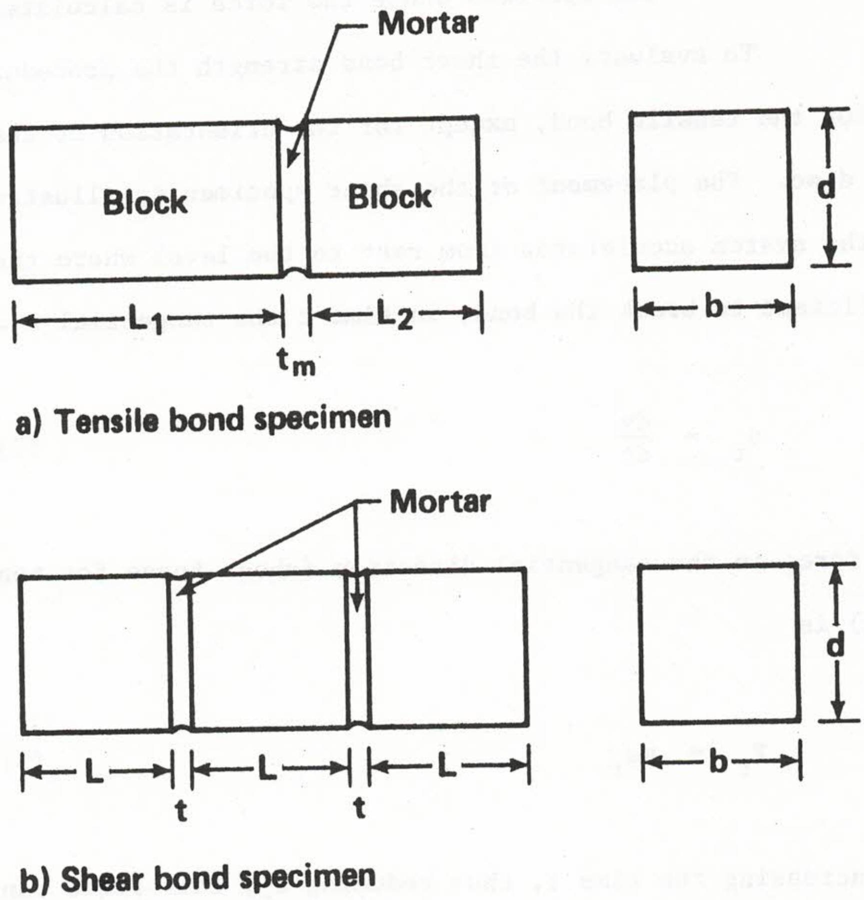

FIG. 4 Test specimens

where F = centrifugal force

m = mass of section considered

w = angular velocity

R = distance to the centre of mass of the portion of the specimen where the force is calculated.

To evaluate the shear bond strength the procedure is the same as for the tensile bond, except for the orientation of the specimen on the disc. The placement of the shear specimen is illustrated in Figure 1. If the system accelerates from rest to the level where the force is sufficient to break the bond, in time t the tangential acceleration is

$$a_t = \frac{dv}{dt} \tag{2}$$

The force in the tangential direction (shear force for tensile bond test) is

$$F_t = ma_t \tag{3}$$

By increasing the time t, thus reducing a_t, this force can be as small as desirable The test apparatus is shown in Figure 5 and 6.

The results of tests of 12 tensile bond specimens similar to that shown in Figure 4(a) are given in Table 3. Results of tests of shear bond specimens similar to that shown in Figure 4(b) are given in Table 4. The average seven day tensile bond strength was 21.7 psi. The average shear bond strength was 25 psi.

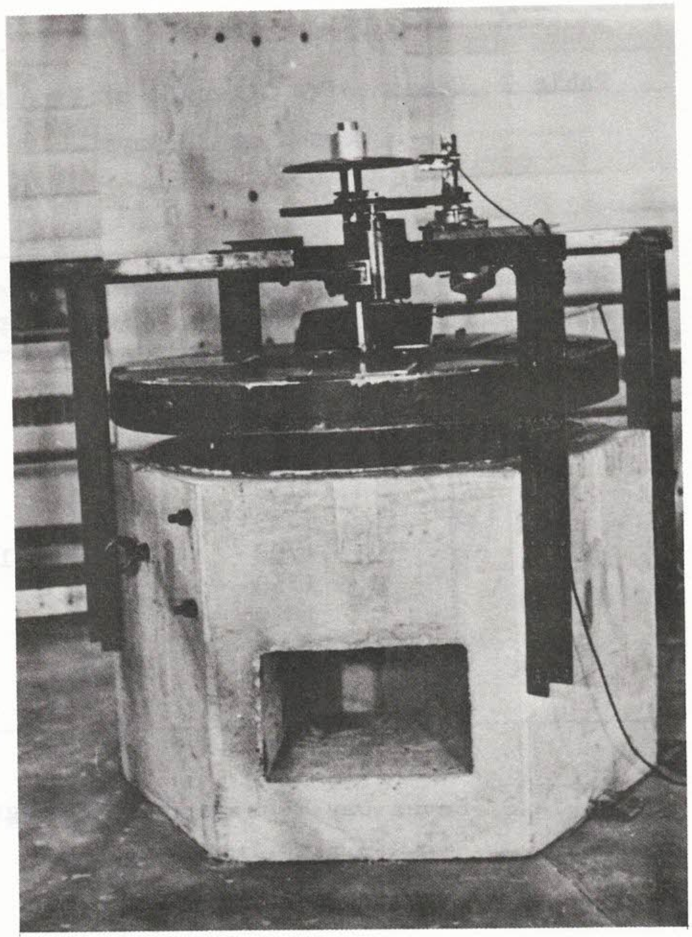

FIG. 5 Centrifugal testing apparatus

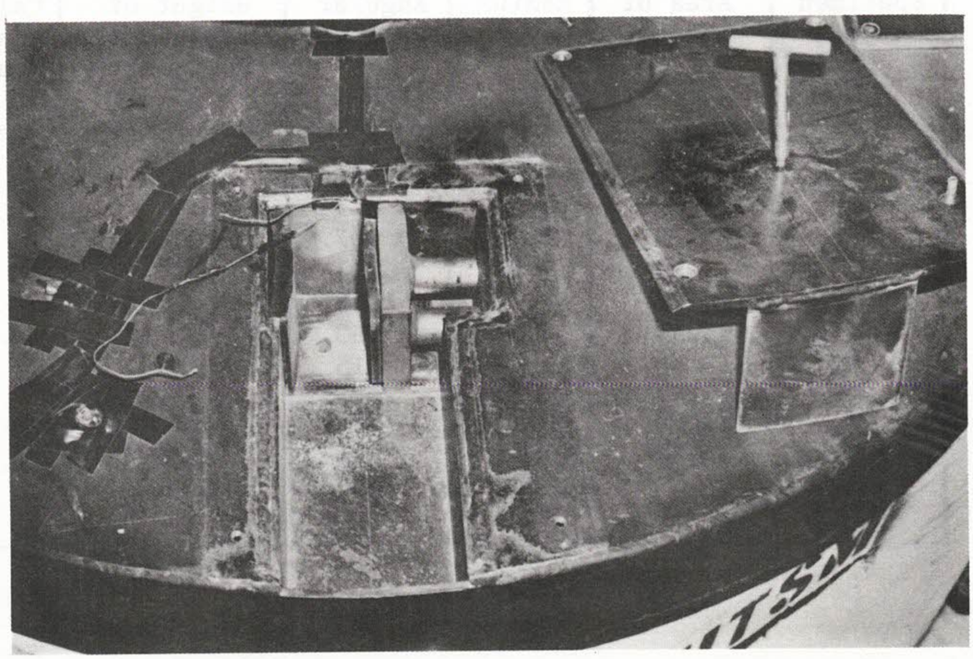

FIG. 6 Tensile bond compartment

Table 2 Compressive Strength of Type S Mortar Tested at 28 Days

Specimen	Compressive strength psi	Average psi
1	1655	
2	1645	
3	1640	
4	1750	
5	1630	
6	1700	1700
7	1750	
8	1800	
9	1650	
10	1780	

Table 3 Seven Day Tensile Bond Strength of Type N Ready Mixed Mortar

Specimen	Area of Contact in^2	Radius in	Angular Velocity RPM	Weight of Separated Portion lb.	Calculated Tensile Bond psi
1	13.47	19.65	335	6.53	30.4
2	13.99	19.68	275	6.54	19.8
3	13.70	19.74	307	5.86	22.7
4	13.95	19.65	227	6.19	12.5
5	13.42	19.63	218	6.18	12.2
6	13.54	19.69	353	6.17	31.8
7	13.50	19.62	215	6.20	11.9
8	13.49	19.75	390	6.22	39.3
9	13.58	19.85	350	6.17	31.0
10	13.72	19.64	246	6.37	15.7
11	13.57	19.80	260	6.32	17.7
12	13.54	19.69	246	6.16	15.4

Average 21.7 psi

Standard Deviation 9.25 psi

Table 4 28 Day Shear Bond Strength

No.	Contact Area in.	Angular Velocity rpm	Weight of Separated Portion	Shearbond Strength psi
1	27.76	482	3.22	15.8
2	27.69	833	3.29	48.6
3	27.53	440	3.23	13.4
4	28.14	474	3.21	15.0
5	27.51	530	3.14	18.8
6	28.01	504	3.04	17.0
7	28.67	705	3.43	34.8
8	27.92	507	3.28	17.8
9	27.58	530	3.18	19.2
10	27.51	838	2.96	44.6
11	27.36	925	2.92	54.0
12	27.52	419	3.22	12.6
13	28.18	565	3.36	22.4
14	27.37	485	3.28	16.7
15	28.25	470	3.17	14.6
16	27.52	415	3.42	15.6
17	27.42	793	3.24	43.9
18	27.60	650	2.79	25.5
19	27.18	406	3.63	13.0
20	28.42	650	3.28	28.7
			Average	25.0
			Standard Deviation	13.25

RESISTANCE TO FREEZE-THAW CYCLES

Damage of the mortar because of freezing and thawing is common in Canada. At present there are no requirements for resistance of mortar to freezing and thawing. The results presented in this study were obtained by subjecting the test specimens to freezing and thawing cycles in accordance with ASTM Standard C666-75 "Standard Method of Test for Resistance of Concrete to Rapid Freezing and Thawing".

The ready mixed mortar was 8 hours old at the time when the freeze-thaw specimens were molded. The dimensions and weights of the specimens before and after testing were given in Tables 5 and 6. Tests were also conducted on control specimens consisting of type S mortar mixed in the laboratory. The average compressive strength of these control specimens was 3300 psi.

The test results are given in Tables 7 and 8 for the laboratory prepared mortar and the ready mixed mortar respectively. The results are plotted in Figure 7.

DISCUSSION OF TEST RESULTS

a) Compressive Strength

The test data demonstrates that the compressive strength of the ready mixed mortar was not affected by the elapsed time between mixing and molding of specimens for at least 36 hours. The compressive strength remained almost constant, and the workability of the mortar remained very good.

Table 5 Physical Properties of Type S Mortar of Freeze-Thaw Specimen Before and After Testing

Specimen	Dimensions (inches)		Weight (lbs)	
	Initial	Final	Initial	Final
1	16 x 3.5 x 4.5	15.0 x 3.3 x 4.3	19.38	15.85
2	16 x 3.5 x 4.5	15.1 x 3.2 x 4.3	19.42	15.42
3	16 x 3.5 x 4.5	15.5 x 3.3 x 4.3	19.22	16.32
4	16 x 3.5 x 4.5	15.4 x 3.4 x 4.3	19.32	16.28
5	16 x 3.5 x 4.5	15.2 x 3.0 x 4.1	19.10	14.50
6	16 x 3.5 x 4.5	14.8 x 3.0 x 4.2	19.00	14.12
		Average	19.24	15.41

Table 6 Physical Properties of Ready Mixed Mortar (Type N) Freeze-Thaw Specimens Before and After Testing

Specimen	Dimensions (inches)		Weight (lbs)	
	Initial	Final	Initial	Final
1	16 x 3.5 x 4.5	16.0 x 3.5 x 4.4	17.68	16.16
2	16 x 3.5 x 4.5	15.5 x 3.4 x 4.3	17.05	16.05
3	16 x 3.5 x 4.5	15.9 x 3.4 x 4.2	17.92	16.25
4	16 x 3.5 x 4.5	16.0 x 3.5 x 4.3	17.65	16.15
5	16 x 3.5 x 4.5	16.0 x 3.3 x 4.5	17.58	16.75
6	16 x 3.5 x 4.5	16.0 x 3.5 x 4.4	17.00	16.35
		Average	17.48	16.285

Table 7. Freeze-Thaw Durability of Laboratory Prepared Mortar (type S)

Cycle	Relative Dynamic Modules of Elasticity x 10^3 psi						Average
	1	2	3	4	5	6	
0	1700	1690	1740	1725	1700	1710	1710
21	1140	953	825	1060	765	700	907
48	596	578	710	690	550	450	595
68	500	500	570	540			527
87			450	500			475
116							

Table 8 Freeze-Thaw Durability for Ready Mixed Ready-to-Use Mortar (Type N)

Cycle	Relative Dynamic Modulus For Individual Specimens x 10^3 psi						Average
	1	2	3	4	5	6	
0	1280	1260	1285	1255	1260	1270	1268
36	1230	1190	1220	1240	1220	1240	1223
50	1220	1230	1235	1235	1225	1245	1231
77	1220	1230	1235	1233	1220	1235	1228
104	1210	1220	1240	1220	1220	1250	1226
124	1200	1200	1230	1220	1220	1240	1218
143	1200	1200	1220	1220	1220	1240	1216
172	1120	1120	1220	1210	1220	1240	1188
192	1100	1100	1200	1210	1220	1240	1178
212	1000	1095	1190	1200	1220	1240	1157
239	1000	1025	1180	1180	1180	1240	1134
259	950	1050	1180	1170	1180	1240	1128
279	950	1030	1120	1170	1180	1220	1111
309					1040	1220	

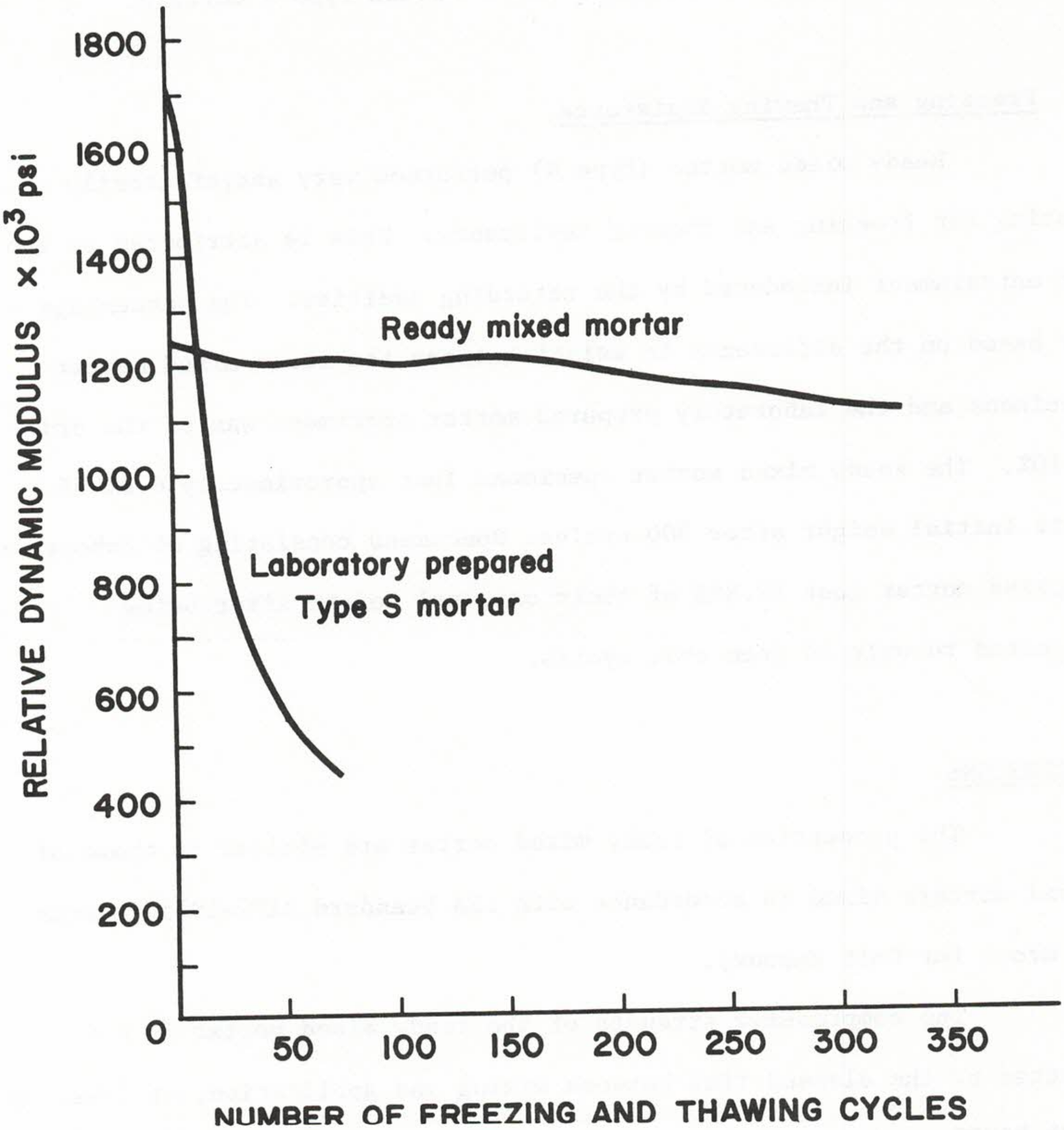

FIG. 7 Durability of mortars as determined by its relative dynamic modulus

b) Tensile and Shear Bond

The values obtained for the tensile and shear bond strength using the centrifugal testing apparatus are of the same order as strengths reported in the literature for normal type N mortars.

c) Freezing and Thawing Resistance

Ready mixed mortar (type N) performed very satisfactorily in testing for freezing and thawing resistance. This is attributed to the air entrainment introduced by the retarding additive. The percentage of air based on the difference in weight between the ready mixed mortar specimens and the laboratory prepared mortar specimens was of the order of 10%. The ready mixed mortar specimens lost approximately 6.8% of their initial weight after 300 cycles. Specimens consisting of laboratory prepared mortar lost 19.88% of their original weight after being subjected to only 68 free-thaw cycles.

CONCLUSIONS

The properties of ready mixed mortar are similar to those of normal mortars mixed in accordance with CSA Standard A179-1975, Mortar and Grout for Unit Masonry.

The compressive strength of the ready mixed mortar is not affected by the elapsed time between mixing and application, at least up to 36 hours.

Ready mixed, ready to use mortar has substantially higher resistance to freezing and thawing than normal mortar.

Acknowledgements

The research program on which this paper is based was contacted at the University of Alberta and was made possible by Research Funds provided by the Alberta Masonry Institute and Alberta Housing and Public Works.

Concrete block units were provided by Edcon Block and mortar supplied by North American Mortar Supply Ltd.

REFERENCES

1. Hatzinikolas, M., J. Longworth, J. Warwaruk, "The Use of Centrifugal Force for Determining the Tensile Bond Strength of Masonry". Proceedings of the British Ceramic Society, "Load-Bearing Brickwork" (6) No. 27, December 1978. Edited by H.W.H. West, British Ceramic Society, Shelton House, Stoke-on-Trent.

2. CSA Standard A179-1975, "Mortar and Grout for Unit Masonry", Canadian Standards Association 178 Rexdale, Ontario, Canada, M9W 1R3.

3 Hatzinikolas, M., J. Longworth, J. Warwaruk. "Evaluation of Tensile Bond and Shear Bond by Means of Centrifugal Force". Canadian Journal of Civil Engineering, Volume 7, Number 1, March 1980.