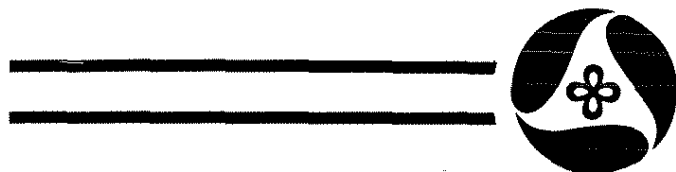


Determination Of Tension Crack Development In Plastic P.C. Concrete With Retarding Admixtures

**Final Report
for
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September 1987

Highway Division



**Iowa Department
of Transportation**

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DETERMINATION OF TENSION CRACK DEVELOPMENT
IN PLASTIC P.C. CONCRETE WITH RETARDING ADMIXTURES

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INTRODUCTION

Bridge deck cracking occasionally occurs during construction for any number of reasons. Improper design, concrete placement or deck curing can result in cracks. One contributing factor toward cracking may be dead load deflections induced during concrete placement. For both continuous and non-continuous bridges, specific placement sequences are required to minimize harmful deflections in previously placed sections. Set retarding admixtures are also used to keep previously placed concrete plastic until the pour is completed. The problem is--at what point does movement of the concrete cause permanent damage to the deck.

OBJECTIVE

The study evaluated the time to crack formation relationship for mixes with low and high dosages of set retarding admixtures currently approved for use in Iowa state and county projects.

TEST PROCEDURE

Twenty-one concrete mixes using Iowa DOT D57-6 p.c. concrete proportions were made. Testing consisted of deflecting 33-inch long concrete beams 0.025 inches at various times prior to final set and performing time of set of concrete by penetration resistance.

Apparatus

The equipment used for testing the concrete mixes is shown in Figure 1. Two 6"x6"x33" aluminum beam molds were modified using a 1/2" exterior plywood bottom to replace the aluminum bottom and a

jacking plate. The two deflection gauges are graduated in 0.001 inches. Two bolts were used to evenly apply and remove the deflection.

The appropriate deflection to apply to the 33-inch beam was arrived at from information provided by the Office of Bridge Design. A 0.025-inch deflection was used in the testing.

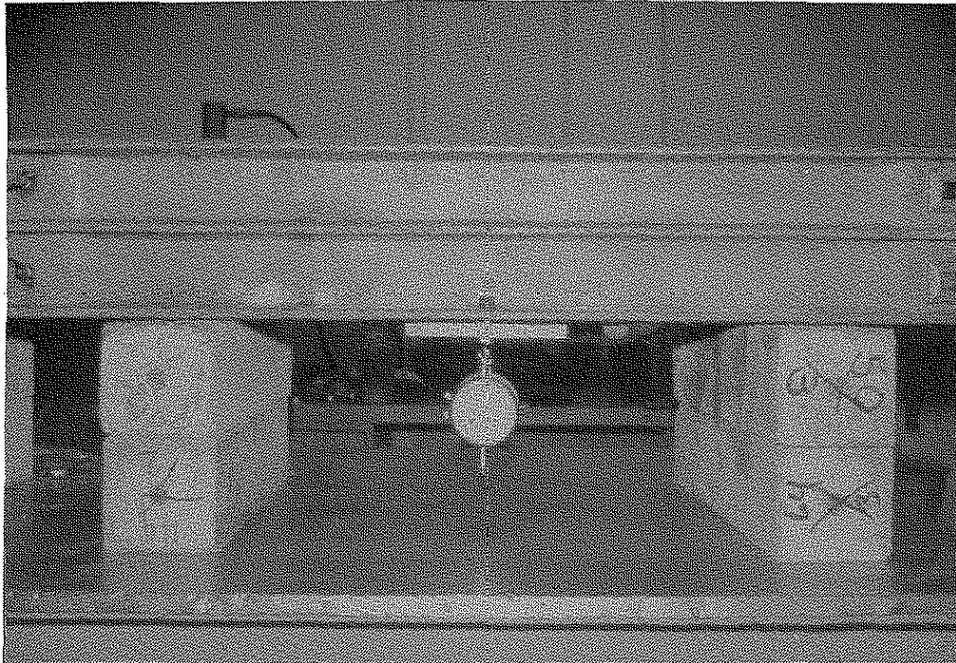


Figure 1 - Test Mold Apparatus

Materials

The following materials were used:

Cement - Lab Blend	
Coarse Aggregate - Martin Marietta, Ft. Dodge	
Fine Aggregate - Sand, Cordova, IL	
Air Entraining Admix. - AD-Aire, Single Strength	
Set Retarding Admix. -	
Plastiment 100	Sika Chemical Corp.
Pozzolith 100XR	Master Builders Co.
PDA 25R	Protex Industries, Inc.
Daratard 17	W. R. Grace & Co.
Lubricon R	American Admixtures
Protard	Protex Industries, Inc.
PSI-R Plus	Gifford Hill & Co.
Lubricon HSR	American Admixtures
Eucon 75R	Euclid Chemical Co.
Catexol 1000R	Solay Constr. Materials, Inc.

The concrete mix is as follows:

Cement -	709 pounds
Water -	261 pounds
Fine Aggregate -	1426 pounds
Coarse Aggregate -	1422 pounds
Air -	6.5%
Slump -	1 to 3 inches
Gradation - 50% fine/50% coarse -	See Appendix A
Mix Temperature	77°F
Air Temperature	73°F

Testing

Mix with the proper dosage of retarding admixture was placed into the two beam molds and into a one gallon container. Setting time was measured by AASHTO Standard Method T197, "Time of Setting of Concrete Mixtures by Penetration Resistance". Penetration resistance is obtained by forcing a needle into concrete that has been sieved over the number 4 sieve. The reading is in pounds per

square inch (psi). A reading of 500 psi indicates initial set and a reading of 4000 psi indicates final set.

Initial penetration resistance testing showed that below 150 psi the concrete was in a fluid condition. Flexing of the beams was begun at about 150 psi for the first couple mixes. Based on early experience, the subsequent testing was done by applying the deflection to one beam at about a reading of 200 psi. If no crack appeared, the deflection was removed. At either about 250 psi or 1/2 hour after the first test, the second beam was flexed. If no crack appeared, testing was performed at each 50 psi increase in penetration or about every 1/2 hour alternating beams until a visible crack formed. The remaining beam was then flexed to confirm the results. Test data is in Appendix B. A summary is in Table 1.

DISCUSSION OF RESULTS

The first sign of cracking occurred from 200 to 300 psi on the concrete setting time determination for over 75 percent of the test mixes. Over 50 percent of the test mixes cracked at a resistance of 250 psi or less. The crack, when it formed, was readily visible as the deflection was applied. A 1976 Iowa DOT study of retarding admixtures concluded that hairline cracking would occur during the penetration resistance test near 250 psi. (1) The 1976 study recommended that a "time to workable limit" be set at 235 psi.

In a similar study, Fouad and Furr examined behavior of portland cement mortar in flexure at early ages. (2) Figure 2 is the result

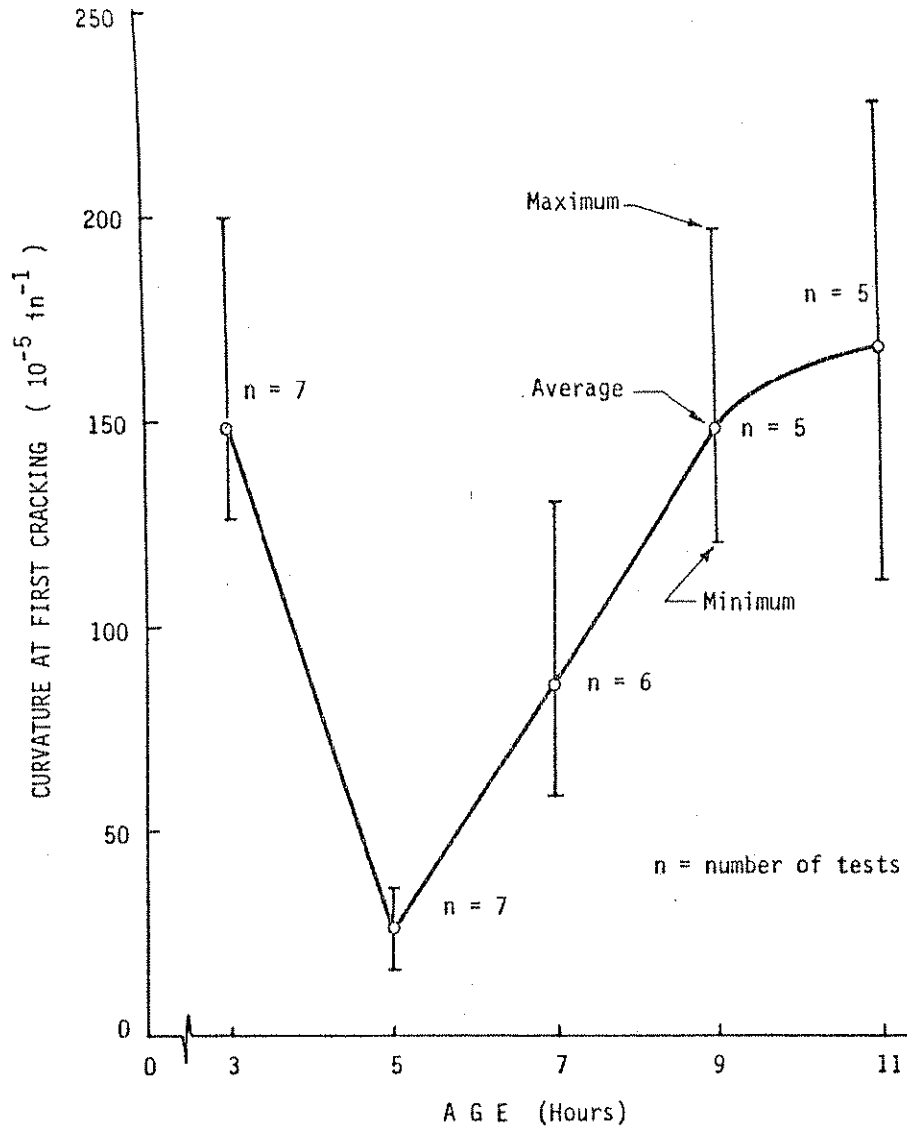


Fig. 2 --Relation between curvature at first cracking and age for mortar beams as reported by Fouad and Furr (2)

of that testing. Initial set was between 3 and 5 hours and final set was about 9 hours. Testing was with a cement sand mortar rather than a concrete mix. However, the age-curvature trend substantiates Iowa's study goals and findings on early age cracking. Fouad and Furr show that the most critical time for early age concrete with respect to cracking is from just prior to initial set up to final set.

CONCLUSIONS

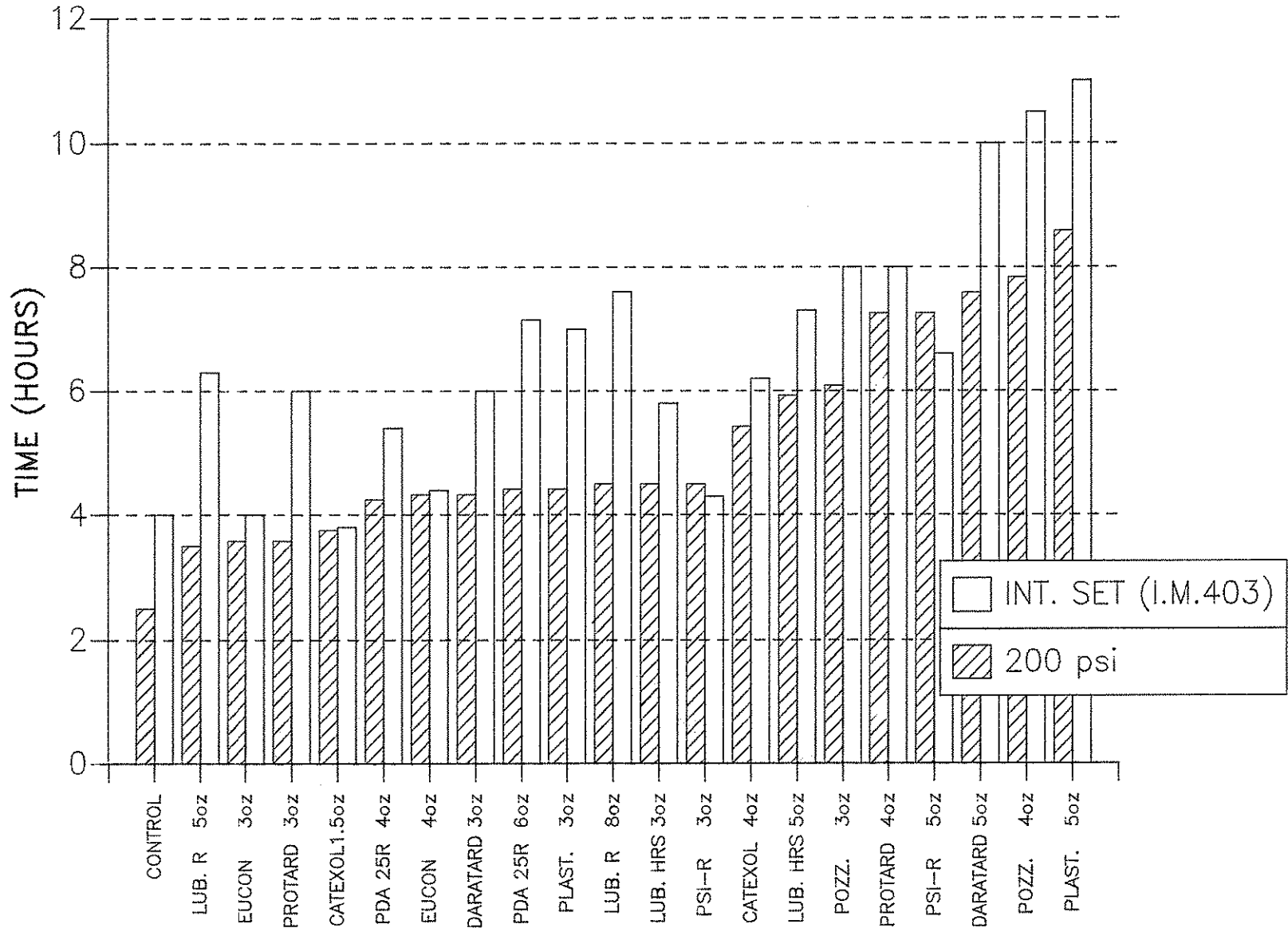
The conclusion of the study is that movement in plastic concrete before initial set can cause cracks in concrete. A deflection (as could be encountered during bridge construction) will cause cracking in concrete generally at a concrete setting penetration of between 200 and 300 psi (500 psi is initial set of concrete).

RECOMMENDATIONS

Based on the study the following changes are recommended for bridge construction:

1. Iowa DOT Office of Materials Instructional Memorandum 403, "Inspection and Acceptance of Air Entraining, Retarding, and Water Reducing Admixtures for PC Concrete" should be revised to include a working limit. That limit should be set at 200 psi as measured by AASHTO T197. Figure 3 shows the time to 200 psi penetration resistance for each retarder and the time to initial set listed in I.M. 403 for each retarder.

FIGURE 3 TIME OF SET DETERMINATION



2. Iowa DOT Office of Construction Manual Section 11.52, "Sequence of Pouring Bridge Floor Section and Use of Retarders" should be revised to use working limit rather than initial set time when computing placement time. The one hour safety factor should be retained.

REFERENCES

1. Schmit, Charles, and Less, Ronald D., An Investigation of Concrete Settling Time, Iowa Department of Transportation - Office of Materials, May 1975.
2. Young, J. Francis, Properties of Concrete at Early Ages, American Concrete Institute, 1986, pages 93-113.

APPENDIX A
Aggregate Gradations

Project Gradation
Percent Passing

Sieve	Coarse Aggregate	Fine Aggregate	Combined
1"	100		100
3/4"	77		88
1/2"	40		70
3/8"	12	100	56
#4	0.5	99	50
#8	0.3	92	46
#16		79	40
#30		44	22
#50		7.4	3.8
#100		1.2	0.8
#200	0.3	0.4	0.4

APPENDIX B

Test Data

Appendix B - Penetration Resistance Measurements Prior to Crack Formation

ADMIX.	C O N T R O L	L U B	E U C O N	P R O T A R D	C A T E X O L	P D A 2 S R	E U C O N	O A R A T A R D	P D A 2 S R	P L A S T	L U B	L U B H R S	P S I R	C A T E X O L	L U B H R S	P O Z Z	P R O T A R D	P S I R	O A R A T A R D	P O Z Z	P L A S T
DOSEAGE		5	3	3	1.5	4	4	3	6	3	8	3	3	4	5	3	4	5	5	4	5
TIME	1																				
	1.08																				
	1.17																				
	1.25								12												
	1.33																				
	1.42	20																			
	1.5																				
	1.58																				
	1.67																				
	1.75												16								
	1.83																				
	1.92									20											
	2									20											
	2.08	60																			
	2.17		28																		
	2.25			44																42	
	2.33	110																			
	2.42																				
	2.5	180																			
	2.58	220								64		24									
	2.67		40																		
	2.75			44		24															
	2.83						24														
	2.92				44																
	3																				
	3.08									110		40	16								24
	3.17								42												
	3.25				72																
	3.33			126																	
	3.42																				36
	3.5	200				60	80					56		24							
	3.58	240	208																		
	3.67				160																
	3.75												44								
	3.83				240	120															
	3.92																				40
	4					160					104										
	4.08																				
	4.17						180														
	4.25			360		200				160	160					20					
	4.33								200												
	4.42																				
	4.5					400	232			240	220	200	200	200	60	100			60		
	4.58																				
	4.67							250													
	4.75							300								64					48
	4.83										260										
	4.92											290									
	5													104	120						
	5.08																				
	5.17																				
	5.25														80						
	5.33														120						56
	5.42														100						
	5.5															30					
	5.58													220							60
	5.67														120						
	5.75																				
	5.83														176	50	68				

ADMIX.	C O N T R O L	L U B R	E U C O N	P R O T A R D	C A T E X O L	F D A 2 5 R	E U C O N	D A R R A T A R D	P O A 2 S R	P L A S T	L U B R	L U B H R S	P S I R	C A T E X O L	L U B H R S	P O Z Z	P R O T A R D	P S I R	D A R R A T A R D	P O Z Z	P L A S T
DOSAGE		5	3	3	1.5	4	4	3	6	3	8	3	3	4	5	3	4	5	5	4	5
	5.92																				
	6.08																				
	6.17															180				72	
	6.25															220				100	
	6.33													260							90
	6.42																				
	6.5																				
	6.58																				
	6.67																				
	6.75																				
	6.83																				
	6.92																				
	7																				
	7.08																				
	7.17																				
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