Evaluation of Type I Cement Fast Track Concrete

Final Report for MLR-87-6

October 1988

Highway Division
Iowa Department of Transportation

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of
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TABLE OF CONTENTS

DISCLAIMER

ABSTRACT

There are projects where opening the pavement to traffic in less than the 5 to 7 days is needed, but an 8 to 12 hour opening time is not necessary. The study examined fast track concrete with Type I cement and admixtures.

The variables studied were:

1. cure temperature
2. cement brand
3. accelerators
4. water reducers

A standard water reducer and curing blankets appear to be effective at producing a 24 hour to 36 hour opening strength. An accelerator and/or high range water reducer may produce opening strength in 12 to 24 hours. Calcium chloride was most effective at achieving high-early strength.

INTRODUCTION

Experience with fast track concrete in Buena Vista County on Highway 71 and in additional projects constructed in 1987 and 1988 has shown that it is a viable construction alternative for some locations. There are other projects where opening the pavement to traffic in less than 5 to 7 days is needed, but an 8 to 12 hour opening is not necessary. For these projects a Type I cement may be financially beneficial over a Type III cement.

OBJECTIVE

The objective of the study was to evaluate the strength gain of fast track mix with Type I cement.

MATERIALS

The following materials were used in this study (Aggregate gradations are in the Appendix):

Portland Cement - Type I (See Table I)

Fly Ash - Type C, Ottumwa (ACF8-1)

Coarse Aggregate - Martin Marietta (Ft. Dodge)(AAC7-28)

Fine Aggregate - Cordova, IL (AAS7-196)

Air Entraining Agent - Ad-Aire single strength,
Carter-Waters Corp.

Water Reducer - WRDA-82, W. R. Grace and Pozzolith 400N,
Master Builders

Accelerating Agents - Flaked calcium chloride
Daraset (Non-Chloride), W. R. Grace and Co.

TABLE I
Cement Characteristics

	Cement A	Cement B
Blaine Specific Surface (M^2/Kg)	341	381
C3S %	64	51
C2S %	12	24
C3A %	5	10
Compressive Strength ASTM C109(PSI)		
12-hr	320	710
24-hr	1260	1630
3-day	3390	4830
7-day	4090	5280

PROCEDURE

Normal mix procedures (ASTM C192) were followed for all the mixes. Materials for the 50°F cure were cooled to 50°F prior to mixing. The mixes were as follows:

Cement - 635 pounds per cu. yard

Fly Ash - 73 pounds per cu. yard

Coarse Agg. - 50%

Fine Agg. - 50%

The 50°F cure temperature was maintained in a refrigerated unit with lime water. The 72°F cure was maintained in a 97%+ relative humidity condition. Fiberglass insulation was placed over the specimens to obtain an elevated temperature. The insulation was removed after 24 hours and the remaining specimens were subjected to 72°F, moist cure.

DISCUSSION OF RESULTS

The intent of the research was to evaluate the effect of cement characteristics, cure temperature and admixtures on the early age strength of concrete. A summary of the results are in Table II.

Cement Effect

Cement A was chosen as a cement having typical cube strength for a Type I cement available in Iowa. Cement B was chosen as a cement having a high-early cube strength. Figures 1 through 4 show the effect of cement on concrete strengths. The strength difference in the two mixes is much less at 72°F than at 50°F. At 72°F, the flexural strength with cement A was 680 psi and with cement B it was 700 psi.

Cure Temperature Effects

Curing conditions were 50°F, 72°F and insulated. The insulation resulted in a temperature of 89°F at 12 hours and 77°F at 24 hours. Figures 5 and 6 show the effect of curing condition as a percentage of the 28-day, 72°F cured concrete.

Figures 7 and 8 are results from a study of curing temperature done by the Portland Cement Association. The results of the research show a similar trend to the PCA results. No loss in ultimate strength was found from the short duration of insulated curing.

TABLE II
Testing Summary

MIX NO.	CEMENT	FLY ASH	WATER REDUCER	ACCELERATOR	W/C+FA	SLUMP (IN.)	AIR CONTENT	CURE	FLEXURAL STRENGTH (PSI) 12-HR	24-HR	36-HR	48-HR	7-DAY	COMPRESSIVE STRENGTH (PSI) 24-HR	48-HR	7-DAY	28-DAY
1	A	Ottumwa	WRDA-82	---	0.326	1.75	6.8	50 DEG F.	---	150	510	530	720	310	1740	5950	7130
2	A	Ottumwa	WRDA-82	---	0.331	1.25	6.2	72 DEG F.	---	680	740	740	900	3880	5280	6270	7810
4	B	Ottumwa	WRDA-82	---	0.338	1.25	5.7	50 DEG F.	---	480	720	820	880	1630	3840	5830	7540
5	B	Ottumwa	WRDA-82	---	0.344	1.50	6.0	72 DEG F.	440	700	---	800	970	4500	5690	6720	7940
6	B	Ottumwa	WRDA-82	---	0.344	1.50	6.0	INSUL.	480	630	---	740	920	4640	5980	6590	7960
7	B	Ottumwa	WRDA-82	Daraset	0.351	1.00	5.5	INSUL.	600	710	---	720	890	5580	6500	6750	8770
8	B	Ottumwa	WRDA-82	CaCl-1.5%	0.387	1.25	5.7	INSUL.	620	760	---	1040	1140	6950	7690	8960	9520
9	B	Ottumwa	POZZ 400N	---	0.298	1.50	5.0	INSUL.	590	810	---	860	1060	6450	7100	8450	9450

ADMIXTURE DOSAGES:

WRDA-82	4 oz/100 # of cement
Pozzolith 400N	20 oz/100 # of cement
Calcium Chloride	1.5 #/100 # of cement
Daraset	60 oz/100 # of cement

FIGURE 1. FLEXURAL STRENGTHS– 50 DEG. CURE

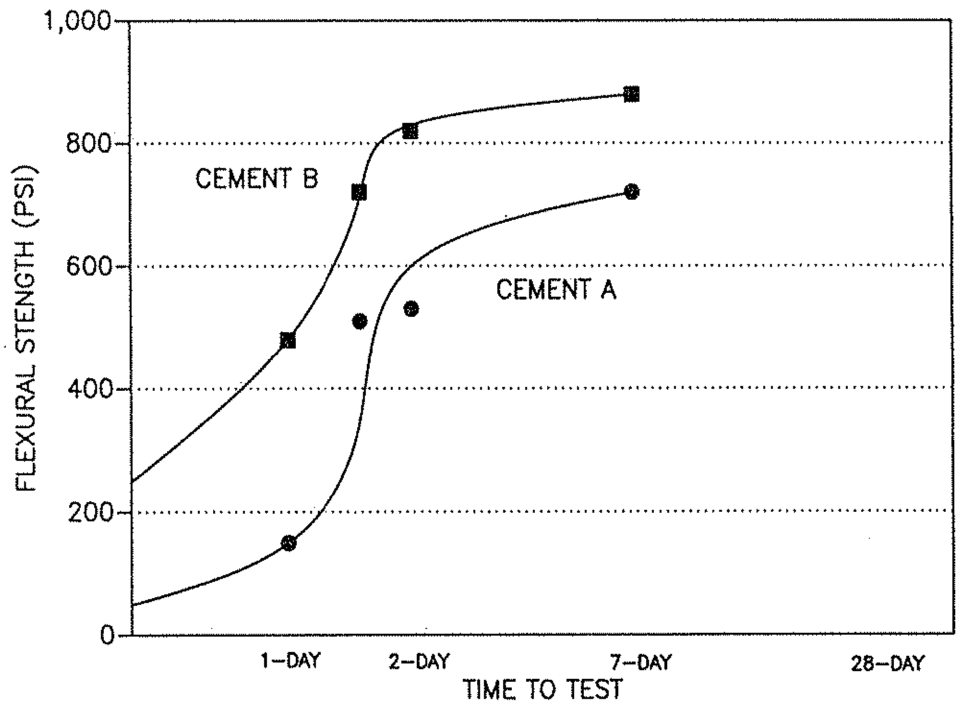


FIGURE 2. FLEXURAL STRENGTHS– 72 DEG. CURE

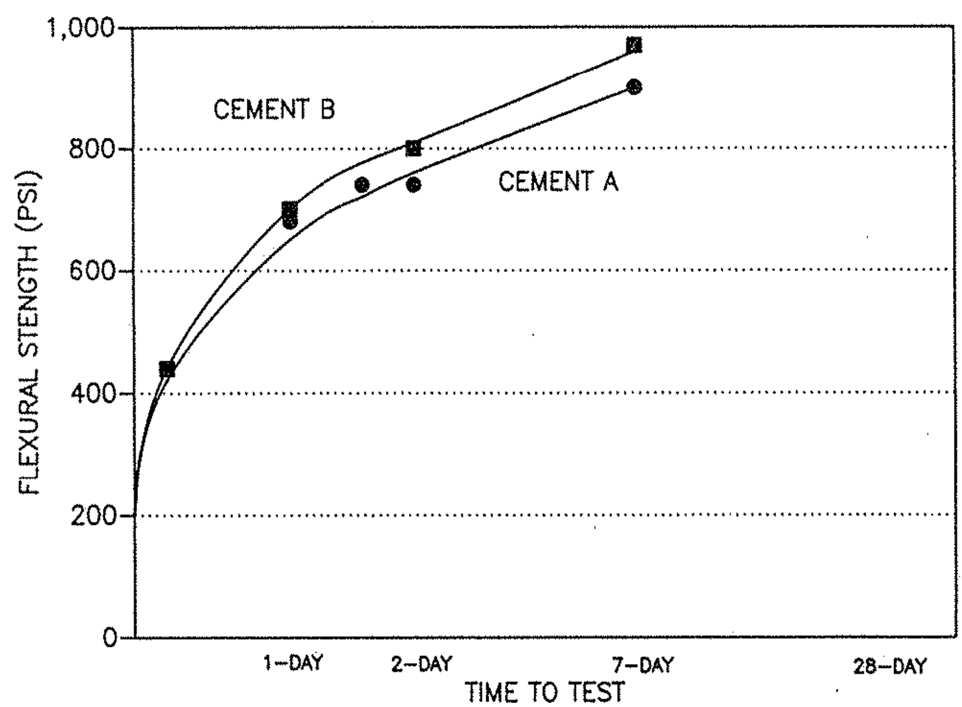


FIGURE 3. COMPRESSIVE STRENGTHS– 50 DEG. CURE

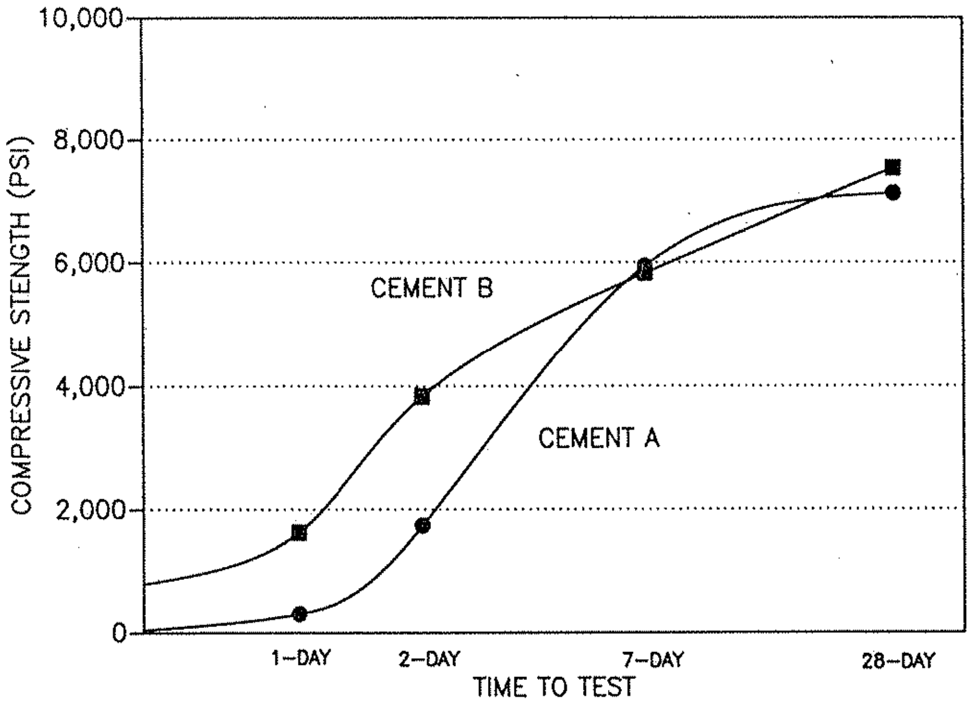


FIGURE 4. COMPRESSIVE STRENGTHS– 72 DEG. CURE

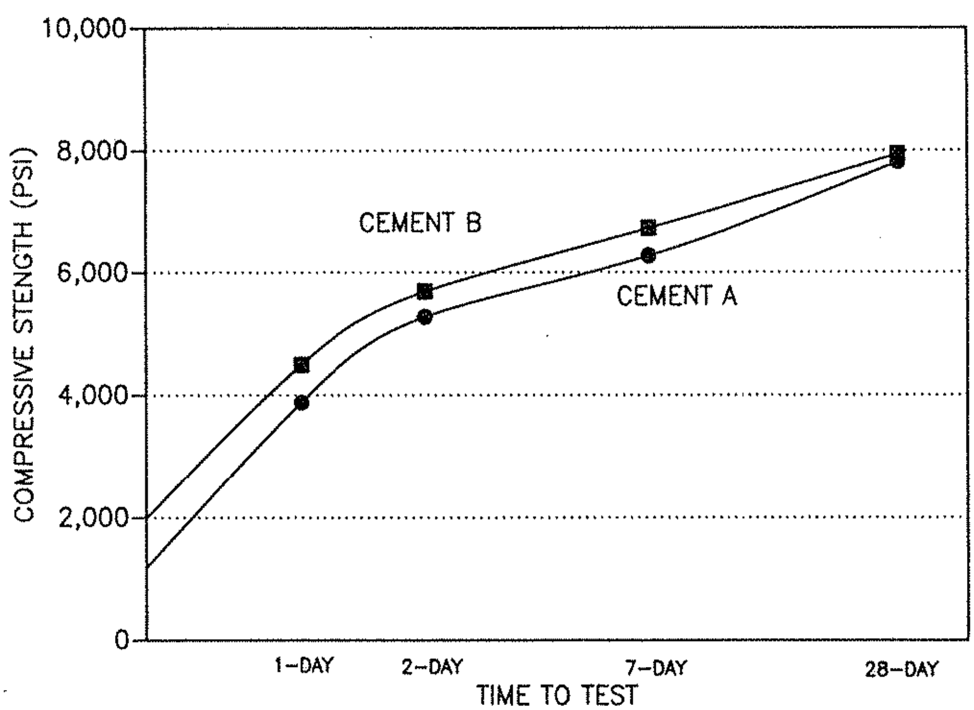


FIGURE 5. EFFECT OF CHANGE IN CURE TEMPERATURE
CEMENT A

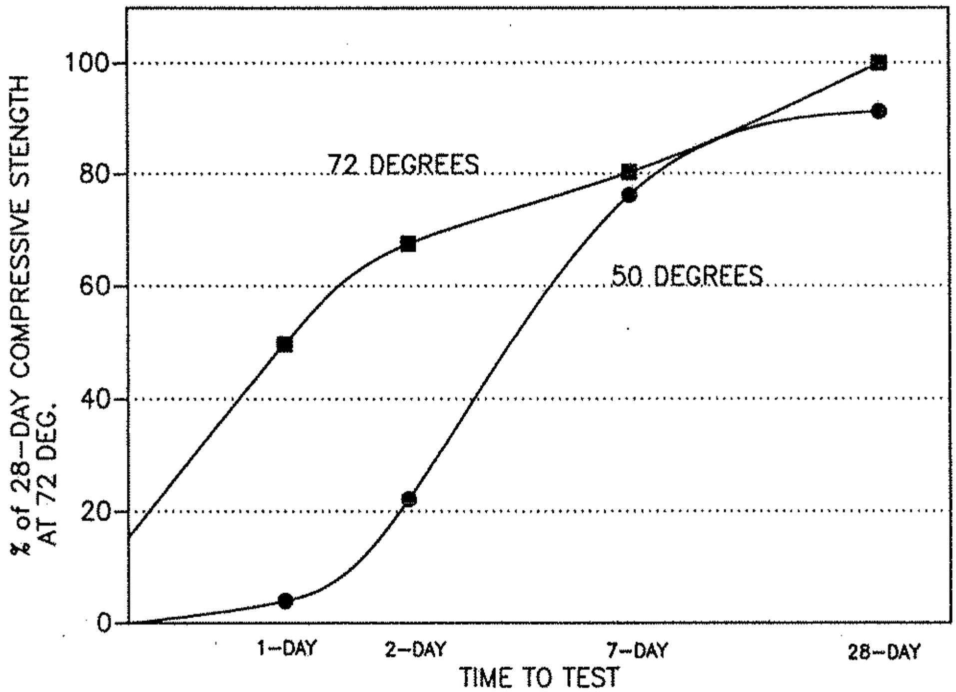
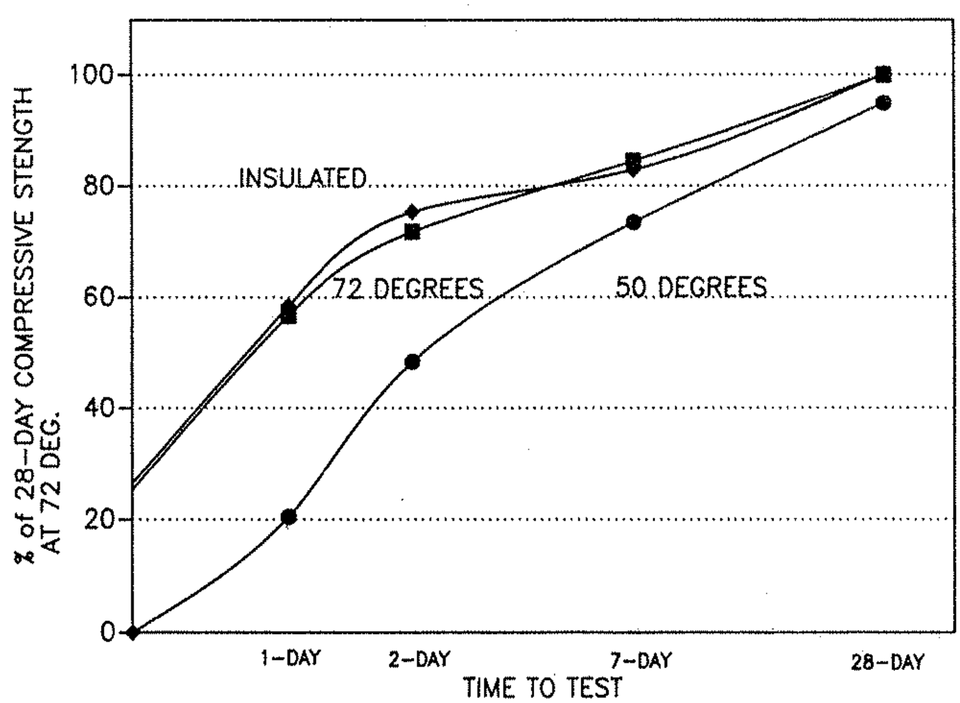


FIGURE 6. EFFECT OF CHANGE IN CURE TEMPERATURE
CEMENT B



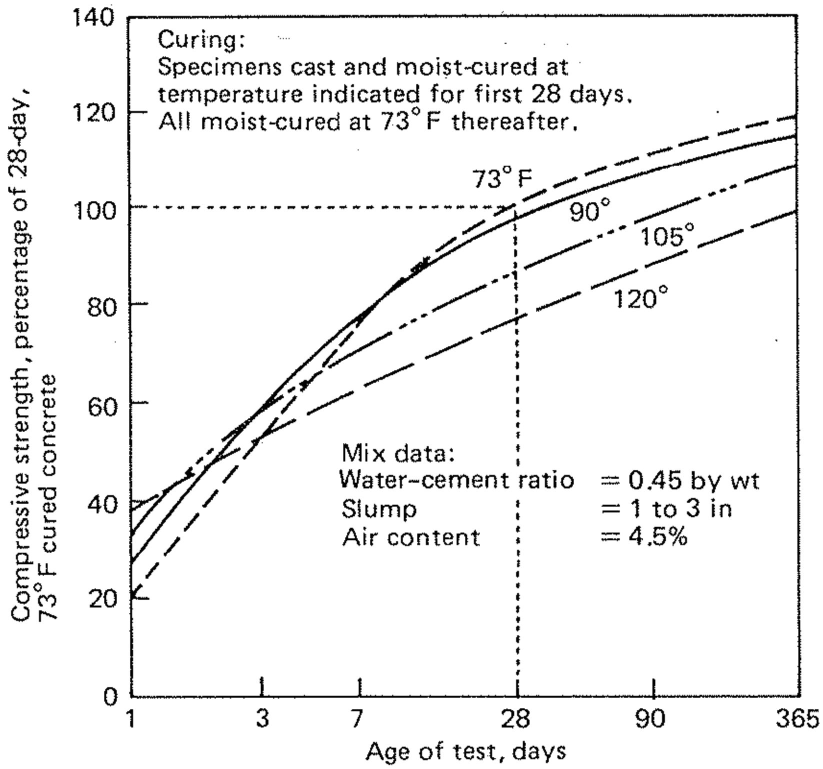


FIGURE 7. EFFECT OF HIGH TEMPERATURE CURING–PCA RESULTS (1)

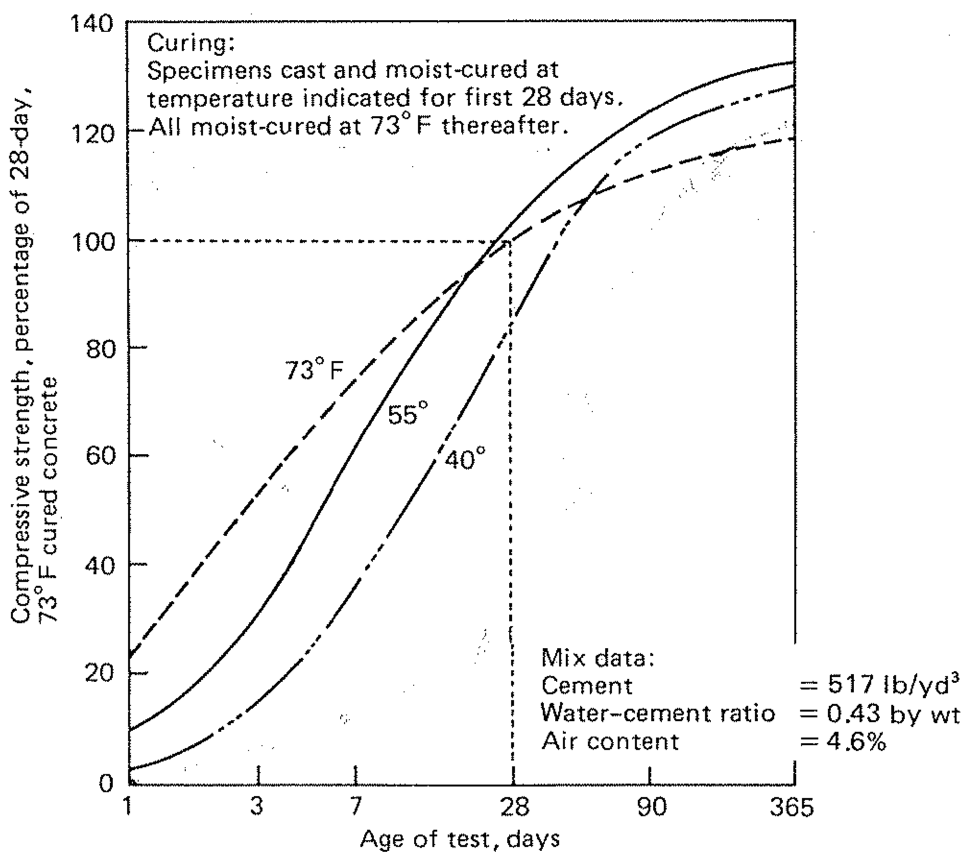


FIGURE 8. EFFECT OF LOW TEMPERATURE CURING–PCA RESULTS (1)

Admixture Effects

Calcium chloride, a non-chloride accelerator and a high range water reducer were tested with cement B. Calcium chloride achieved the highest flexural strength at 12 hours with 620 psi. Both the non-chloride accelerator and high range water reducer were close at 600 and 590 psi at 12 hours.

COSTS

The cost of the various accelerators is shown in Table III. Not surprising, calcium chloride is the lowest in terms of material cost. The Type III cement, high range water reducer and non-chloride accelerator have application where steel is used in the pavement.

TABLE III
Cost Comparison

Accelerator Type	Dosage (/100 lb Cement)	Cost/Yd³ Above Type I Cement and Water Reducer (1)
CaCl2	1.5%	$1.25
Type III Cement	---	3.20
Pozz. 400N(2)	20 oz.	5.90
Daraset	60 oz.	7.45

1. WRDA-82 $0.65/yd³
2. Standard water reducer eliminated from mix and subtracted from the cost.

SUMMARY

Concrete mixes with Type I cement have the potential for high early strength. Low mix temperature and low curing temperature appear to be a significant factor on early strength gain. An increase in mix and curing temperature of 72°F resulted in a 150 to 450 percent flexural strength increase at 24 hours. This suggests that the practice of an insulating cure on pavement may be most effective when shielding the pavement from heat loss during cool nighttime temperatures. Work done in 1987 in Boone County showed similar results (2).

The properties of the cement appear to play a role in early strength gain of the concrete. Properties such as fineness, C3A and C3S content and the rate of heat evolution in cement do effect early hydration and early strength gain.

CONCLUSIONS

The following conclusions can be drawn from the research:

1. Cold temperature during mixing, placing and curing may significantly reduce the early age strength of Type I cement fast track. A restriction on the concrete temperature and the use of insulating blankets may be warranted for Type I fast track.

2. Source of cement may be a factor in the early age strength of the concrete.

3. Use of high range water reducer or accelerators may produce early strengths with Type I cement equal to or greater than those with Type III cement fast track. The three admixtures tested do have drawbacks associated with their use in a mix.

RECOMMENDATIONS

1. Use of cure blankets with an R-value of 0.5 should be effective at increasing early age strength of Type I cement fast track, especially in cold weather. In addition, restrictions should be placed on the mix temperature and the base temperature.

2. Admixtures may produce early age strengths in Type I cement fast track equal to Type III cement fast track. On small pour projects, Type I cement fast track with admixtures may be more economical and practical than the Type III cement fast track.

3. Because of the variation in cements, admixtures and aggregate it would be difficult to develop a standard mix design to produce satisfactory strength in all cases. A trial mix procedure may work for alternates to Type III cement fast track.

REFERENCES

1. Popovics, Sandor, Concrete Making Materials, Hemisphere Publishing Corporation, 1979.

2. Grove, Jim, Early Strengths of Class F, C and B Portland Cement Concrete, Office of Materials, Iowa Department of Transportation, November 1987.

APPENDIX

Sieve Size	Coarse Agg.	% Passing Fine Agg.	Comb. Agg.
1"	100		100
3/4"	96		98
1/2"	68		84
3/8"	33	100	66
#4	3.4	99	51
#8	1.2	93	47
#16		79	40
#30		44	23
#50		8.5	4.8
#100		1.0	1.1
#200	1.2	0.2	0.7