IOWA STATE HIGHWAY COMMISSION
MATERIALS DEPARTMENT
SPECIAL INVESTIGATIONS SECTION

FINAL REPORT OF R-249

A STUDY OF

Portland Cement Maintenance Mix

AND

Set Accelerators

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A STUDY OF PORTLAND CEMENT MAINTENANCE MIX AND SET ACCELERATORS

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by

Don Johannsen

and

Vernon J. Marks

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INTRODUCTION

The large volume of traffic on the interstate system makes it difficult to make pavement repairs. The maintenance crew needs 4-5 hours to break out the concrete to be replaced and prepare the hole for placing new concrete. Because of this it is usually noon before the patch can be placed. Since it is desirable to remove the barricades before dark there are only 7-8 hours for the concrete to reach the required strength. There exists a need for a concrete that can reach the necessary strength (modulus of rupture = 500 psi) in 7-8 hours.

PURPOSE

The purpose of this study is to determine if type III cement and/or an accelerator can be used in an M-4 mix to yield a fast setting patch with very little shrinkage. It is recognized that calcium chloride is a corrosive material and may therefore have detrimental effects upon the reinforcing steel. The study of these effects, however, is beyond the scope of this investigation.

MATERIALS

The fine aggregate was from Hallett's pit at Ames (Lab. No. AAS0-277) and complied with section 4110 of the standard specifications.

The coarse aggregate was from Hallett's pit at Ames (Lab. No. AAG0-213) which met AASH0-57 grading and complied with section 4115 of the standard specifications. The two different types of cement were a blend of seven type I cements (R-11 blend, Lab. #AC0-149), and Penn Dixie type III (Lab. #AC0-367).

There were three admixtures used; Ad Aire, an air entraining agent (Lab. #ACA9-24) and two set accelerators, calcium chloride (Lab. #ADA8-27) and DSA (calcium formate)(Lab. #AAM0-21).

PROCEDURE

M-4 mix proportions were used for all concrete. This is a standard maintenance mix commonly in use in Iowa, and has the following proportions:

	Abs. Vol.	Lbs/yd^3
Cement	0.1555690	823
Fine Agg	0.3120875	1404
Coarse Agg	0.3120875	1404
Water	0.160256	270
Air	0.060000	

The mixing procedure was as follows:

1. Proportion cement and dry fine aggregate.
2. Mix for one minute.
3. Proportion saturated surface dry coarse aggregate.
4. Mix for one minute.
5. Add air entraining agent in one-half of the water to obtain 6 ± 1% entrained air.
6. Mix for one minute.
7. While mixing for three minutes, add water (set accelerator in designated mixes) and adjust to a slump not to exceed 1 1/2" (calcium formate was added as a powder, calcium chloride was dissolved in the water added to the mix).

The seven mixes were as follows:

1. M-4 mix using type III cement.
2. M-4 mix using type III cement + CaCl @ 1%.
3. M-4 mix using type I, R-11 blend cement.
4. M-4 mix using type I, R-11 blend cement + CaCl @ 1%.
5. M-4 mix using type III cement + calcium formate @ 1%.
6. M-4 mix using type III cement + calcium formate @ 2%.
7. M-4 mix using type I, R-11 blend cement + calcium formate @ 1%.

From each mix eight 6" x 6" x 20" beams, eight 4 1/2" x 9" horizontal cylinders and one 4 1/2" x 9" vertical cylinder were molded for the determination of flexural strength, compressive strength and shrinkage respectively. All consolidation was by a platform vibrator. After the beams had been molded they were covered by a moist cloth and a polyethylene film until they were to be tested at which time they were removed from the molds. Two beams and two cylinders were tested at five, eight, twelve and twenty-four hours after the time of mixing.

A 2" diameter flat metal lid was embedded into the top of the vertical cylinder. The cylinder, still in the mold, was moved to a

platform stand and a dial indicator (incremented in thousandths of an inch) was clamped such that the dial indicator plunger was in the center of the metal lid. An initial reading was then taken. Readings were taken at five, eight, twelve and twenty-four hours after the time of mixing and once a day thereafter. Several days after all mixes had been completed the cylinders were moved from a work bench to a window sill where it was felt they would have less chance of being disturbed.

RESULTS

The results of the various strength tests performed are shown on Fig. 1 and 2. The mixture containing type III cement and calcium chloride (mix No. 2) gave the best overall performance from the standpoint of high early strengths. Both set accelerators used gave increased early strength but calcium formate did not yield as much increase as calcium chloride. In an effort to get better strengths from calcium formate the rate was increased from 1% to 2%. This improved the strength but not enough to surpass the strength obtained with 1% of calcium chloride.

Tests were also made using R-11 blend type I cement. The effect of the admixtures on this cement are the same as those obtained from the type III cement; calcium formate at 2% rate is more effective than at a 1% rate, and calcium formate is not as effective as a set accelerator as calcium chloride.

The beams that were tested at eight and twelve hours for the type III mix (mix No. 1) gave nearly the same modulus of rupture value. Since the ultimate compressive strength increases 1,365 psi in this same period, it appears that both beams tested for the 12 hour break were weakened by some outside influence. Two of the four beams tested at eight and twelve hours broke at a location 1 1/2" from the midpoint of the beam, possibly indicating flaws in the beams.

One of the cylinders tested for the twelve hour test of the type III cement + CaCl mix (mix No. 2) gave a very low ultimate compressive strength. This is attributed to a flaw in the cylinder therefore the results of this test were not used for computing the average twelve hour strength.

When calcium formate is added to either type III or R-11 blend cement at 1% the 24 hour ultimate compressive strength is less than the strength attained by type III or R-11 blend cement alone. Thus the addition of

calcium formate at 1% seems to have a detrimental effect on the strength of the concrete.

The mixture containing type III cement and calcium chloride (mix No. 2) had the fastest time of set needing only 70 minutes to reach initial set (500 psi resistance). The mixture containing type III cement and 2% calcium formate (mix No. 6) needed 110 minutes to reach initial set. The time of sets for the other mixes are given in Table 2.

From these tests, with respect to their ability to produce the greatest strength in the least time, the mixes would be rated in the following order:

1. Type III cement + 1% calcium chloride.
2. R-11 blend cement + 1% calcium chloride or type III cement + 2% calcium formate.
3. Type III cement.
4. R-11 Blend.

The two mixes containing calcium formate @ 1% performed poorly and gave unpredictable results; therefore, it is not possible to rank them.

Consolidation is the change in length of the shrinkage cylinder occurring during the time it takes the concrete to reach an initial set. It was difficult to obtain an accurate determination of consolidation for the following reasons: The time of set for the seven mixes tested varied from 1 to 4 hours, and the distance the metal lid will settle into the concrete is dependent on the amount of laitance brought to the top by vibrating the mix and on the spring constant of the dial indicator plunger. To avoid these difficulties it was decided to let the change in length during the first five hours be consolidation and any change in length after that be shrinkage. There was a fairly large amount of consolidation occurring during the first five hours for the mix made with R-11 blend (mix No. 3) and the mix made with type III cement (mix No. 1). After the initial consolidation there was very little shrinkage occurring in any of the mixes. There was a large variation in the shrinkage reading occurring five days after the beginning of the test. This discrepancy is probably due to a jolt to the work bench on which the shrinkage cylinders were sitting. The shrinkage cylinders were moved to a window sill to reduce the chances of another jolt. The smaller

variations in readings are probably due to changes in room temperature and the subsequent expansion and contraction of the platform stand and dial indicator.

SUMMARY

In summary it can be concluded from this study that from a strength standpoint, the best mix to use for patching interstate pavement would be a (high early) type III cement with CaCl as an accelerator. The next best mix to use would be either a type I cement with 1% CaCl or a type III cement with 2% calcium formate. A factor that should be taken into consideration is that CaCl is more corrosive than calcium formate.

None of the mixes tested reached the desired strength in the time required. The mix made with type III + CaCl reached the desired strength in 9 1/2 hours which is not fast enough to allow the removal of barricades before dark. Since the rate used (1%) is only half of the maximum allowed (Standard Specification 2301.22-B2) it is probable that a satisfactory mix can be obtained. It should be pointed out that these tests were made under laboratory conditions and that results obtained in the field may vary from the results obtained here.

Shrinkage should not present problems with any of the mixes used.

FIGURE 1

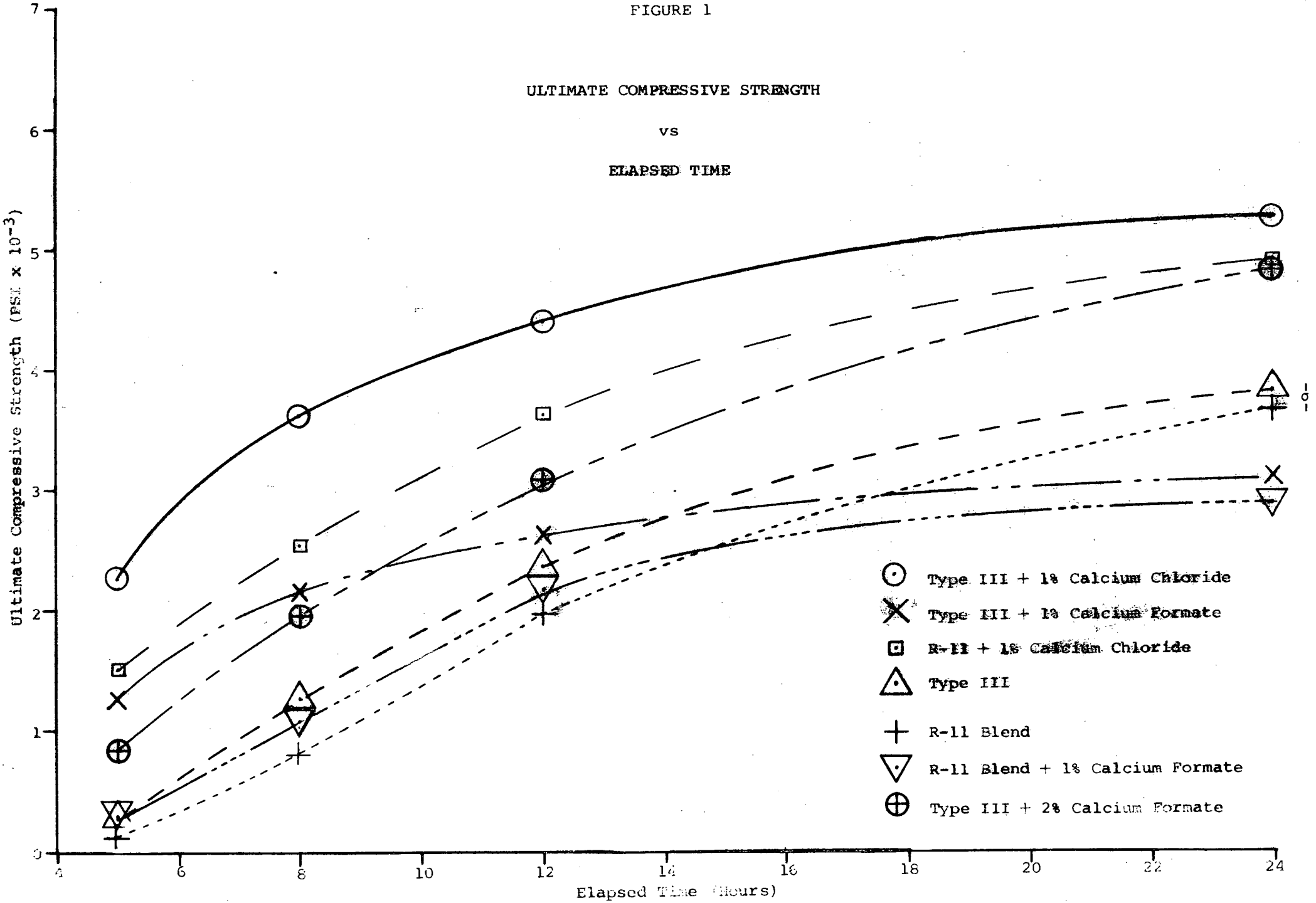
ULTIMATE COMPRESSIVE STRENGTH
vs
ELAPSED TIME
Ultimate Compressive Strength (PSI x 10^{-3})
Elapsed Time (Hours)
Type III + 1% Calcium Chloride
Type III + 1% Calcium Formate
R-11 + 1% Calcium Chloride
Type III
R-11 Blend
R-11 Blend + 1% Calcium Formate
Type III + 2% Calcium Formate

FIGURE 2

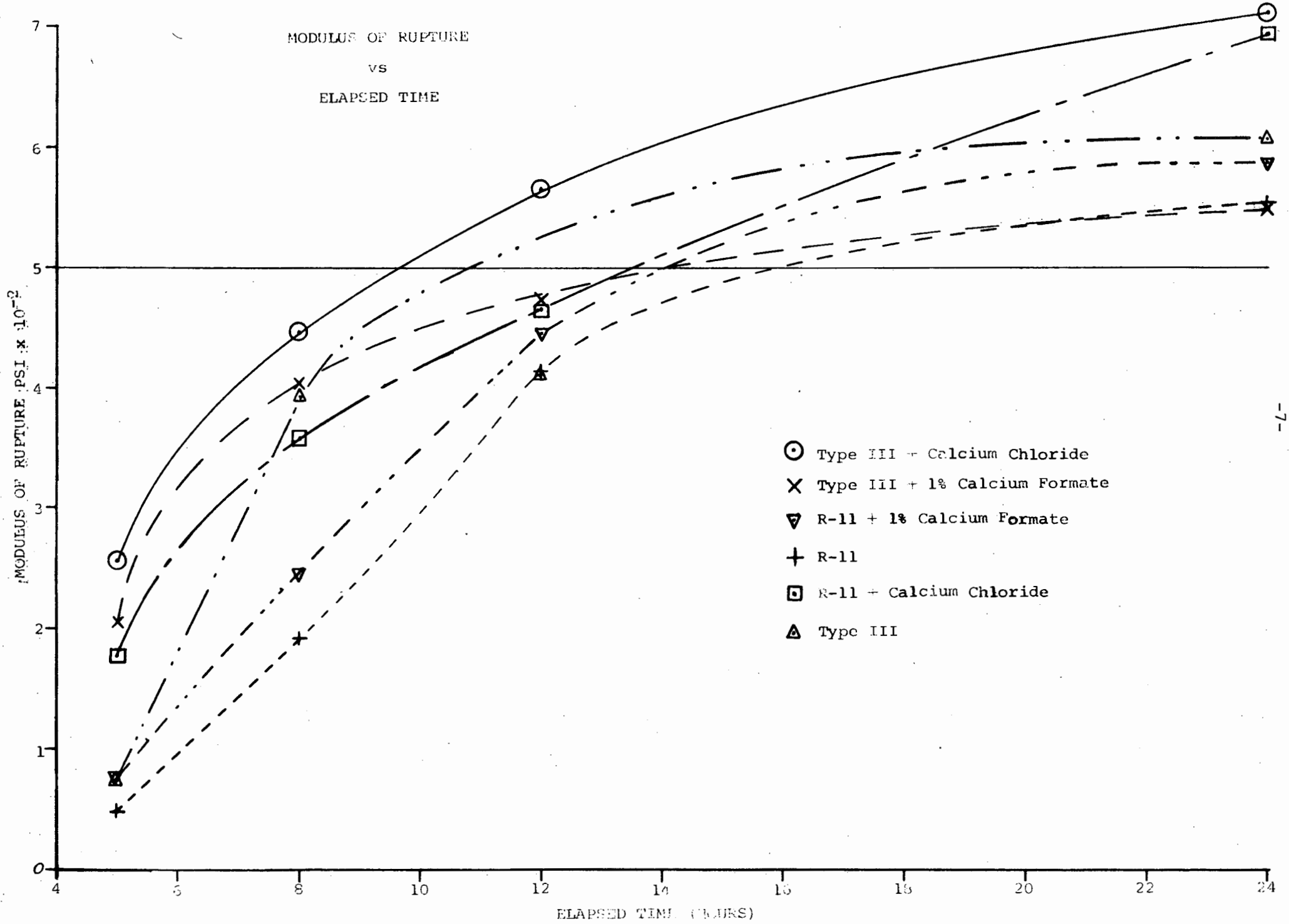
MODULUS OF RUPTURE
vs
ELAPSED TIME
MODULUS OF RUPTURE PSI x 10^{-2}
ELAPSED TIME (HOURS)
0
1
2
3
4
5
6
7
4
6
8
10
12
14
16
18
20
22
24
Type III + Calcium Chloride
Type III + 1% Calcium Formate
R-11 + 1% Calcium Formate
R-11
R-11 + Calcium Chloride
Type III

TABLE I

Consolidation & Shrinkage (Inches x 10^{-3})

Elapsed Time	Type III + 1% Calcium Chloride	Type III	R-11 Blend + 1% Calcium Chloride	R-11 Blend	Type III + 1% Calcium Formate	R-11 Blend + 1% Calcium Formate	Type III + 2% Calcium Formate
5 hr.	3.0	5.6	0.0	15.5	3.7	-0.2	-0.1
8 hr.	0.5	0.2	0.0	-0.3	0.3	0.1	-0.1
12 hr.	1.0	0.1	"	-0.6	0.9	0.3	-0.3
1 day	"	-0.2	0.3	"	1.2	0.5	0.0
2 "	"	-0.6	0.4	"	1.3	"	"
3 "	"	-0.5	0.8	-0.4	1.2	"	"
4 "	"	-0.2	"	-0.6	"	0.6	"
5 "	"	"	0.9	-0.3	1.2	0.8	0.2
6 "	"	-0.3	0.6	"		0.7	0.0
7 "	0.8	-0.4	1.2	"		"	"
8 "	"	"	1.3	-0.2		0.8	"
9 "	0.7	-0.2	1.1	"		0.7	0.1
10 "	"	-0.4	"	"		"	-0.2
11 "	0.5	-0.3	"	0.3		"	0.0
12 "	"	-0.4	"	-0.4		"	"
13 "	"	"	"	-0.5		"	"
14 "	0.1	-0.2	1.0	-0.4		0.4	"
15 "	-0.2	-0.3	1.1	-0.4		0.5	0.0

Shrinkage values for the type III mix and R-11 mix are averages of two tests.

Changes in length occurring in the first five hours after mixing is considered consolidation. Changes in length after the first five hours is considered shrinkage.

Corrections were made to the data when external influences caused large fluctuations in dial readings.

TABLE 2

MIX	TIME OF INITIAL SET (HRS.)
1. Type III	2.63
2. Type III + 1% CaCl	1.16
3. R-11 Blend	4.05
5. Type III + 1% CaF	2.46
6. Type III + 2% CaF	1.83
7. R-11 Blend + 1% CaF	3.32