Paper No. 880193

PREPRINT

BLANKET CURING TO PROMOTE EARLY STRENGTH CONCRETE

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Iowa Department of Transportation
Research Project MLR-87-7

For Presentation at the
Transportation Research Board
68th Annual Meeting
January 22-26, 1989
Washington, D.C.

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Blanket Curing to Promote Early Strength Concrete

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ABSTRACT

Fast Track concrete has proven to be successful in obtaining high early strengths. This benefit does not come without cost. Type III cement and insulating blankets to accelerate the cure add to its expense when compared to conventional paving. This research was intended to determine the benefit derived from the use of insulating blankets to accelerate strength gain in three concrete mixes using Type I cement. The goal was to determine mixes and curing procedures which would result in a range of opening times. This would allow the most economical design for a particular project by tailoring it to a specific time restraint.

Three mixes of different cement content were tested in the field. Flexural beams were cast for each mix and tested at various ages. Two test sections were placed for each mix, one section being cured with the addition of insulation blankets and the other being cured with only conventional curing compound.

Iowa Department of Transportation specifications require 500 psi flexural strength before a pavement can be opened to traffic. Concrete with Fast Track proportions and Type I cement and insulation blankets reached that strength in approximately 36 hours, a standard mix (nominal 6 1/2 bag) using the blankets in approximately 48 hours, and the Fast Track proportions with Type I cement without blankets in about 60 hours.

The results showed a significant improvement in early strength gain by the use of insulation blankets.

INTRODUCTION

In 1986, 1987 and 1988 several Portland Cement Concrete (P.C.C.) paving projects were constructed using the Fast Track mix and procedures developed in Iowa. Figure 1 represents a compilation of test data obtained from six Fast Track projects constructed in Iowa during these years. Many dissimilarities existed among them: thickness of pavement, temperature during construction, brands of cement, type of mixing, and type of transport vehicles. Yet these data produce a very distinct locus of points in the first 24 hours. All achieved 400 psi flexural strength in twelve hours or less. These and other projects have established that Fast Track can produce the high early strengths for which it was designed.

Two aspects of Fast Track which normally are not seen in conventional paving include the use of a special Type III cement and the placement of insulating blankets over the finished pavement. (Note: Special Type III cement is a modification of AASHTO M85 to include a compression strength of hydraulic mortar, using two inch cube specimens, of at least 1300 psi at 12 hours, when tested in accord with ASTM C109.) The Type III cement is used to accelerate the hydration process and the blankets are used to trap the heat from that process. The Type III cement is not a widely used product. Most ready mix plants do not keep this in inventory and many do not have the storage facilities to accommodate more than one cement. The insulation blankets are a costly item in terms of initial cost and the labor-intensive procedure for installation. Both add to the expense of the fast track procedure. If either or both could be eliminated while still achieving an acceptable time of opening, significant savings could be realized.

Not all projects need to obtain opening strengths in less than twenty-four hours. Yet, some roadways may need to be open to traffic in less than The five to fourteen days that are required for conventional paving. This research was intended to determine the strength gain over time for various mixes, each being cured with and without insulation blankets. The goal was to determine what effect the type of mix and insulation had on early strength gain. This information will be helpful in determining the most economical design for a project with a given time table for opening the facility to traffic.

OBJECTIVES

The objective of this research was to establish a range of alternative designs, in terms of various mixes and curing methods, using Type I cement and either conventional curing or enhanced conventional curing through the addition of insulating blankets, which provide opening strengths at various times, sooner than conventional paving but not as quickly as Fast Track.

SCOPE

The research examined two standard Iowa Department of Transportation concrete mix classes and a modified fast track class. Each mix was placed and then divided into two sections. Conventional curing and insulating blankets were used to cover one section and conventional curing only was used on the other. This resulted in six test sections. Test beams were cast from each section and tested at particular ages. Temperatures in the pavement and test beams were monitored. Conventional cure would consist of a single application of white pigmented curing compound at a rate of 0.067 gallons per square yard. The insulating blankets consisted of a layer of closed cell polystyrene foam, protected by plastic film, with an R-value rating of at least 0.5. The three mixes used in this research are shown in Table 1. The Fast Track mix (the F mix) was modified by the use of Type I cement instead of Type III cement.

The sand and gravel source was Hallett's at the Jenkins-Sturtz pit. Ash Grove cement was used. Class C fly ash from Midwest Fly Ash, Sioux City, Iowa, was used. Air entraining agent was W.R. Grace, Darvar R. No water reducer was used.

CONSTRUCTION

The research project was located in Boone County, just east of Boone, Iowa. The test sections were on E41 (Old Highway 30), a short distance west of the east line of Section 26, Township 84N, Range 26W. This section of roadway was being reconstructed with a new 24' pavement, 9" thick, utilizing a Class B P.C.C. pavement mix. The portion of the construction project where this research took place was 1.36 miles long.

The sections were constructed on September 25, 1987, on a clear day with the temperature in the mid 70's and a slight breeze. The first section was placed at approximately 2:20 p.m. with the last section being finished at 3:25 p.m. The locations and tests of the concrete are listed in Table 2.

Eight beams were cast for each of the six test section. After the curing cart had passed the test sections, these beams were placed adjacent to the edge of the slab. All sections and beams were sprayed with curing compound at the normal specified rate. The insulating blankets were then spread over both the slab and beams on those sections being cured in that manner. The blankets were placed at approximately 5:00 p.m. and remained over the pavement for approximately 24 hours.

TESTING

Strength

Two beams were tested from each section at each of the following times: 18 hours, 24 hours, 3 days and 7 days. The results of the tests of the 48 flexural beams are listed in Table 3. These data are shown in Figure 2 as modulus of rupture versus time.

The F mix showed a 42 percent increase in strength with the blankets at 18 hours and a 27 percent increase at 24 hours when compared to the section cured without blankets. The C mix gave a 13 percent increase at 18 hours and a 27 percent increase at 24 hours. The B mix had a 31 percent increase at 18 hours but no difference at 24 hours.

Four inch cores were taken from the pavement test sections and tested at 28 days. The test results are shown in Table 4.

Temperature

Table 5 shows the temperatures that were recorded during the research. Measurements were taken in a test beam and also in the pavement for each of the test sections. Figures 3 and 4 are plots of these data with the former showing the temperatures in the pavement and the latter representing the temperatures in the test beams.

The heat retained by the blankets resulted in an increase in temperature, when compared to the conventionally cured sections, (at the time of the coolest air temperature) of 21^{o}F, 13^{o}F, and 9^{o}F for the Class F, C, and B mixes respectively.

DISCUSSION

Strength

With both the Class F and Class C mixes, a significant gain in additional strength during the first twenty-four hours resulted from the use of the insulating blankets. Overall the F mix had the largest gain in strength with the use of blankets and the additional gain was evident over the longest period of time. The tests show that some gain in extra strength occurred when the blankets were used with the Class B mix, but only in the initial curing period. By twenty-four hours, both Class B mix sections exhibited the same strength. The extra strength gained before that time may not be of great importance since the actual flexural strength at that time was still very low.

The Iowa Department of Transportation Standard Specifications, Section 2301.36, require a strength of 500 psi before a pavement can be opened to traffic, in addition to a minimum age. Based on this strength, three sections exhibited early strength gain sufficient to provide three distinct opening times. The covered F mix reached 500 psi in approximately 36 hours, the covered C mix in about 48 hours, and the noncovered F mix in about 60 hours. As a comparison, the Fast Track mix normally reached that strength in 18 hours.

The results of the 28 day compressive strength tests performed on core samples were rather inconclusive. The intent of including these tests was to provide information on pavement strength at a more mature age. A significant variation in strength occurred between each of the test beams for each F mix section. The B mix exhibited little strength gain or temperature change by the use of the blankets. Nevertheless, a significantly higher strength was exhibited by the B mix with the use of the blankets. A loss in ultimate strength may be expected with a gain in early strength but the significant loss of strength at 28 day exhibited by the C mix seemed rather high.

Temperature

When the temperature plot is compared with the figure showing the strengths, it appears that the uniformity in temperature contributes to the higher gain in strength. Even if the maximum temperature is not as high, the consistent temperature has a significantly favorable effect.

The insulating blankets affected the pavement temperatures by reducing the effect of both the ambient air temperature and the solar heat. In all three classes of concrete, the pavement sections with the insulation blankets gained some temperature during the cool night. On the other hand, the uncovered B and C mix sections dipped in temperature as the air cooled. The F mix section, without blankets, exhibited a small temperature gain during the night. Even with the gain, it was much less than the F mix section that received the insulating blankets.

All the beams gained in temperature initially, during the sunny afternoon. But, the uncovered beams closely paralleled the air temperature during the night. The next day those uncovered beams achieved higher temperatures than the covered beams. The warm ambient temperature and the heat from the sun actually warmed the beams more than the benefit derived from the blankets. It may also be true that the covered beams achieved more hydration earlier and over a longer period of time so that a much smaller portion of the process was left to take place during the heat of the following afternoon.

A comparison of the pavement temperatures and the beam temperatures reveals a rather unsettling situation. The beam temperatures were roughly 20 degrees cooler than the pavement temperatures at 14 hours. The beams generally followed the air temperature; whereas the pavement temperatures were somewhat constant. This raises the question as to how well the strengths obtained from testing the beams actually represent the strengths existing in the pavement. Fortunately, the error will likely be such that the pavement is actually stronger than what the beam tests would indicate.

SUMMARY

Insulating blankets promote a greater increase in early strength for higher cement content concrete mixes.

Insulating blankets reduce temperature loss during the first night after placement and thereby prevented interruption of the hydration process.

There was no significant strength benefit with the use of insulating blankets for a 444 lb. cement/79 lb. fly ash mix.

Insulating blankets may inhibit temperature gain on a warm, sunny day by shielding the solar heat.

An F-mix (7 1/2 bag mix with Type I cement) can be expected to reach opening strength (500 psi) when cured with insulating blankets in 36 hours.

A C mix (6 1/2 bag mix) can be expected to reach opening strength when cured with insulation blankets in 48 hours.

An F-mix can be expected to reach opening strength with conventional curing in 60 hours.

ACKNOWLEDGEMENTS

The author wishes to gratefully acknowledge the assistance and cooperation of Dave Anthony, Boone County Engineer and Jim Mikulanec, President, Central Paving Corporation, in the construction of this research and Kevin Jones, Cement and Concrete Engineer, Iowa Department of Transportation, in the preparing of the test specimens, the performance of the testing and in the report preparation.

Table Titles

Table 1

Mix Proportions, lbs/cy

Mix No.	Cement-Type I	Fly Ash	Fine Aggregate	Coarse Aggregate	Water	W/C
F-4	710	0	1403	1434	218	0.307
C-4	624	0	1483	1516	195	0.312
B-6-C	444	74	1820	1228	253	0.488

Table 2

Test Section Locations and Concrete Test Results

	Location Station	Station	Slump in.	Air %
Class F with blankets	1076+60	1077+00	2	7.2
Class F without blankets	1077+00	1077+40	2 1/4	7.5
Class C with blankets	1075+95	1076+30	1 3/4	7.8
Class C without blankets	1076+30	1076+60	2 1/4	7.8
Class B with blankets	1078+90	1078+20	1 1/2	6.5
Class B without blankets	1078+20	1078+50	3/4	6.0

Table 3

Flexural Test Results
Modulus of Rupture, psi*
(center point loading)

Section	18-hr	24-hr	3-day	7-day
Class F w/Insulation	418	462	619	744
Class F Std. Cure	294	363	550	677
Class C w/Insulation	318	406	606	712
Class C Std. Cure	282	319	538	669
Class B w/Insulation	200	282	506	650
Class B Std. Cure	153	282	506	638

Note: Insulation removed after 24 hours of cure

*Average of two tests

Table 4

Compressive Strengths Test Results, psi

	28-day Compressive Strength	
	Tests	Average
Class F w/Insulation	4945; 3820	4385
Class F Std. Cure	5065; 3945	4505
Class C w/Insulation	3500; 3630	3565
Class C Std. Cure	4610; 4295	4455
Class B w/Insulation	3450; 3545	3500
Class B Std. Cure	3130; 2960	3045

Table 5

Pavement and Beam Temperatures, ^{o}F

Section		Mix	1.5-2 hr*	7-hr	17-hr	24-hr**	3-day**
Class F	Pavement	77	80	97	105	103	74
w/Insulation	Beam	83	92	83	87	77	
Class F	Pavement	77	79	83	84	97	75
Std. Cure	Beam	81	71	59	95	73	
Class C	Pavement	77	83	92	93	94	74
w/Insulation	Beam	85	75	74	81	68	
Class C	Pavement	75	79	78	80	95	73
Std. Cure	Beam	88	71	62	93	72	
Class B	Pavement	78	76	83	84	90	71
w/Insulation	Beam	82	82	75	80	73	
Class B	Pavement	76	76	79	75	91	71
Std. Cure	Beam	77	69	59	91	74	
Ambient Air		80	80	64	54	82	68

*Temperature taken when beams were moved next to slab and insulation was placed on the slab.
**Insulation removed after 1 day of cure

Figure Captions

1. Iowa Fast Track Concrete
2. Beam Strengths
3. Pavement Temperatures
4. Flexural Beam Temperatures

FIGURE 1
IOWA FAST TRACK CONCRETE

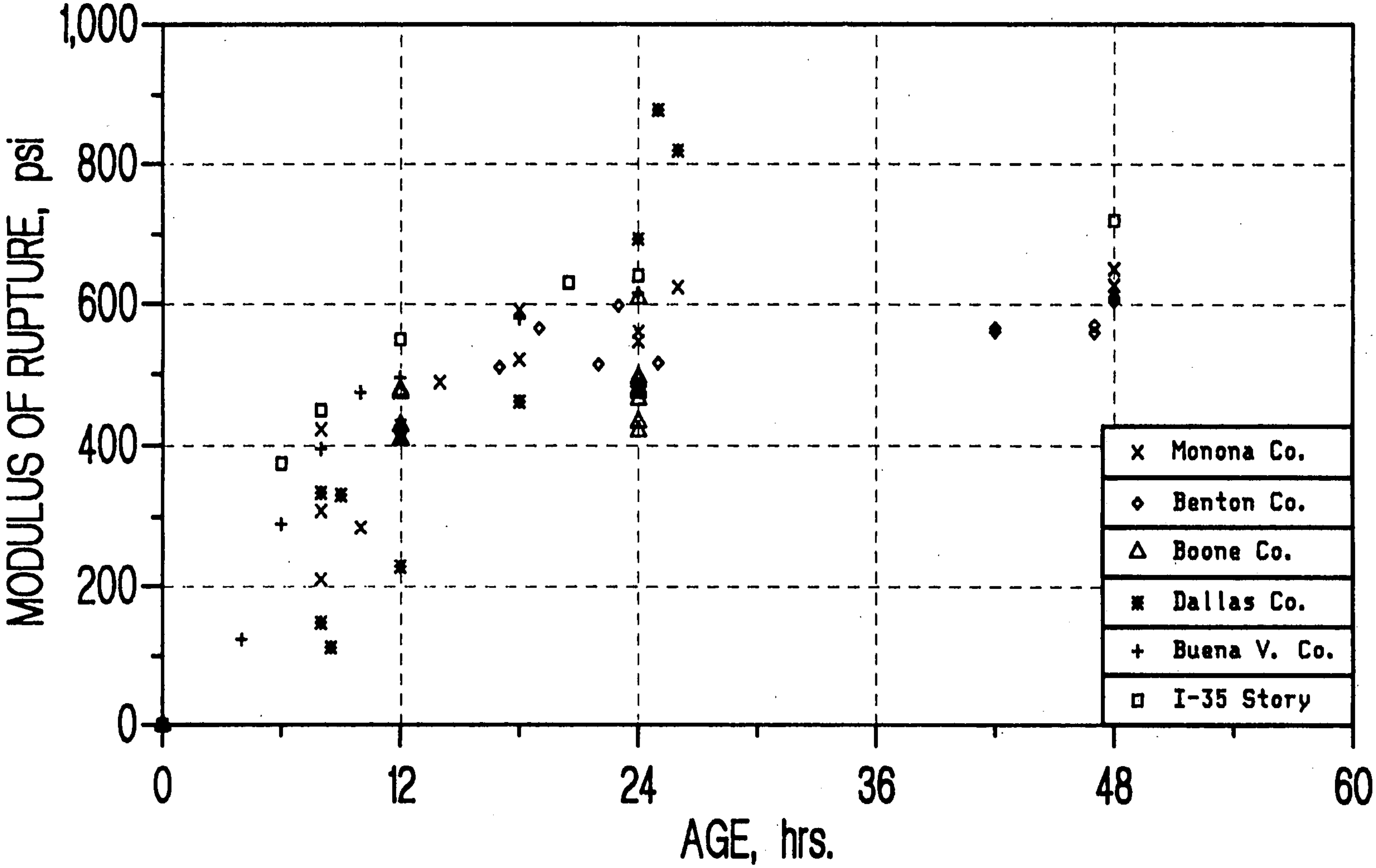

FIGURE 2
BEAM STRENGTHS

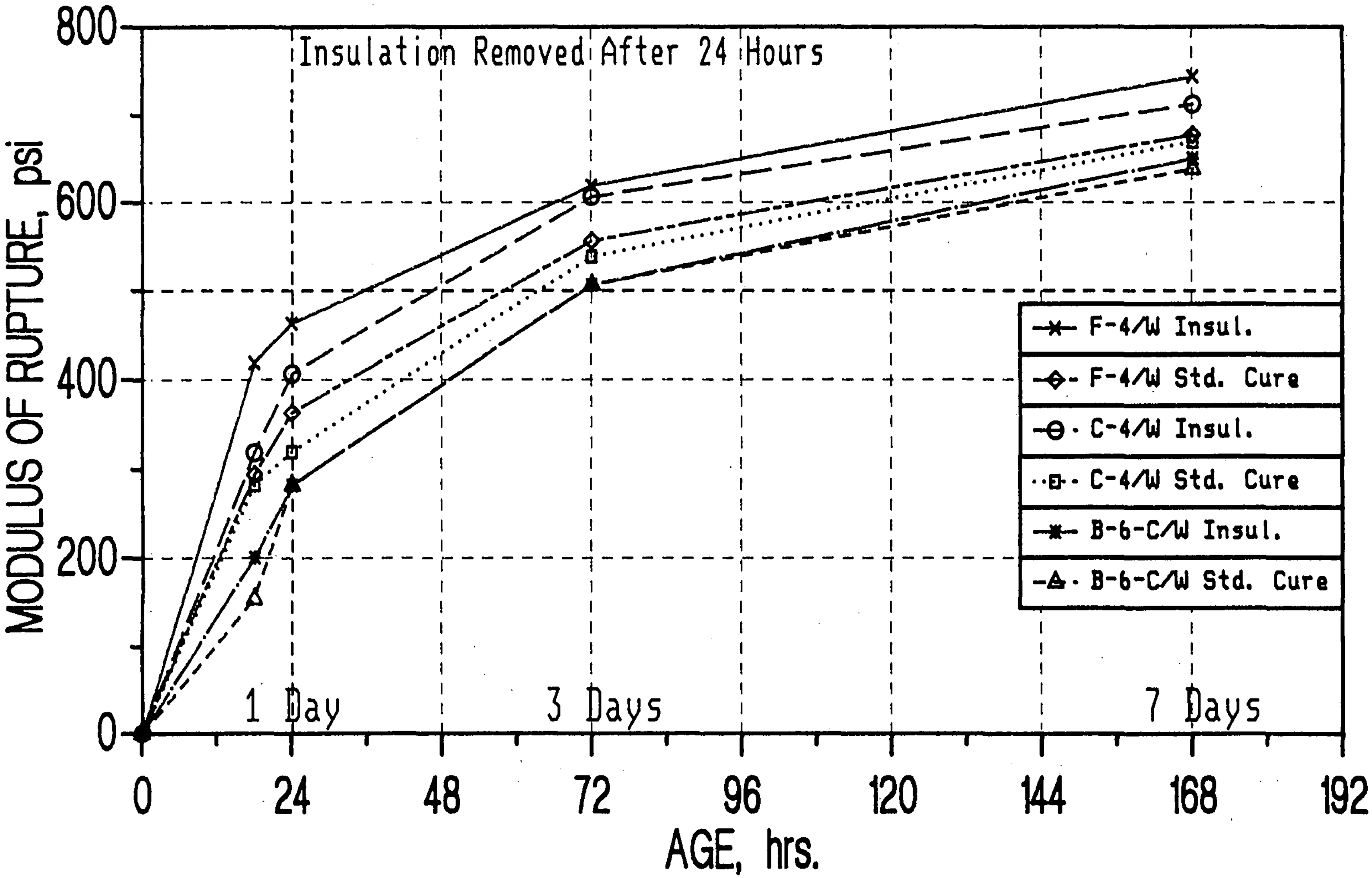

FIGURE 3
PAVEMENT TEMPERATURES

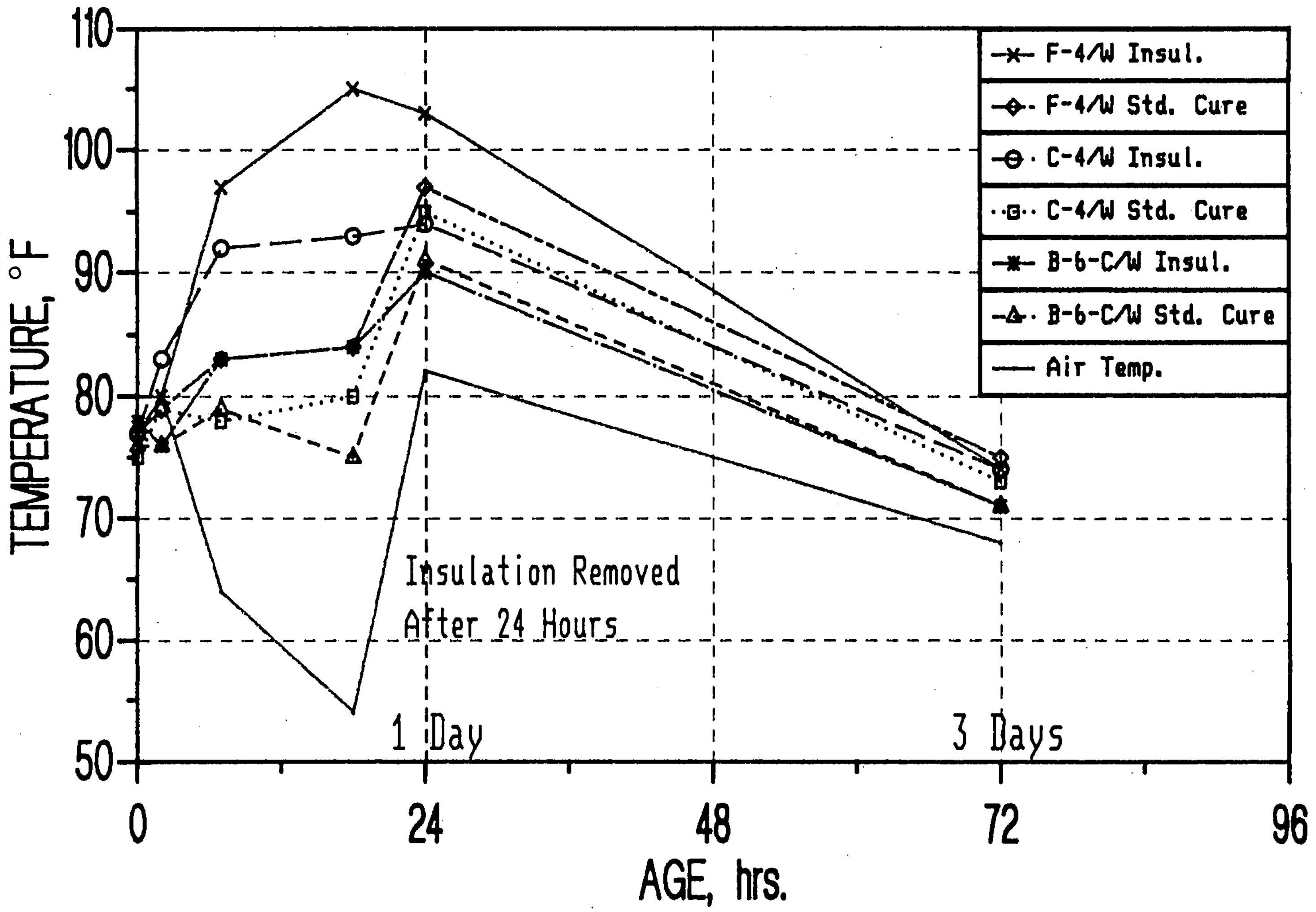

FIGURE 4
BEAM TEMPERATURES