Blanket Curing to Promote Early Strength Concrete

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Fast Track concrete has proven to be successful in obtaining high early strengths. This benefit does not come without cost. Special 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 that would result in a range of opening times. This determination would allow the most economical design for a particular project by tailoring it to a specific time restraint. Three mixes of various 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 insulating 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 (nominal 7 1/2 bag), Type I cement, and insulating blankets reached that strength in approximately 36 hr, a standard mix (nominal 6 1/2 bag) using the blankets in approximately 48 hr, and the Fast Track proportions with Type I cement without blankets in about 60 hr. The results showed a significant improvement in early strength gain with the use of insulating blankets.

In 1986, 1987, and 1988 several Portland cement concrete (PCC) 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. However, these data produce a distinct locus of points in the first 24 hr. All achieved 400 psi flexural strength in 12 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 that 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 2-in.-cube specimens, of at least 1,300 psi at 12 hr, when tested in accordance with ASTM C109. Further reference to Type III hereafter means Special Type III.) 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 cement in inventory and many do not have the storage facilities to accommodate more than one cement. The insulating 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.

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Not all projects need to obtain opening strengths in less than 24 hr. Some roadways, however, may need to be open to traffic in less than the 5 to 14 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 timetable 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, by 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 earlier than conventional paving but not as early 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 division 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 gal/yd^2. 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, north of Ames, Iowa. Ash Grove cement was used. Class *C* fly ash from Midwest Fly Ash, Sioux City, Iowa, was

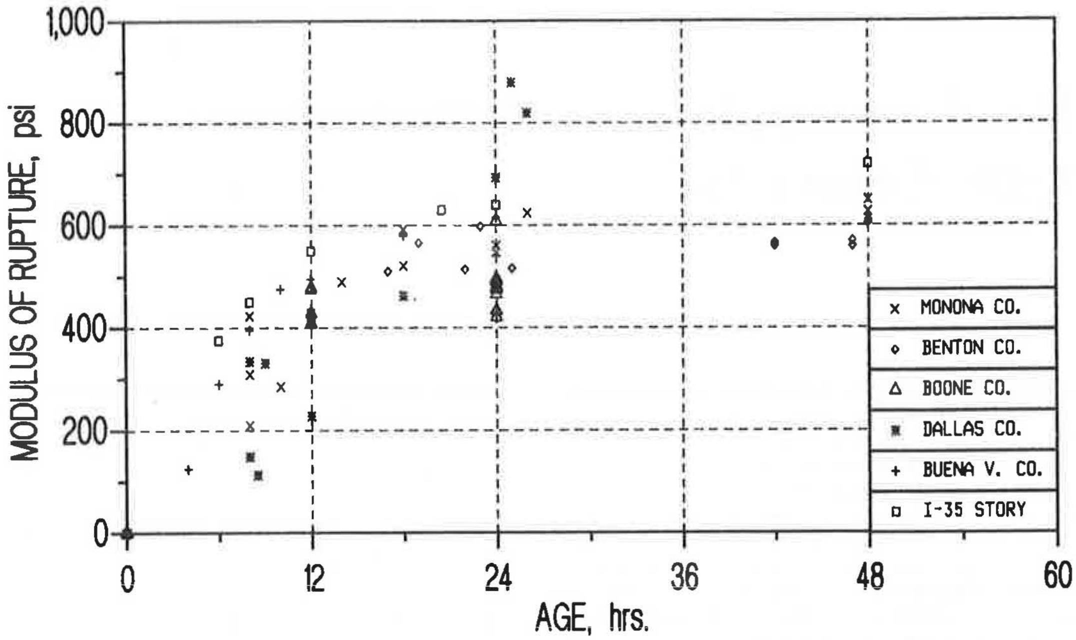

FIGURE 1 Iowa Fast Track concrete.

TABLE 1 MIX PROPORTIONS (LB/YD^3)

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

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-ft pavement, 9 in. thick, using a class *B* PCC pavement mix. The portion of the construction project where this research took place was 1.36 mi long.

The sections were constructed on September 25, 1987, on a clear day with the temperature in the mid-70s 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 sections. 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 hr.

TESTING

Strength

Two beams were tested from each section at each of the following times: 18 hr, 24 hr, 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 age.

TABLE 2 TEST SECTION LOCATIONS AND CONCRETE TEST RESULTS

	Location		Slump	Air
	Station	Station	in.	%
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 (LB/IN.^{2})[a]

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.

[a]Average of two tests; center point loading.

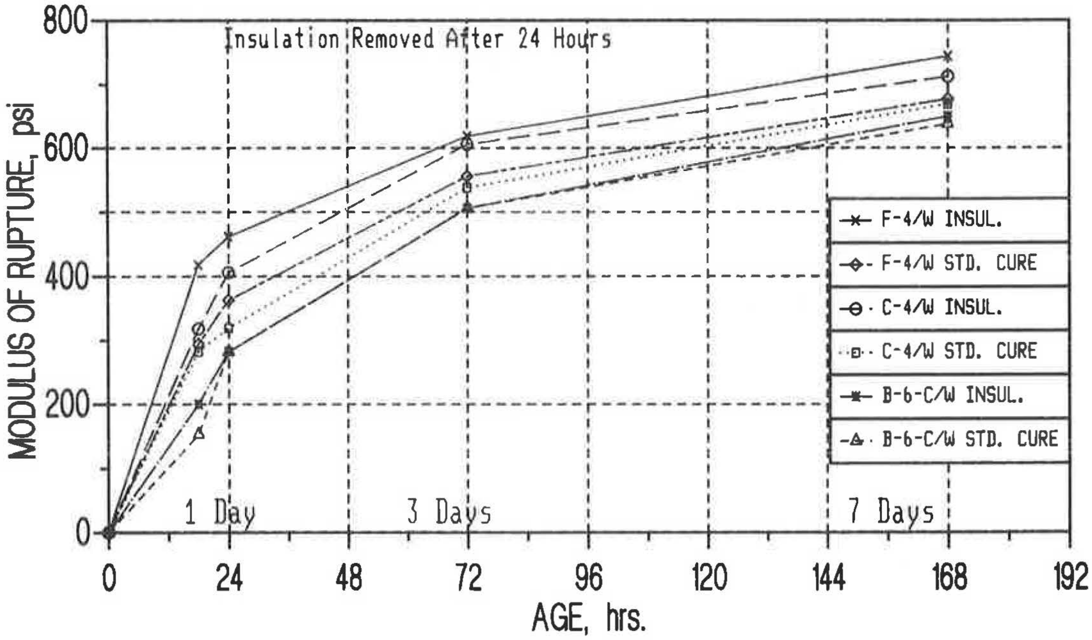

FIGURE 2 Beam strengths.

TABLE 4 COMPRESSIVE STRENGTHS TEST RESULTS (LB/IN.²)

	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

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

Cores of 4 in. 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, compared with the conventionally cured sections (at the time of the coolest air temperature) of 21°F, 13°F, and 9°F for the Class *F*, *C*, and *B* mixes, respectively.

DISCUSSION OF RESULTS

Strength

With both the Class *F* and Class *C* mixes, a significant gain in additional strength during the first 24 hr resulted from the

TABLE 5 PAVEMENT AND BEAM TEMPERATURES (°F)

Section		Mix	1.5-2 hr[a]	7-hr	`17-hr	24-hr[b]	3-day[b]
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

[a]Temperature taken when beams were moved next to slab and insulation was placed on the slab.

[b]Insulation removed after 1 day of cure

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 24 hr, 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 early opening times. The insulated *F* mix reached 500 psi in approximately 36 hr, the insulated *C* mix in about 48 hr, and the noninsulated *F* mix in about 60 hr. As a comparison, the Fast Track mix normally reached that strength in 18 hr.

The results of the 28-day compressive strength tests performed on core samples were 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 with 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 days exhibited by the *C* mix seemed 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

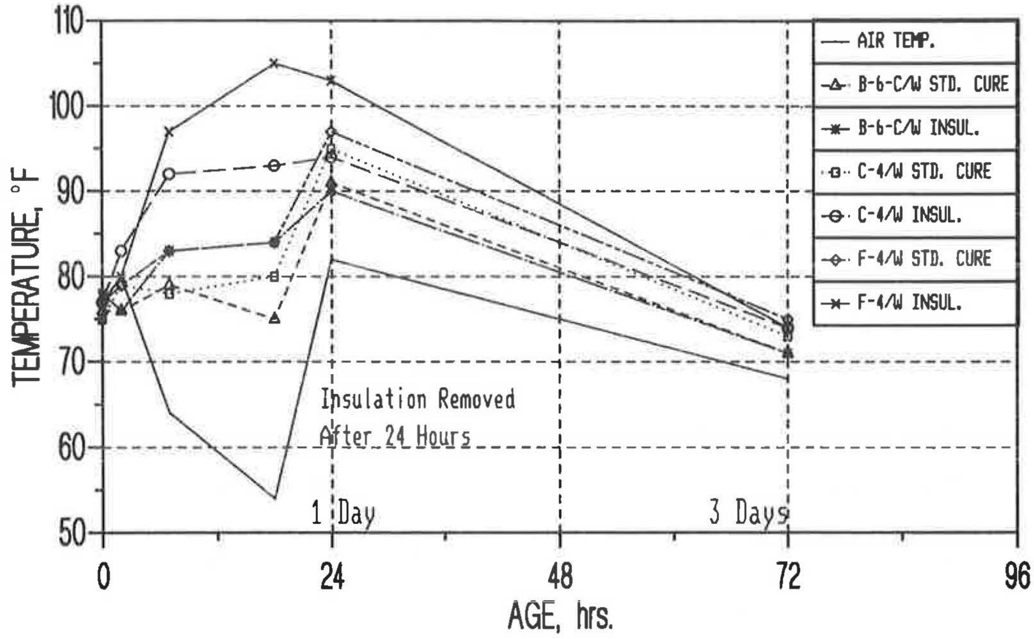

FIGURE 3 Pavement temperatures.

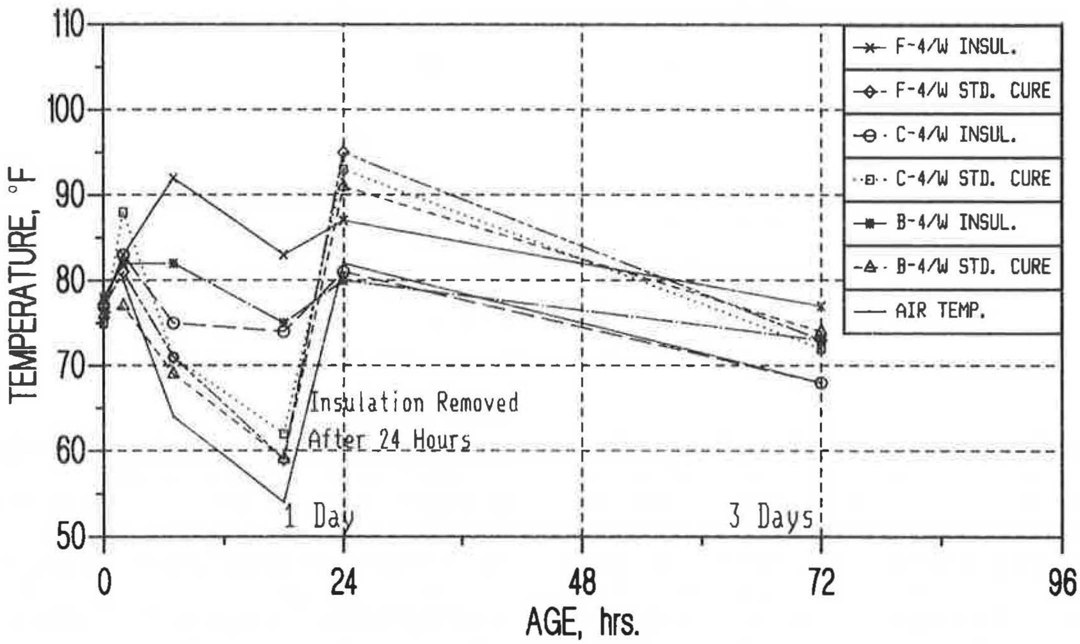

FIGURE 4 Beam temperatures.

and the solar heat. In all three classes of concrete, the pavement sections with the insulating 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 noninsulated beams closely paralleled the air temperature during the night. The next day those noninsulated beams achieved higher temperatures than the insulated beams. The warm ambient temperature and the heat from the sun actually warmed the beams more than the heat derived from the blankets. It may also be true that the insulated beams achieved more hydration earlier and over a longer period 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 an unsettling situation. The beam temperatures were roughly 20° cooler than the pavement temperatures at 14 hr. The beams generally followed the air temperature, whereas the pavement temperatures were somewhat constant. This raises the question of 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

The following were found to be true in this study:

1. Insulating blankets promote a greater increase in early strength for concrete mixes with a higher cement content.
2. Insulating blankets reduce temperature loss during the first night after placement and thereby prevented interruption of the hydration process.
3. There was no significant strength benefit with the use of insulating blankets for a 444-lb cement–79-lb fly ash mix.
4. Insulating blankets may inhibit temperature gain on a warm, sunny day by shielding the solar heat.
5. 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 hr.
6. A *C* mix (6 1/2 bag mix) can be expected to reach opening strength when cured with insulating blankets in 48 hr.
7. An *F* mix can be expected to reach opening strength with conventional curing in 60 hr.

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The contents of this report reflect the views of the author and do not necessarily reflect the official views or policy of the Iowa Department of Transportation. This report does not constitute a standard, specification, or regulation.

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