# Paper No. 890520

# PREPRINT

# Fast Track and Fast Track II
# Cedar Rapids, Iowa

by
James D. Grove
Kevin B. Jones
Kumari Bharil
Dr. A. Abdulshafi
Willie Calderwood

## Iowa Department of Transportation
## Research Project HR-544

## Federal Highway Administration
## Special Project 201



For Presentation at the
Transportation Research Board
69th Annual Meeting
January 7-11, 1990
Washington, D.C.



Highway Division

Iowa Department
of Transportation

Iowa Department of Transportation
Construction Report
Research Project HR-544
Federal Highway Administration
Special Project 201

# FAST TRACK AND FAST TRACK II
# CEDAR RAPIDS, IOWA

By

James D. Grove
Portland Cement Concrete Engineer

Kevin B. Jones
Cement and Concrete Engineer

Kumari S. Bharil
Assistant to Cement and Concrete Engineer

Office of Materials - Highway Division
Iowa Department of Transportation
800 Lincoln Way
Ames, Iowa 50010
515-239-1433

Dr. A. Abdulshafi
Vice President
C.T.L. International
2860 Fischer Road
Columbus, Ohio 43204
614-276-8123

Willie Calderwood
Vice President
Cedar Valley Corporation
P.O. Box 368
Cedar Falls, Iowa 50613

December, 1989

DISCLAIMER

The contents of this report reflect the views of the authors 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.

# TABLE OF CONTENTS

ABSTRACT

Two lanes of a major four lane arterial street needed to be reconstructed in Cedar Rapids, Iowa. The traffic volume and detour problem required that closure for construction be held to a minimum. Closure of the intersections, even for one day, was not politically feasible. Therefore, Fast Track and Fast Track II were specified for the project.

Fast Track concrete paving has been used successfully in Iowa since 1986. The mainline portion of the project was specified to be Fast Track and achieved the opening strength of 400 psi in less than twelve hours. Fast Track II was specified for the intersections and achieved the opening strength of 350 psi in six to seven hours.

Two test sections were selected in the mainline Fast Track and two intersections were chosen to test the Fast Track II. Both flexural and compression specimens were tested. Pulse velocity tests were conducted on the pavement and test specimens. Maturity curves were developed through monitoring of the temperatures. Correlations were performed between the maturity and pulse velocity and the flexural strengths. The project was successful in establishing the feasibility of constructing P.C.C. pavement at night and having the roadway open to traffic the next day, using Fast Track II.

## INTRODUCTION

Experience with the first Fast Track concrete in Buena Vista County on U.S. Highway 71 in 1986 and in several additional projects constructed since, has shown that Fast Track is a viable construction alternative for certain locations. Fast Track concrete is produced from a high cement factor mix, using a special Type III Portland cement, and utilizing insulation blankets in the initial curing process. Strengths for opening Fast Track pavement have always been achieved in less than 24 hours and often in less than 12 hours. The construction is performed using conventional equipment and techniques. The one new technique is the use of insulating blankets to contain and uniformly distribute the heat in the pavement during the early stages of curing.

Both contractors and contracting authorities have begun thinking of Portland cement concrete (PCC) pavement as an option for locations with critical traffic control requirements. This was the situation in an urban area on a reconstruction project in Iowa. Neither the city nor the area businesses would support closing intersections for the duration of the paving. A compromise was reached where the intersections would be closed during the nighttime hours and be open during the day. The reconstruction was scheduled to be PCC pavement. The question became, "could the pavement be conventional PC concrete in the intersections?" This would require concrete that could achieve opening strength in 6 to 8 hours.

Testing was performed in the laboratory using the Fast Track concept and higher cement content concrete. At a rate of 822 pounds of special Type III cement per cubic yard, flexural strengths of above 300 psi were achieved at 6 hours. With the laboratory information, the design and specifications were completed for letting.

## OBJECTIVE

The objective of the research was to evaluate the early strength and temperature gain of both conventional Fast Track and the new Fast Track II mixes.

## PROJECT DESCRIPTION

The project was along a section of Iowa Highway 100 located in the northern part of the city of Cedar Rapids, Iowa. The work involved replacing 2 lanes of a 1.84-mile, 4-lane urban section divided by a raised median. A 10.5 inch plain dowelled and jointed PCC pavement was designed to replace the 29 year old PCC westbound lanes. The project involved 33,000 sq. yds. of Fast Track mix and 1700 sq. yds. of Fast Track II mix. Figure 1 shows the project layout. Restrictions on closures of the intersections were as follows: Council Street, Duffy Drive, Park Lane, Rockwell Drive (Sta. 53+), Rockwell entrance (Sta. 68+), C Avenue, Northland Avenue, and Twixt Town Road could be closed from 6:00 p.m. to 6:00 a.m. any day. K-Mart entrance (Sta. 110+) could be closed from 10:30 p.m. to 10:30 a.m. any day. In addition, the following restrictions were specified: Council Street and Rockwell Drive (Sta. 53+) shall not be closed at the same time. Rockwell entrances (Sta. 68+) and C Avenue shall not be closed at the same time. Northland Avenue and K-Mart entrance (Sta. 110+) shall not be closed at the same time. Note that Rockwell entrance (Sta. 68+) may be closed from 6:00 p.m. Friday to 6:00 a.m. Monday.

Current traffic on the road is 15,400 vehicles per day with 4 percent trucks. Westbound traffic was detoured to a roadway north of the project. Within three days after each mainline segment was completed past an intersection, the contractor was required to open that segment to traffic.

MATERIALS

The following materials were used:

Cement - Continental Type III (special - 1300 psi at 12 hrs. ASTM C109)

Lehigh Type III (special - 1300 psi at 12 hrs. ASTM C109)

Fly Ash - Louisa Class C

Coarse Aggregate - Lee Crawford, Cedar Rapids (A57022)

South Cedar Rapids, Cedar Rapids (A57018)

Fine Aggregate - Open Pit, Cedar Rapids (A57528)

Air Entraining Admixture - Daravair, Double Strength,
W. R. Grace & Co.,
Protex A.E.S., Prokrete Industries

Water Reducing Admixtures - WRDA-82, W.R. Grace & Co.,
Pro-krete N-3, Prokrete Industries

The conventional Fast Track mix (Class F) consists of 710 pounds of special Type III cement, 6 percent entrained air, 50 percent fine and 50 percent coarse aggregate. Fast Track mix with fly ash contains 10 percent Class C fly ash substituted for Type III cement on a 1:1 weight basis. Fast Track II mix (Class FF) contains 822 pounds of special Type III cement. The Fast Track II mix also permits a 10 percent fly ash substitution. The water/cement ratio for Fast Track mixes generally ranges from .48 to .40. Refer to Tables 1, 2 & 3 for Fast Track and Fast Track II concrete mix proportions, absolute volumes and gradations used on the project.

## CONSTRUCTION

Cedar Valley Corporation of Waterloo, Iowa was the successful bidder for this 1.9 million dollar project. General weather conditions during paving were sunny and warm with few rainy days. The average daily high temperature was 85 deg. F. and the average daily low temperature was 61 deg. F. Paving on the project started on June 19, 1989. The roadway was entirely open to traffic on June 30, 1989 with the remaining work to be finished in three to four weeks.

Paving began on the west end of the mainline. As the paving train approached the intersection, a header was placed and paving was resumed on the other side of the intersection. A Rex-TBM belt placer and a CMI-SF350 slip form paver were used to place the 26.5 foot pavement and inside curb.

Prior to paving in the intersections, the pavement was removed and replaced with granular base and 3 inches of asphaltic concrete for a temporary wearing surface. The contractor was able to complete the removal and replacement during the 6:00 p.m. to 6:00 a.m. closure period. The remaining work on the westbound lanes proceeded without interference to intersection traffic.

Once the mainline pavement adjacent to an intersection gained sufficient strength to allow construction traffic, the contractor was permitted to begin the intersection work. The intersection was closed to traffic at 6:00 p.m. to begin the asphalt removal. The contractor removed the 3 inches of asphalt and base and prepared the grade in 3 to 4 hours. This left 2 to 3 hours to place 50 to 79 feet of Fast Track II pavement. The intersections were generally open by the 6:00 a.m. requirement. Penalties were assessed for being 1/2 hour late on opening two intersections and being three hours late on one intersection.

No major problems were encountered in placing the Fast Track II mix. Some initial difficulty was encountered in maintaining the target entrained air content. Type III cement traditionally has required higher dosages of air entrainment than Type I cement. Finishers reported some difficulty in finishing the surface. This was somewhat surprising since finishers on an experimental section of Fast Track II in Dubuque County reported the mix to be very easy to finish. No definite reason for this was determined. Some possible reasons are: higher mix temperature, warmer weather, longer elapsed time between batching and finishing, or a different gradation or particle shape.

Concrete for the mainline was batched from a portable batch plant two blocks from the project. The Fast Track II concrete was supplied from a local ready mix plant four miles from the project. Haul times were generally less than 20 minutes.

Both the intersections and the mainline were cured using a white pigmented curing compound and burlene thermal blankets were placed over the pavement. At the intersections, the contractor placed the blankets within an hour after the section was poured. On the mainline, placement of the blankets was usually delayed for several hours after placement of the concrete in order to avoid marring of the surface.

Joint sawing and sealing at the intersections began four to five hours after the concrete was placed. Preformed neoprene joint material was used to expedite the sealing process in the intersections. An ASTM D 3405 type hot pour material was placed on the mainline pavement.

## PROJECT TESTING

Testing to evaluate the Fast Track mixes consisted of strength testing, pulse velocity testing and maturity testing.

### Strength Testing

Both the flexural and compressive strength of the concrete were determined for two placements of Fast Track and two placements of Fast Track II. The locations and the results are listed in Table 4.

Seventy-five beams and cylinders were cast for testing. Vibrators were used for molding cylinders and beams. An external vibrator was used for 4-1/2-inch x 9-inch horizontal cylinders and an internal vibrator was used for 6-inch x 6-inch x 20-inch beams. Beams and cylinders were sprayed with curing compound and then were placed on the slab under the blankets.

Three beams and three cylinders were tested at each test time. The flexural strength of the concrete was determined using center point loading. The test results are listed in Table 5 and shown graphically in Figures 2, 3, 4, and 5 for both the flexural tests and the compression tests. In Table 5 a dash (---) is used for unavailable data.

## Pulse Velocity Testing

The V-meter has been used by the FHWA staff on active projects in several states, including Virginia, Pennsylvania, Ohio, Indiana, Iowa, and Michigan. In general, good correlation was obtained between strength and pulse velocity as measured by multiple correlation coefficients of not less than 0.8. A unique set-up for measuring pulse velocity on the pavement was established in the Cedar Rapids-Collins Road Fast Track project. A hollow block-out device was designed and provided by the Iowa Department of Transportation to form a hole 6-inch x 6-inch x 6-inch in the pavement after the texturing operation. Two holes three feet apart were required to perform the test. The surface in contact with the ultrasonic transducers was smoothed out using a steel trowel. The two holes were then covered with insulating blankets. Every time a strength test was performed, ultrasonic pulse velocity measurement of the pavement was also taken. A best fit line between the flexural strength and pavement pulse velocity was developed and presented in Figure 6.

<u>Maturity Testing</u>

Maturity is defined as the accumulated product of the time and temperature. Maturity-strength curves have been widely used in the precast/prefabricated concrete industry with much success. Several commercial products are available in the marketplace which record temperatures on a continual basis. All use a temperature measuring probe and a triggering time clock. Information is stored in a micro-chip board and can be retrieved at any later time. The test for maturity is covered by ASTM C1074-87.

In the Cedar Rapids-Collins Road Fast Track project, the test locations in the pavement and field cured test specimens were monitored by an M-meter. The following locations were monitored with the temperature probe thermocouples:

- At center slab - 0.5-inch from top, 0.5-inch from bottom, and mid depth
- One foot from edge of slab - same locations as at center slab
- Air
- Test Specimens - 4 1/2-inch diameter cylinder and 6-inch x 6- inch x 20-inch beam

Figures 7 and 8 present the time/temperature data in one Fast Track section and one Fast Track II section, respectively. A maturity versus flexural strength correlation was developed from the data (integration of time/temperature plot using the Nurse-saul equation).

The correlations are presented in Figure 9.

## DISCUSSION OF RESULTS

The results of the various tests and procedures are discussed below.

### Strength Results

Fast Track: The two Fast Track sections exhibited similar strength gains. The flexural tests resulted in nearly identical strengths at twelve hours, twenty-four hours, and fourteen days. The compression tests were nearly identical for the first twenty hours. This consistency is an important verification of the results.

Both mainline test sections reached the 400 psi flexural strength required for opening in less than twelve hours. Also, they reached 500 psi, the opening strength required for conventional paving, in less than twenty four hours. The results of these tests are shown in Figures 2 and 3 and are very similar to other Fast Track projects constructed in Iowa in the past three years.

Fast Track II: The two test sections exhibited some variation, not only between the two intersections, but also between the flexural and compression test results. The differences do not suggest unusual problems or specific trends. Construction variations would likely account for the differences. Northland Avenue exhibited a continual increase in the rate of flexural strength gain when compared to C Avenue throughout the first twenty-four hours. But, at seven days, the tests from the two sections showed virtually the same flexural strength.

The flexural strengths at both intersections were nearly identical for the first seven hours. Both intersections exceeded the 350 psi flexural opening strength requirement by that age, even though both had strengths less than 200 psi at five hours. The goal of this mix was achieving 350 psi in six hours. In both test sections, that strength was reached in less than seven hours but more than six hours. These results closely matched research conducted by the Iowa Department of Transportation in October, 1988, with the Fast Track II mix in Dubuque County, Iowa. The previous work was conducted under very different weather conditions and with different materials. With all three test sections reaching opening strength between six and seven hours, some degree of confidence can be placed in achieving these results in future projects.

The compression tests gave very impressive results. The cylinders gained considerable strength between five and seven hours. The compressive strength went from around 1500 psi to over 3500 psi in that two hour period. The rate then began to decline, but still achieved almost 4500 psi at Northland Avenue and about 5000 psi at C Avenue in twelve hours. A comparison between the flexural strength and the compressive strength is interesting to note. The rate of flexural strength gain was not the same at these very early ages. The rapid rate of strength gain began to decrease at approximately seven hours as represented by the compression tests but the flexural strength did not exhibit this decrease until an age of nine hours.

## Pulse Velocity Results

Figure 6 shows the relationship between the pulse velocity and the flexural strength. This integration yielded R-squares of 0.88.

Pulse velocity has potential for this type of application. The difficulty comes in trying to establish vertical surfaces from which to take measurements. Since materials change from project to project, its application will probably be limited to larger projects. Those projects involving a large quantity of concrete will justify the initial correlation effort.

## Maturity Results

Fast Track: The temperature versus age plots are shown in Figure 7 for one of the Fast Track mainline test sections.

The maturity of the pavement was only slightly higher than that of the flexural beams at the 12 hour test.

Compression tests were performed on the cylinders. The maturity of the cylinders varied between the two test sections. At station 48+00 the cylinder reached a higher maturity than the slab at 12 hours except at station 118+75, the maturity of the cylinder was lower than that of the slab. The cause is certainly a result of the sun-heating up the small specimen at the first section. This research would suggest that in terms of the test specimens representing the actual concrete in the pavement, the flexural beams give a strength which represents the pavement more closely than cylinders.

Fast Track II: The temperature versus time plots are shown in Figure 8. The maturity of the concrete in the two Fast Track II test sections was more consistent than in the Fast Track sections. The temperatures in the pavement of the Fast Track II and the test specimens were more consistent in the Fast Track sections. The sun shining on the specimens during the day caused them to become warmer than the slab on the Fast Track sections. This warming effect was eliminated on the night time Fast Track II work. The flexural beams and cylinders exhibited maturity consistently less than the pavement slab. This would indicate that a margin of safety exists between the strength indicated by the test specimens and that of the actual pavement. The strength in the pavement is in fact higher than what the test result would show.

Figure 9 is a plot of the maturity versus the flexural strength results. The figure illustrates the best fit lines of our test data and represents predictive models which have R-square values greater than 0.8.

Maturity testing for opening time has potential for Fast Track paving. Future maturity evaluations on Fast Track may prove the viability of maturity testing instead of flexural beams to determine opening time.

## SUMMARY AND CONCLUSIONS

Based on the results of this project, the following is concluded:

1. Fast Track and Fast Track II can be placed with conventional paving procedures and equipment.

2. Fast Track II achieved a 350 psi flexural strength for opening in less than seven hours.

3. Fast Track achieved a 400 psi flexural strength for opening to traffic in less than 12 hours.

4. Fast Track II will require higher amounts than normal of air entraining agent to obtain desired entrained air. The high cement factor mix may require more effort to float and finish.

5. Construction staging and restrictions required for the project were achievable. The system is applicable for certain future projects.

## RECOMMENDATIONS

1. This project should be evaluated for performance after five years of service. Cracking, smoothness and friction properties should be summarized.

2. Study should continue on the occasional problem of finishing of Fast Track II Concrete.

3. Further evaluation of the maturity concept should be performed on future Fast Track projects.

## ACKNOWLEDGEMENT

The evaluation portion of the research was partially funded by the Federal Highway Administration under Special Projects 201, "Accelerated Rigid Paving Techniques".

The authors wish to extend appreciation to the District #6 Materials staff and the Cedar Rapids Construction Residency staff for their efforts in performing the additional testing required by the project. The commitment by the FHWA of their mobile concrete laboratory and personnel contributed to the success of the research and was greatly appreciated. We also want to thank Cedar Valley Corporation for their cooperation during the project.

TABLE TITLES

TABLE 1

MIX PROPORTIONS

| Mix | Cement lb. per cu. yd. | Fly Ash lb. per cu. yd. | Fine Aggregate lb. per cu. yd. | Coarse Aggregate lb. per cu. yd | Air Entr. Admix. oz. | Water Reducer Admix. oz. | Mix Temp. (°F) |
|---|---|---|---|---|---|---|---|
| F | 641 | 73 | 1393 | 1359 | 10 | 28.6 | 80 |
| FF | 742 | 80 | 1305 | 1302 | 11 | 24.8 | 93 |

TABLE 2

BASIC ABSOLUTE VOLUME OF MATERIALS

| | Fast Track (Class F) | Fast Track II (Class FF) |
|---|---|---|
| Cement | .120 | .139 |
| Fly Ash | .016 | .018 |
| Fine Aggregate | .312 | .294 |
| Coarse Aggregate | .312 | .293 |
| Water | .180 | .196 |
| Air Voids | .060 | .060 |

TABLE 3

GRADATION PERCENT PASSING

| | Fast Track (Class F) | | | Fast Track II (Class FF) | | |
|---|---|---|---|---|---|---|
| Sieve | Coarse Agg. | Fine Agg. | Combined | Coarse Agg. | Fine Agg. | Combined |
| 1" | 100 | | 100 | 100 | | 100 |
| 3/4" | 88 | | 94 | 77 | | 89 |
| 1/2" | 54 | | 77 | 42 | | 71 |
| 3/8" | 20 | 100 | 60 | 9.6 | 100 | 55 |
| #4 | 1.5 | 97 | 49 | 1.5 | 96 | 49 |
| #8 | 1.1 | 89 | 45 | 0.6 | 88 | 44 |
| #16 | | 75 | 38 | | 76 | 38 |
| #30 | | 45 | 23 | | 45 | 23 |
| #50 | | 8.7 | 4.4 | | 8.2 | 4.1 |
| #100 | | 0.8 | 0.4 | | 1.2 | 0.6 |
| #200 | 1.4 | 0.4 | 0.9 | 0.9 | 0.6 | 0.8 |

TABLE 4

PLACEMENT LOCATIONS AND CONCRETE TEST RESULTS

| MIX | STATION | SLUMP IN. | AIR % | W/C RATIO |
|---|---|---|---|---|
| MAINLINE | | | | |
| Fast Track (F) | 48+00 | 2.00 | 5.5 | .415 |
| Fast Track (F) | 118+75 | 1.75 | 5.0 | .411 |
| INTERSECTION | | | | |
| Fast Track II (FF) | 81+30 | 2.50 | 5.2 | .376 |
| Fast Track II (FF) | 99+80 | 2.25 | 5.2 | .382 |

TABLE 5

STRENGTH TEST RESULTS

FAST TRACK (MAINLINE)

| AGE | Average Flexural Strength (PSI) (Center Point Loading) STA. 48+00 | STA. 118+75 | Average Compressive Strength (PSI) STA. 48+00 | STA. 118+75 |
|---|---|---|---|---|
| 6 hour | 270 | 150 | 1680 | 1500 |
| 12 hour | 420 | 420 | 3550 | 3590 |
| 20 hour | 460 | --- | 4570 | ---- |
| 24 hour | 530 | 550 | 4660 | 5080 |
| 7 day | 720 | 810 | 5840 | ---- |
| 14 day | 790 | 810 | ---- | 6440 |

FAST TRACK II (INTERSECTION)

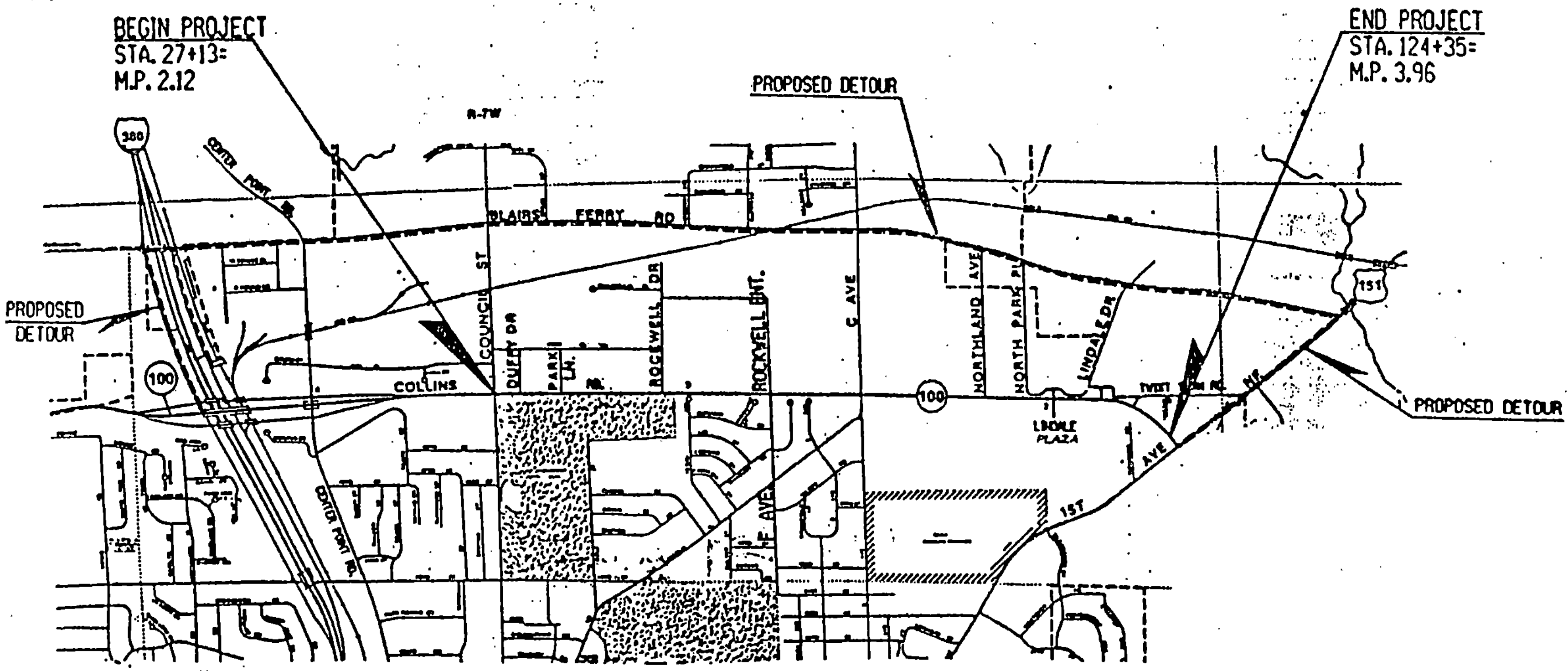
| AGE | Average Flexural Strength (PSI) (Center Point Loading) C. Avenue | Northland Ave. | Average Compressive Strength (PSI) C. Avenue | Northland Ave. |
|---|---|---|---|---|
| 5 hour | 180 | 190 | 1130 | 1570 |
| 7 hour | 360 | 380 | 3840 | 3550 |
| 9 hour | 500 | 560 | ---- | 4250 |
| 12 hour | 570 | 640 | 4990 | 4430 |
| 24 hour | 690 | 840 | 5260 | 5230 |
| 7 day | 950 | 940 | ---- | ---- |
| 14 day | 1000 | 1040 | 7090 | 7470 |

NOTE: Unavailable data are indicated with a dash (----).

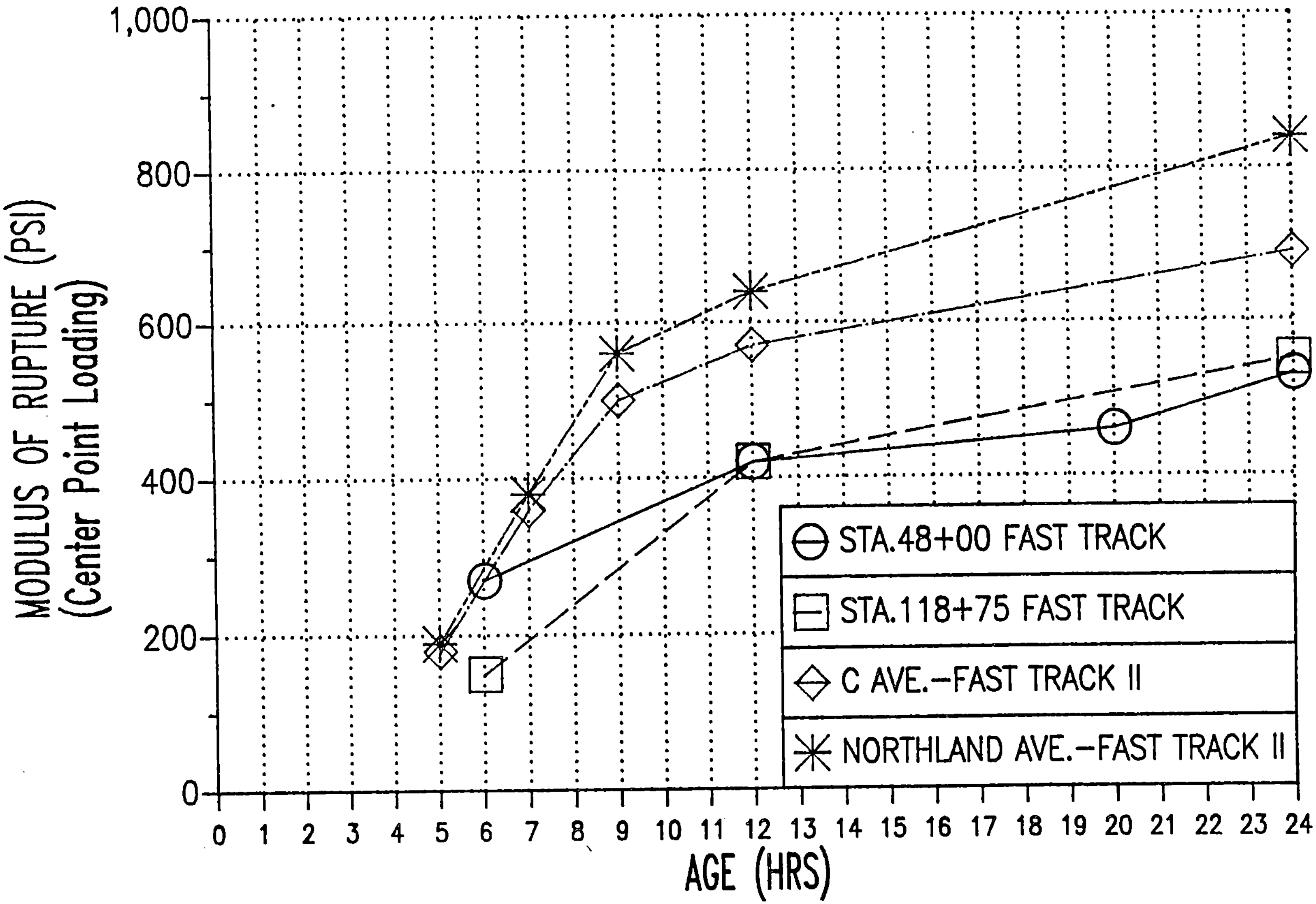
# FIGURE CAPTIONS

# FIGURE 1

# PROJECT LOCATION

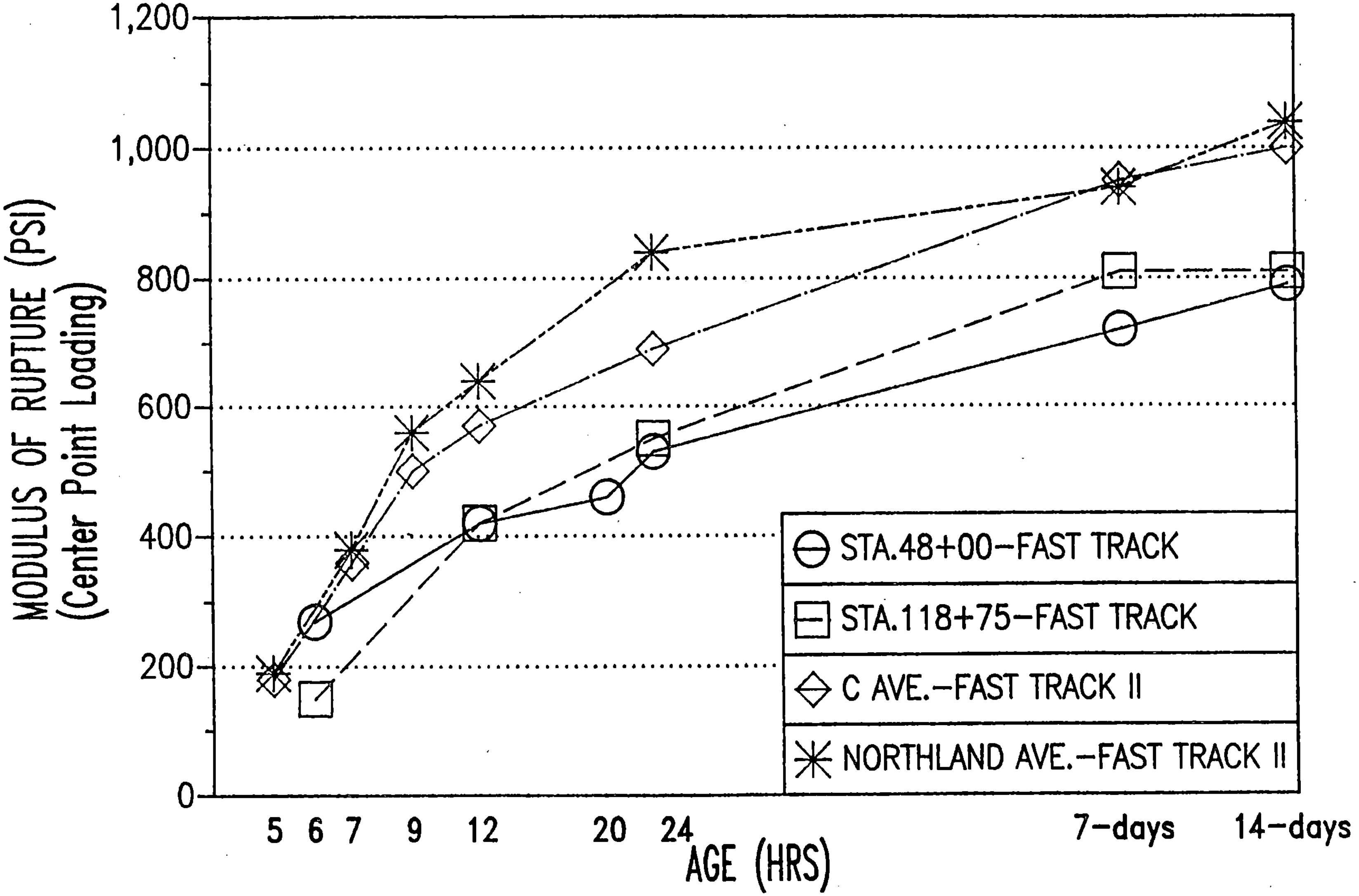


# FIGURE 2
## EARLY FLEXURAL STRENGTHS



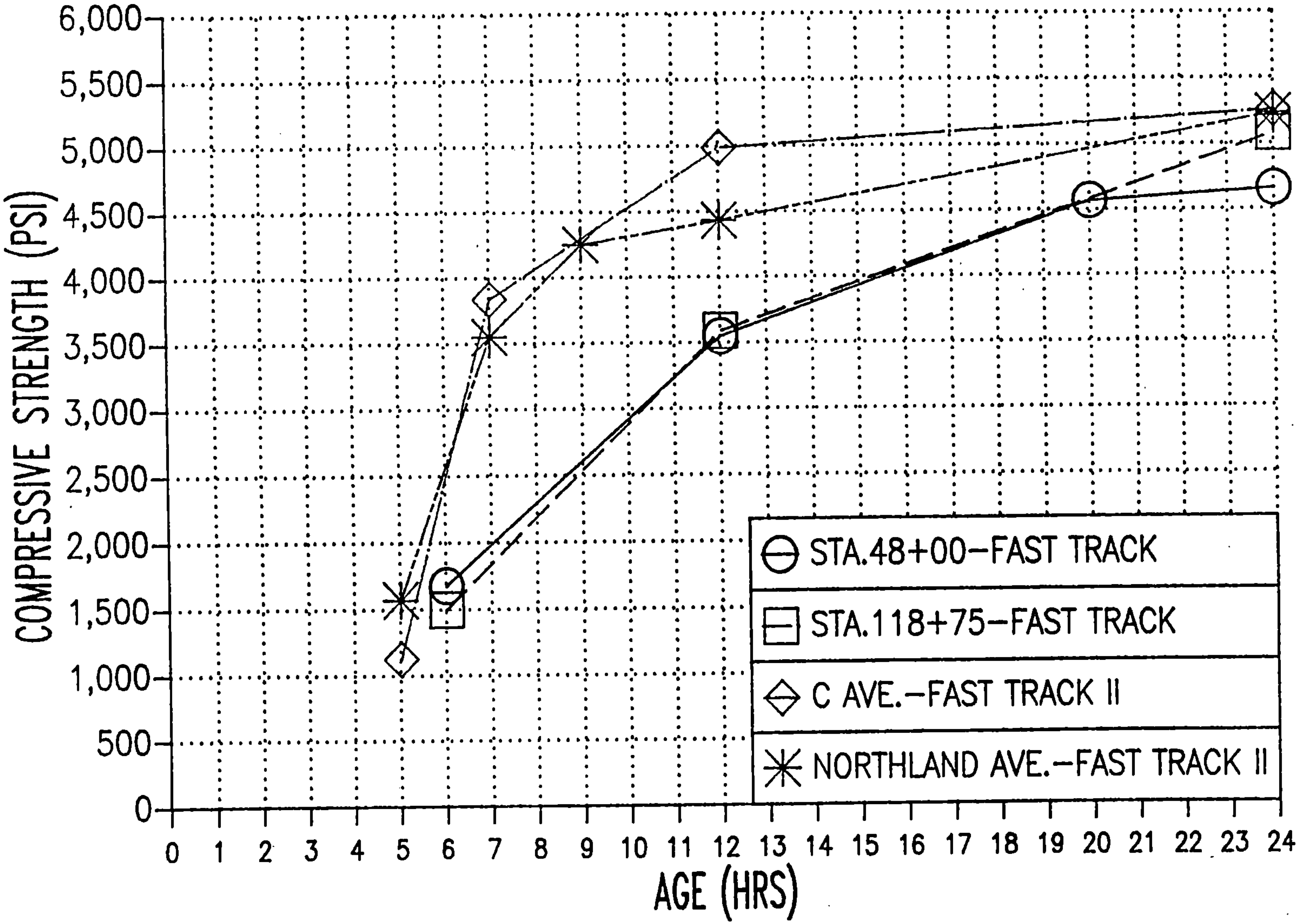

Grove, et al.

# FIGURE 3
# LONG TERM FLEXURAL STRENGTHS

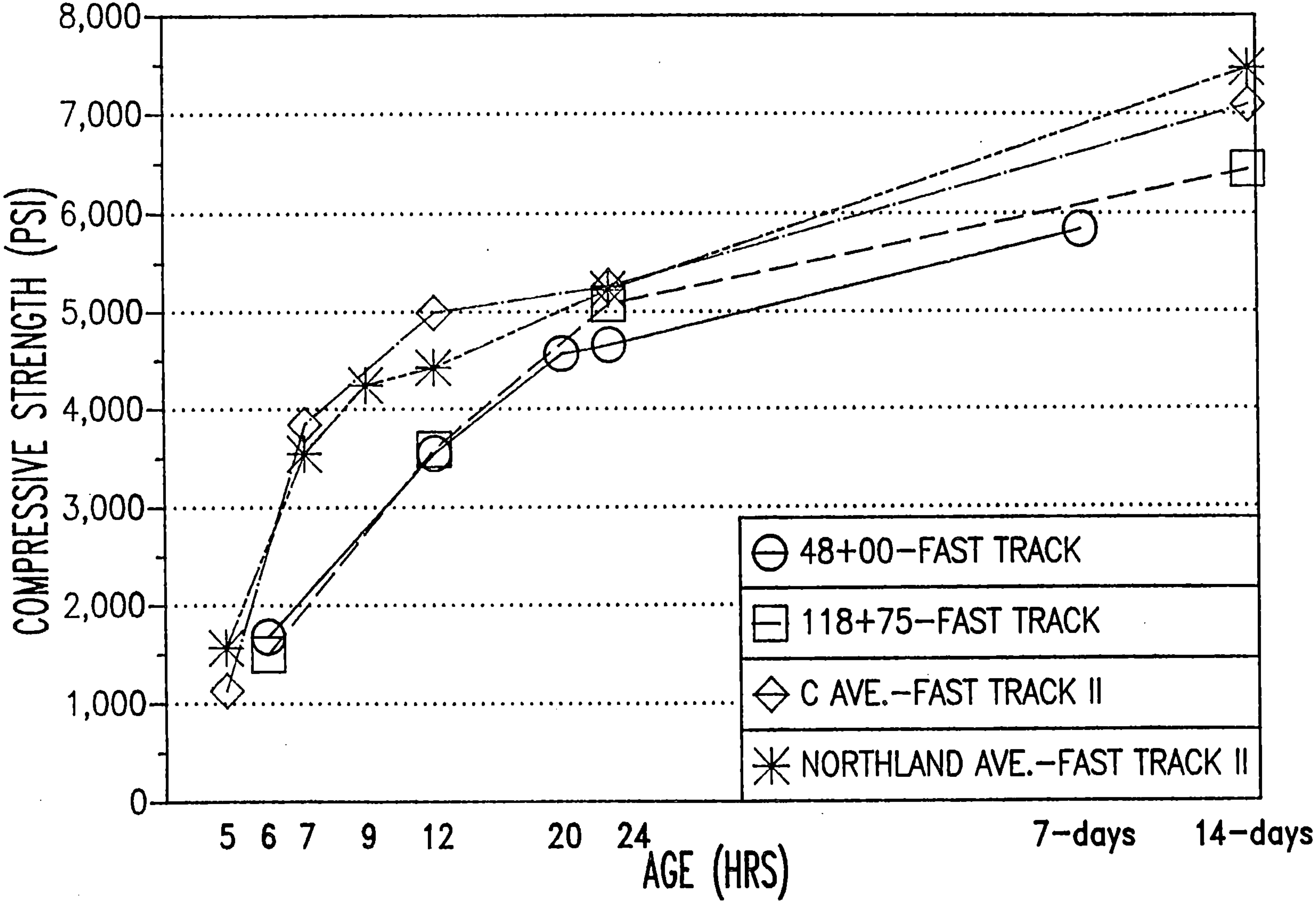



Grove, et al.

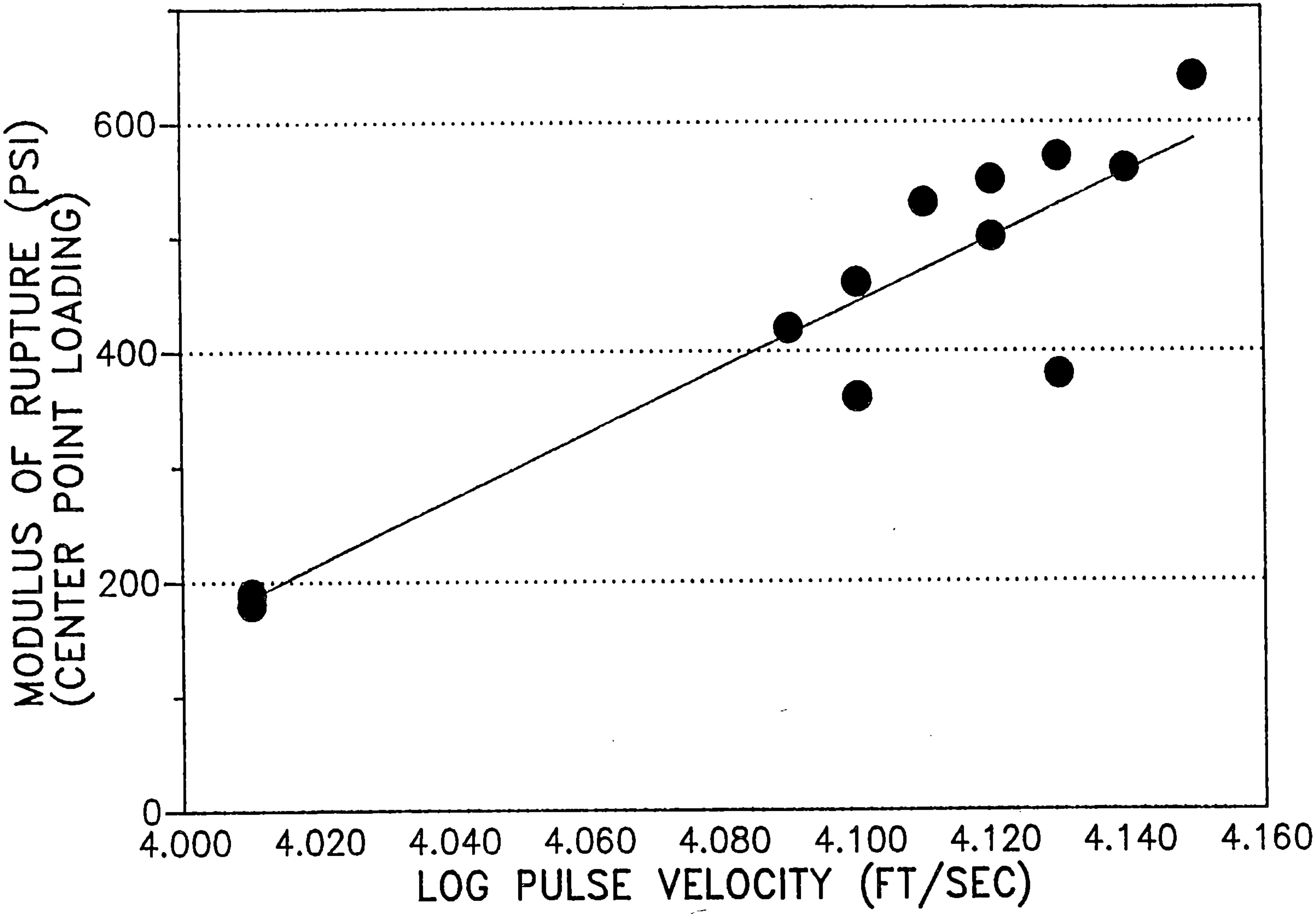
# FIGURE 4
# EARLY COMPRESSIVE STRENGTHS



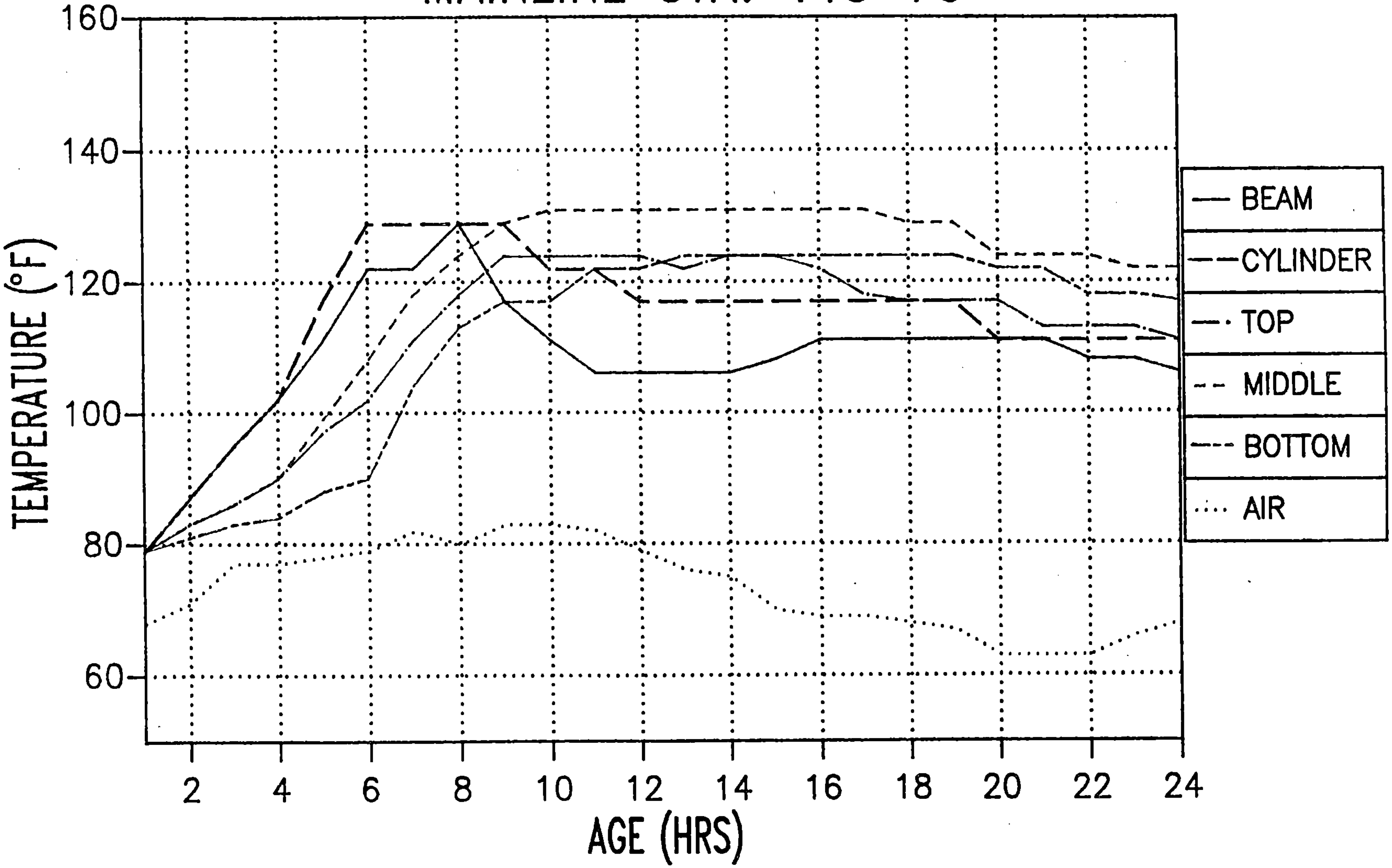
# FIGURE 5
# LONG TERM COMPRESSIVE STRENGTHS



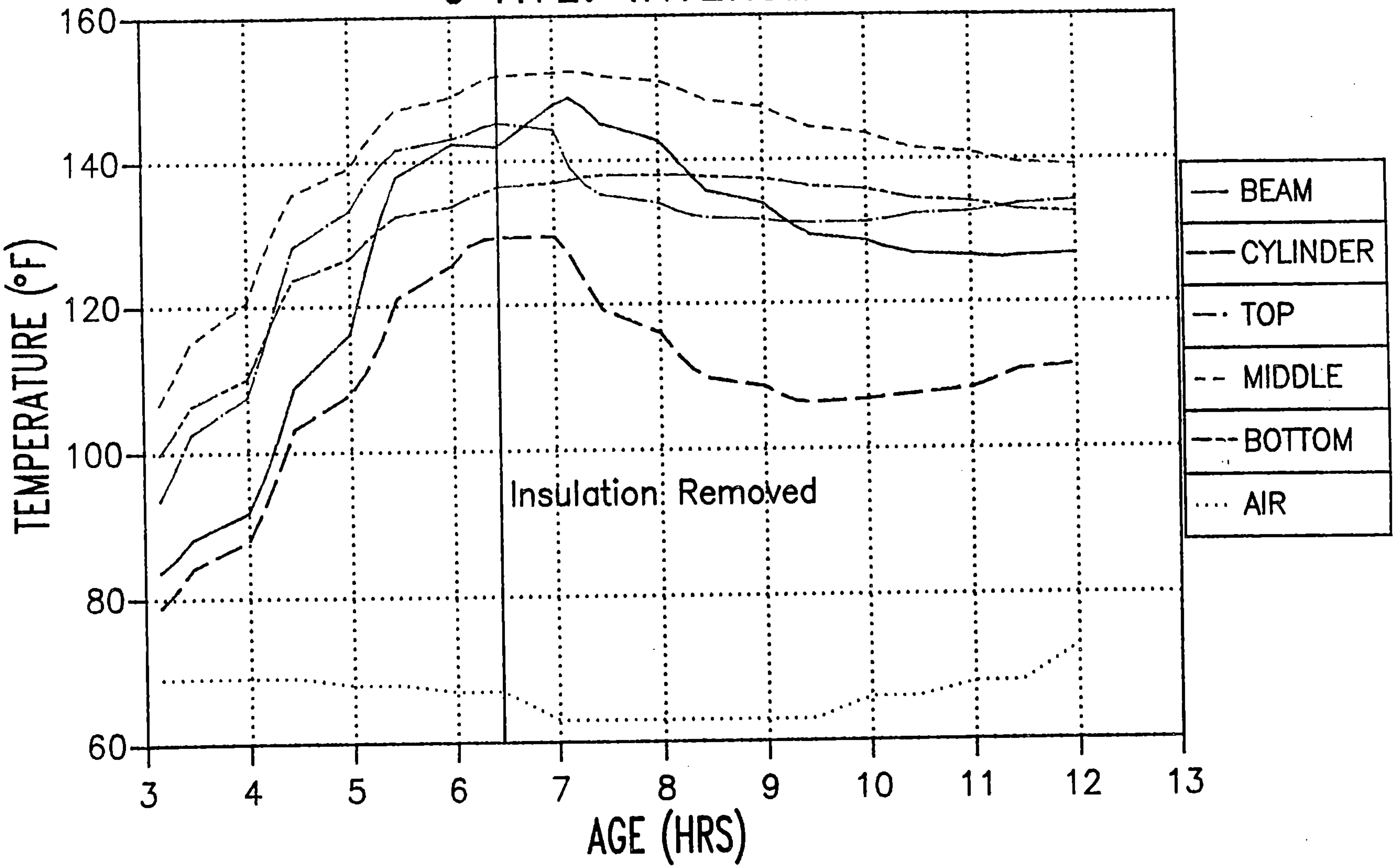
# FIGURE 6
## PULSE VELOCITY VS. FLEXURAL STRENGTH



# FIGURE 7
## FAST TRACK TEMPERATURES
## MAINLINE STA. 118+75



# FIGURE 8
## FAST TRACK II TEMPERATURES
## C AVE. INTERSECTION



# FIGURE 9
# MATURITY VS. FLEXURAL STRENGTH