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

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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.

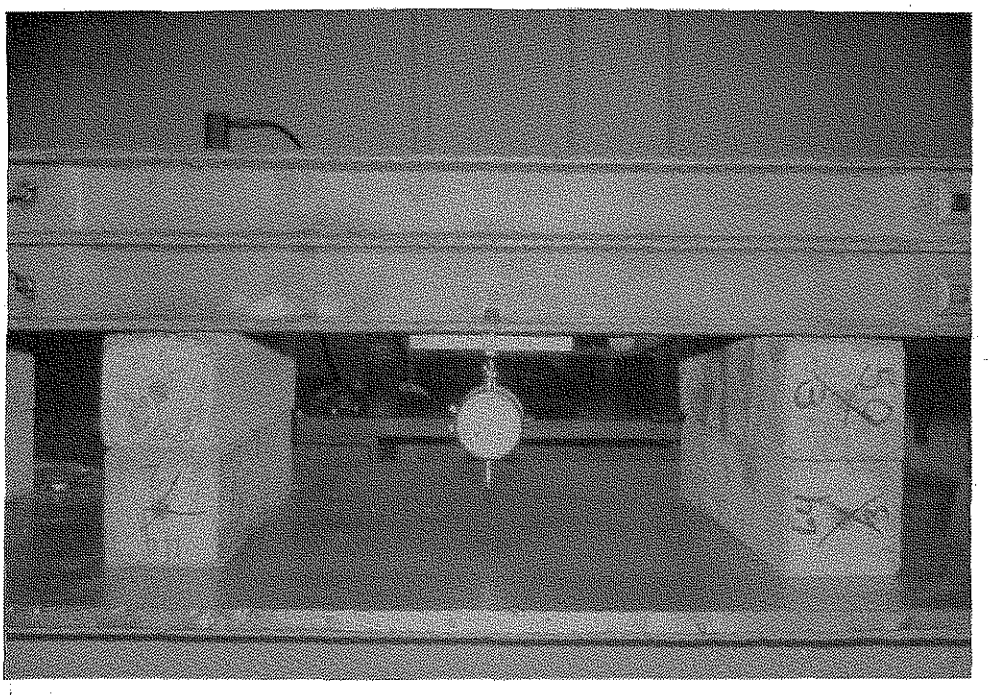

Figure 1 - Test Mold Apparatus

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

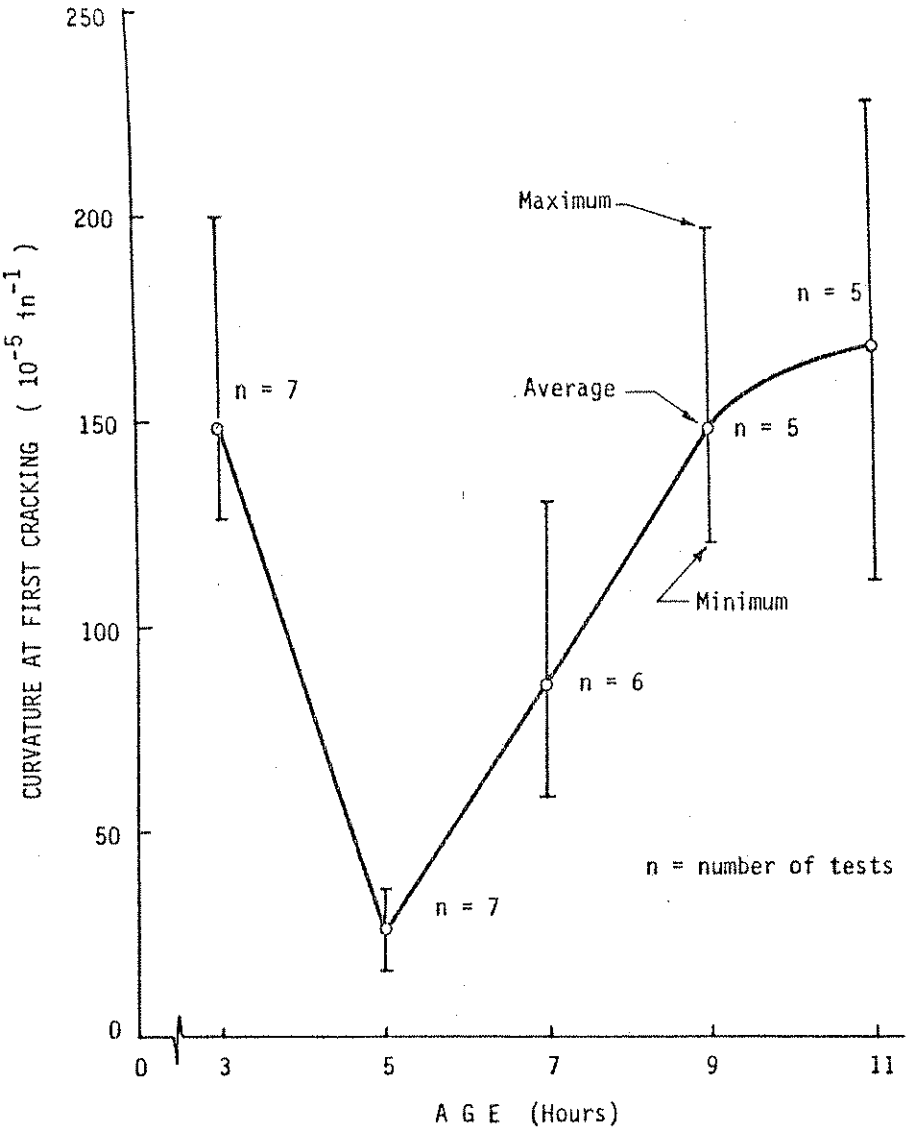

Fig. 2 --Relation between curvature at first cracking and age for mortar beams as reported by Fouad and Furr (2)

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.

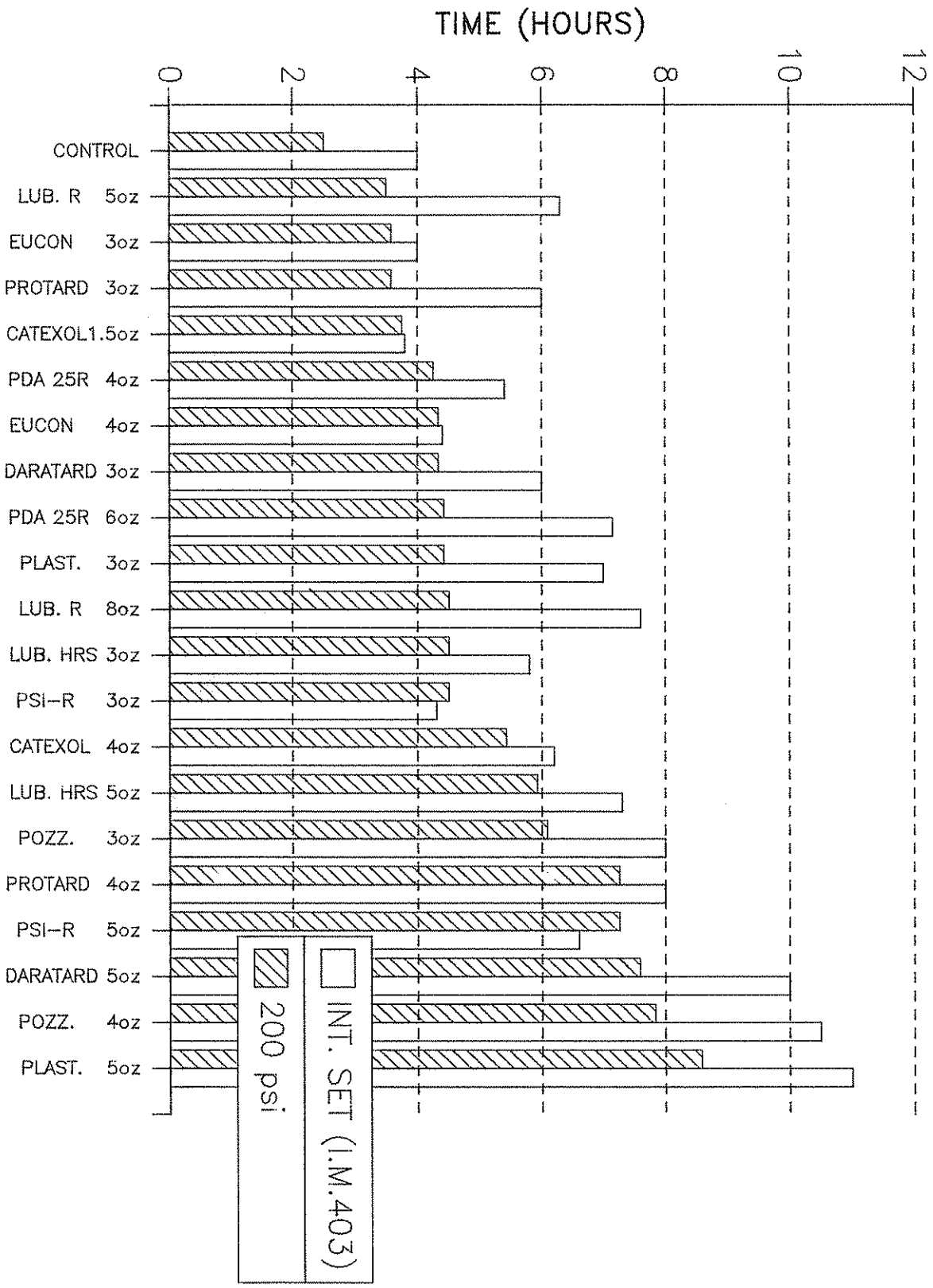

FIGURE 3 TIME OF SET DETERMINATION

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.	CONTROL	LUBR	ECON	PROTARD	CATEXOL	PDA 2SR	ECON	DARATARD	PDA 2SR	PLAST	LUBR	LUBHRS	PSIR	CATEXOL	LUBHRS	POZZ	PROTARD	PSIR	DARATARD	POZZ	PLAST
DOSAGE		5	3	3	1.5	4	4	3	6	3	8	3	3	4	5	3	4	5	5	4	5
TIME FROM MIXING	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										24									
	2.58	220							64												
	2.67		40																		
	2.75			44		24															
	2.83						24														
	2.92				44																
	3								110			40	16								24
	3.08							42													
	3.17																				
	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									180				60					80		
	4.5						400	232	240	220	200	200	200		100						
	4.58							250													
	4.67							300								64					48
	4.75										260										
	4.83																				
	4.92											290			120						
	5													104							
	5.08																				
	5.17															80					
	5.25														120						56
	5.33															100					
	5.42																30				
	5.5													220							60
	5.58															120					
	5.67																				
	5.75																				
	5.83														176		50	68			

ADMIX.		CONTROL	LUBR	EUCON	PROTARD	CATEXOL	PDA 25R	EUCON	DARATARD	PDA 25R	PLAST	LUBR	LUB HRS	PSIR	CATEXOL	LUB HRS	POZZ	PROTARD	PSIR	DARATARD	POZZ	PLAST
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																				72	
	6.08																180			100		
	6.17																220					
	6.25															260					90	
	6.33																					
	6.42																			140		20
	6.5															280	240		100			
	6.58																				100	
	6.67																	120				
	6.75																					
	6.83																					
	6.92																	160				
	7																		150		130	
	7.08																			140		
	7.17															300		180				
	7.25																	200	200		140	
	7.33																	250				
	7.42																					
	7.5															540			240			
	7.58																			200		
	7.67																		240			
	7.75																					
	7.83																		280	200	200	
T	7.92																				260	
I	8																					60
M	8.08																			200		
E	8.17																				200	
	8.25																					
F	8.33																			200		
R	8.42																					
O	8.5																					
M	8.58																			260		
	8.67																				200	
M	8.75																					
I	8.83																			320		
X	8.92																					
I	9																				280	
N	9.08																			360		
G	9.17																					
	9.25																					
	9.33																					
	9.42																					
	9.5																			360		
	9.58																					
	9.67																					
	9.75																					
	9.83																			400		
	9.92																					
	10																					560
	10.08																			520		
	10.17																					