THIN BONDED CONCRETE OVERLAY WITH FAST TRACK CONCRETE

Final Report for Iowa DOT Project HR-531

Federal Highway Administration Project DTFH 71-86-502-IA-22

November 1990

Highway Division
Iowa Department of Transportation

Final Report
for
Iowa Department of Transportation
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Thin Bonded Concrete Overlay With Fast Track Concrete

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November 1990

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DISCLAIMER

ABSTRACT

Pavements have been overlaid with thin bonded portland cement concrete (PCC) for several years. These projects have had traffic detoured for a period of 5-10 days. These detours are unacceptable to the traveling public and result in severe criticism. The use of thin bonded fast track overlay was promoted to allow a thin bonded PCC overlay with minimal disruption of local traffic.

This project demonstrated the concept of using one lane of the roadway to maintain traffic while the overlay was placed on the other and then with the rapid strength gain of the fast track concrete, the construction and local traffic is maintained on the newly placed, thin bonded overlay.

The goals of this project were:

1. Traffic usage immediately after placement and finishing.
2. Reduce traffic disruption on a single lane to less than 5 hours.
3. Reduce traffic disruption on a given section of two-lane roadway to less than 2 days.
4. The procedure must be economically viable and competitive with existing alternatives.
5. Design life for new construction equivalent to or in excess of conventional pavements.
6. A 20 year minimum design life for rehabilitated pavements.

INTRODUCTION

The highway construction industry has undergone major changes in the last 25 years. During the 1950's and 1960's the primary function of the highway department was to construct interstate and primary highways on new alignments. Now, the department is mainly concerned with maintaining this highway system rather than building new roads. Typical highway construction projects now included in the program would be quarter-mile approaches to bridges that are being replaced, or quarter to half-mile long spot improvements to correct horizontal or vertical sight distance. Additional lanes are also being placed along existing highways to increase the traffic carrying capacity. In addition to this, short by-passes of urban areas are being built, but new highways or highways on a new alignment are less frequent.

Pavements have been overlaid with thin bonded PCC for several years. These projects have had traffic detoured off-site to accommodate a five to ten day curing period. This cure period has been unacceptable to the traveling public, resulting in severe criticism. Most of the highway work planned for the future is system preservation type work. This work will involve reconstruction on present alignment, with minimum delay and inconvenience to the traveling public. Although much of the technology and know-how exists to construct a fast track thin bonded project, many new ideas and equipment and the associated costs must be evaluated. Contractor fears associated with working with very rapid setting concrete must be overcome.

OBJECTIVE

The principal goal of this project was to evaluate the materials, equipment and procedures developed to facilitate constructing PCC under traffic and opening the new construction to legal traffic loads in less than one day. The early bond strength between old and new concrete is important primarily for early pavement loading.

The work required gathering extensive amounts of concrete strength and temperature data. This data was used to develop future projects requiring opening of pavement to traffic in eight hours or less.

Solutions to problems associated with placing large volumes of rapid setting concrete in hot weather were evaluated. This project permitted analysis of most of these problems, including: 1) construction under local traffic conditions; 2) construction of one 12-foot lane at a time; 3) high early strength concrete mixes; 4) use of accelerators and water reducers to further speed strength growth; 5) use of insulation to speed hydration of cement; and 6) evaluation of grouted and ungrouted bond strengths.

PROJECT DESCRIPTION

This project was located on US 71 in Buena Vista County. It was approximately 7.5 miles long. This section of 20-foot wide pavement was in good condition with original curb sections removed.

This pavement was originally constructed 20-feet wide in 1937 out of very high quality aggregate. Under this project the pavement was widened to 24 feet and strengthened with a bonded overlay. The actual paving operation was to take place in two elements. The first was from the centerline of the roadway to the outside edge of the widening unit in one direction and second to pave the other side of the road in exactly the same manner. Accompanying this overlay work was the placement of a longitudinal drain almost the full length of this project under the outside edge of the slab. Iowa has in excess of 30" of rain per year and subdrains have been found to be very effective in increasing the K-value for subgrades during the extreme wet conditions in the spring and thus prolonging the life of the concrete slab. This 4" perforated plastic pipe was placed approximately 42" deep in a 10" wide trench with porous backfill (Figure I). This has been proven to be very successful on other projects.

The overall plan for this project was to overlay and widen one-half of the roadway, place the shoulder material adjacent to it the following day, and open it to contractor and local traffic while the other side of the roadway is being prepared for overlay and widening (Figure II).

MATERIALS

This research-type project included a number of innovative features. Each one of which was intended to solve a specific problem. The number one item was the use of strength accelerators. Calcium chloride was tried in small amounts on this project to ensure that the concrete at driveways and county road intersections would be sufficiently strong to open to traffic the following day. This was very successful. This particular project specified a special Type III cement. Part of the specifications required that this material meet AASHTO M-85 Type III portland cement. In addition, the ASTM C309 compressive mortar strength must reach at least 1300 PSI in 12 hours. This was necessary because of a wide variation found in the strength of concrete from cements that met the regular Type III requirements.

Epoxy-coated reinforcing steel was used to tie across longitudinal random cracks to eliminate or control reflective cracks. Additionally, in an attempt to better control existing transverse random cracks and reflection through the surface, four-mil plastic tape 4 inches wide with pressure sensitive adhesive was placed over random cracks and a control joint was sawed within the limits of the tape. The intent was to yield a transverse saw cut that could be maintained much easier than a random crack.

A thermal blanket was used over this special Type III cement. It was recognized that a lot of heat is generated chemically when cement hydrates. Most of that heat was held in the mix to raise the temperature sufficiently to further accelerate the set of the concrete. This too was very successful.

Two sections of concrete overlay without a bonding grout were constructed. This was based on the theory that sufficient grout was available in the matrix of the concrete to do the bonding. This was a qualified success.

CONSTRUCTION

The first phase of this paving operation in 1986 consisted of removing the old centerline paints, edgeline paints, and any oil drippings, rubber or other contaminants that exist on the roadway. This eliminated all the contaminants on the roadway surface and provided a clean bonding surface. On this project the contractor had the choice of accomplishing this with a milling operation or shotblasting. The contractor elected to shotblast. The largest shotblasting machine used was about 4 feet wide. Machines exceeding 6 feet in width have been used on other projects very successfully. The steel shot that is thrown against the surface to remove this contaminated concrete and any road grime is normally less than 1/8" in size. It is thrown with centrifugal force against the concrete pavement and as it bounces back up, is reclaimed with electromagnets. The material that is shattered off the concrete surface is vacuum removed. This is a very quiet, dust-free operation and can be used in urban as well as rural areas. It does not remove asphalt materials very well and quite often requires two or more passes to remove tightly adhered materials like centerline paint. The end result, however, is very satisfactory.

Because this project called for a 2' widened section to be attached to the old pavement and a stabilized crushed stone shoulder to be placed outside the widening unit, the contractor's next operation involved removing the shoulder material with a CMI subgrader working from a nylon stringline. The stringline was placed with vertical reference to the outside edge of the slab and with horizontal reference to the centerline of the slab so that future passes of other equipment could coincide with both the elevation of the finished slab and the location of the centerline. The removal of this subgrade material from the shoulder with the CMI equipment proved to be a very intelligent move on the part of the contractor. These shoulder materials tend to form hard clay balls which would have been difficult to shape and grade at later stages of the work. The loose grained material removed by the subgrader was easily finished to the desired cross section.

The next operation the contractor performed was to drill holes 3" down from the top of the edge of the slab at 2-foot centers 6" deep. These holes were to receive #6 epoxy-coated tie bars 18" in length whose primary purpose was to tie the widening unit to the main slab. The contractor had a drill rig designed that would drill four holes at a time. These were hydraulic drills that had compressed air to blow the holes clean once they had been drilled. This is a very satisfactory unit and the rate of progress of this machine was estimated to be 1-1/2 miles in a day. Once the holes had been blown clean, the contractor had to glue the rebars in place with a pull-out strength of 10,000 pounds or more. This was accomplished with a special two-component epoxy that was blended in the application nozzle. This was then injected into the back of the hole for a metered period of time. The rebar was stuck into the hole and tapped into place to make sure that it had penetrated the full 6 inches of the depth of the hole. This left approximately one foot of rebar in the widening unit. Tests on the pull-out strength of these bars were very satisfactory, reaching approximately 15,000 pounds in four hours.

A number of surface spalls on this project were corrected by milling partial depth with a milling machine and placing partial depth patches at the time that the 4" overlay was placed. Past experience had indicated that it was beneficial to place reinforcing steel in these partial depth patches to prevent reflective cracking in or around the patch itself. The main problem with these partial depth patches being open and exposed is that the batch trucks bent the rebars and that the paver dropped down into the excavated hole, causing a rougher ride than would have been produced had the patches been placed prior to paving.

One of the very pleasant parts of this project was the success of placing reinforcing bars across random cracks at approximately 30" intervals to control the random cracks. These #5 bars were 36" long and epoxy coated. Very good strengths developed across these cracks and reflective cracking was reduced. This is probably partially due to the fact that the concrete slab did not go into tension or shrink until the bond strength, as measured by flexural strength, had exceeded 400 PSI. This process of placing tie bars across existing cracks and some joints was very liberally used. By placing the tie bars at right angles to the cracks and joints, it was anticipated that the crack would not reflect through the 4" overlay.

The contractor was required to sandblast and airblast the surface to be overlaid immediately in front of the paver. New specifications may require the shotblasting equipment to operate immediately in front of the paver to remove any soil or contaminants from the surface. This would ensure maximum bond strength. The overlay and widening operation was basically the same for attaching the second unit to the existing slab except the centerline joint had to be kept clean. This was a minor problem due to the rainy season and wind causing some contamination of the roadway surface. This seemed to accumulate against the vertical edge of the centerline joint that was exposed. It required substantial effort on the part of the contractor to keep the prepared surface clean so that a good bond could be obtained at the centerline joint on the vertical edge as well as the horizontal surface.

Difficulties were experienced in the bonding of the new concrete to the old concrete that had not previously been experienced. This was believed due to two major elements: 1) The difficulty of keeping the roadway clean immediately in front of the paver, which has been addressed with new specifications and 2) The cement grout which at times was a little thin. New specifications should target value of 0.6 pound of water per pound of cement for the grout consistency, with a maximum permissible water/cement ratio of 0.7 pound of water per pound of cement.

The paver on this job was a Rex paver that had been modified by the contractor to pave a 12' wide strip. One pad line was on the subgrade in the widening unit, the other was just beyond the centerline. The paver worked adequately, although it did not have the zero clearance at the centerline that was desired. One equipment manufacturer built a piece of zero-clearance equipment and delivered it to the job for use. It did not prove satisfactory as the roughness of the pavement behind the finishing machine was in excess of 25 inches per mile. Modifications to the paver did not solve the problem, so the machine was taken back to the factory for further modifications. Other manufacturers of equipment have recognized the need for a zero-clearance paver whether it is used on fast track concrete or conventional concrete and that equipment is now available. The bonded overlay specifications required a smoothness measured with the 25-Foot Profilometer not greater than 15 inches per mile. When the operation was going well, smoothness in the vicinity of 8" to 10" per mile was obtained.

It would be desirable on future projects that traffic be maintained in the lane adjacent to the paver. Although local traffic was maintained on this project at all times, some flagging took place at the paver as the paving operation did extend into the adjacent lane. The contractor, from time to time, had problems with the vertical edge at the centerline and his finishing crews had to intrude into the traffic lane. It is proposed that this will be restricted on future projects. In paving the second pass with the paving machine, one tread of the paver had to operate in the trench that was cut for the widening unit and one tread of the machine traveled on the previously placed thin bonded overlay. This worked very satisfactory.

The pavement texture was obtained by a longitudinal astrograss drag followed by transverse grooving. A liquid curing compound was then applied as soon as the texturing was completed in order to minimize the evaporation of water from the surface. This step was necessary, because it was the plan to saw the transverse joints prior to applying the thermal blanket. The contractor was allowed to make the transverse cuts 3 to 4 hours after placement. At that time, it was very plain to see that although the concrete had set up, the curing compound was not entirely dry, and the tracks of the saw machine and the operator quite often were evident in the surface. This very rapid curing time was beneficial to the contractor in this instance.

The contractor was required to place expansion joints over the top of existing expansion joints in the old roadway surface. Saw cuts in the overlay for contraction joints were placed over top of transverse joints and cracks that were straight enough so that the extremities of the crack deviated no more than 1" from the stringline stretched over the joint. Past experience had indicated that the crack would migrate to the plane of weakness cut in the overlay if it was within 1" of the saw cut. The saw cut was full depth of the overlay. The thermal blanket was placed as soon as the sawing was completed, generally some four hours after the placement of the concrete.

On previous projects some problems occurred with the concrete pavement going into compression after the overlay had been placed and before relief had been cut in the overlay system. This caused the overlay to buckle and debond. Considerable effort was taken on this project to insure that the pressure relief joints were placed immediately after placement of the overlay, removing any possibility of the overlay going into compression and buckling.

It was intended that the new centerline joint be as close to the old centerline joint as possible. The paver was controlled by a nylon line from the shoulder and the centerline joint was usually within an inch of the old centerline joint and it was anticipated that the crack would reflect within an inch of the old joint. In some instances the inspection personnel wrote on the surface of the pavement prior to the second pass on the machine, which way the centerline joint was to be moved when it was sawed so that the joint would reflect through immediately over top of the old joint and prevent two centerline joints in the area. In spite of all this effort, there are some areas where cracks exist adjacent to sawed joints.

The completed roadway is 24' wide, has 6' crushed stone stabilized shoulders and is very adequate to carry the projected 3,000 vehicles per day.

TEST DATA

Much of the concrete placed had a temperature of approximately 90°F at the time of placement (Figure III). After consolidation, placement, sawing of joints, and covering with a thermal blanket, the temperature rise continued under the thermal blanket for several hours but by the next morning it had started to cool (Figure IV). The average strength of beams which were tested with center point loading on this project was 390 psi in eight hours and 490 psi in twelve hours (Figure V). The 24-hour beam strength was 600 psi. The seven-day strength was 720 psi and the 14-day 820 psi. These values show that this was a high strength concrete and it did gain flexural strength rapidly. The rise in compressive strength was not quite as dramatic but was very good. The 8-hour compressive strength of 6 inch by 12 inch cylinders was approximately 1900 psi, over 2500 psi in 12 hours, 3500 psi in 24 hours, 5,000 psi in seven days and 5,300 psi in 14 days (Figure VI and VII).

The mix that was used on this project is paramount to the success of the fast track concrete. The contractor elected to use 640 pound of special Type III cement, and 70 pounds of Type C approved fly ash. It was targeted for 6 1/2 percent entrained air and an approved and compatible water reducing agent was used. Forty-five percent fine aggregate and fifty-five percent coarse aggregate was incorporated into the mix. The slump was maintained at about 1 1/2 inches. The water-cement ratio was generally in the area of 0.43 to 0.45 pounds of water per pound of cement. This concrete was placed during the month of July when the temperatures are in the vicinity of 90°F during the day and slightly over 60°F at night. The temperature under the thermal blanket, the evening following the day that it was placed, generally reached 115°F or slightly more. The flexural strength (center point loading of 6 inch by 6 inch beams) was approximately 600 psi in 24 hours and the bond strength measured by a direct shear test was slightly over 300 psi (Figure VIII and IX). These strengths are considered to be very adequate.

The results from this project have been very successful to date. Test data indicates that this is a very acceptable method of placing concrete and opening it to traffic in 24 hours. As additional data on this type of work is gained and specifications and special provisions are fine tuned, results will be even better than that attained on this first project.

EVALUATION AT ONE YEAR

The project was evaluated again in May 1987 after the first winter. Testing at one year included visual observations, core conditions, and various test results including core compressive strength, direct shear tests on cores for bond strength, profilometer results and Delamtect test results.

In general terms, the pavement condition appeared the same after one year as it was immediately after completion. There was no apparent distress related to traffic usage or to the severe winter conditions.

A close examination revealed a small amount of additional transverse cracking which appeared after one year. This additional cracking is associated with the reflective cracking at mid-panel in the old pavement and apparently was not visible when the majority of reflective cracks were sawed with a crack saw and sealed. Initially, those joints that deviated more than one inch from the stringline were allowed to reflective crack. About six months after construction of the overlay, a small diameter crack saw was used to yield a reservoir. The reservoir was then filled with Sof Seal joint seal material. As estimated, 3500 feet of additional crack sawing and sealing was done.

At isolated locations a multiple transverse crack pattern has developed in the vicinity of the mid-panel cracks in the old pavement and there is also a tendency for minor debonding to occur at the mid-panel cracks. The Delamtect report is attached and shows delamination in the direct vicinity of the transverse reflective cracks. Debonding is very minor and based on past experience is not considered a serious threat to long term performance.

The cause of the debonding is thought to be related to the slight crack closure in the old pavement after overlay placement and during the time of maximum temperature while the insulated covers were in place. Even though crack closure was restricted by incompressibles in the crack, it appears there was enough minor closure to cause a tendency for debonding. This same condition appears to have caused the minor amount of multiple transverse cracks in these same areas.

TESTS CONDUCTED AT ONE YEAR

Compressive strength of the concrete as shown by the strength of cores is very high and shows normal continued strength gain since the previous summer. In general, the concrete containing calcium chloride is a little higher strength than concrete without calcium chloride (Figure XI).

The average strength of age 295 days was as follows:

Noncalcium Chloride	1% Calcium Chloride
Avg. of 3 - 6160 PSI,	Avg. of 3 - 6690 PSI

Direct shear testing at the bond line shows the average bond strength has decreased slightly. The decrease is considered minor and not significant. The bond strength is a little lower than anticipated but is satisfactory and well above the minimum considered necessary to cause the old pavement and the new overlay to work together as a structural unit.

Surface Treatment	Shear Strength (PSI)	Avg. Shear Strength (PSI)
Type I Grout	338	
	294	316
Type III Grout	358	
	318	
	294	
	411	345
Non Grouted	223	
	207	215

Type I Grout & Double Shot Blast	139	
	219	
	398	252

Three 1000 feet long test sections were selected for debonding study. The Delamtect tested along centerline in each direction within one or two feet of centerline. Results are shown in the attached Delamtect survey tabulations. The abbreviations LT and RT represent left and right wheel tracks respectively. It is noted nearly all delamination occurs in the left track near centerline.

Based on these results delamination percentage could be calculated as follows:

10-28-86

$$\frac{\text{3 linear feet of delamination}}{6000 \times 100} = 0.05\%$$

4-14-87

$$\frac{\text{41 linear feet of delamination}}{6000 \times 100} = 0.68\%$$

Although delaminations have increased since initial testing, it is considered minor and is not cause for concern.

Road Rater deflection testing was completed June 23, 1986 just prior to overlay construction. It was repeated April 4, 1987. The average structural rating (SR) at mid-panel in 1986 prior to overlay was 3.49 and at the joints was 3.27. The average soil K values in 1986 were 58 at mid-panel and 76 at the joints. In 1987 the average SR at mid-panel is 6.04 and at the joints is 4.21. The average soil K values in 1987 are 144 at mid-panel and 175 at the joints.

These test results show significant improvement in the pavement structural system, which is thought to result from several beneficial features: additional composite pavement thickness, relocating the outside wheel track to a position where the pavement thickness is at a maximum, improved subgrade conditions resulting from longitudinal drains and surface joint sealing, and improved structural capacity because of the tied and monolithic widening.

Road Rater test results show the new composite unit is structurally adequate to carry current and projected traffic.

Profilometer testing was accomplished by the contractor in 1986 following overlay placement. Profilometer testing was accomplished by the Iowa Department of Transportation April 10, 1987.

Results for representative sections are as follows:

	Profile Index (in./mi.) 1986	1987
Station 498+94 to 502+26 SB	13.50	11.50
521+41 to 526+69 NB	8.00	7.50
576+00 to 581+28 NB	18.50	20.50
628+60 to 633+88 NB	16.50	13.00
719+64 to 724+92 NB	9.50	8.50

These results are interpreted to show there was no perceptible deterioration of the ride quality since rehabilitation construction in 1986.

Debonding tape was placed over three transverse cracks in the old pavement just prior to overlay placement. The tape was 4 mil plastic by 4 inches wide with adhesive on one side. It was placed transversely across the driving lane and about 8 inches wide (two widths alongside each other) so that the total tape width covered the old transverse crack. The overlay was then placed and contraction joint was sawed full depth of the overlay inside the bounds of the debonding tape. The goal was to control reflective cracking in the overlay and transform a crack in the old pavement into a straight sawed joint in the overlay.

Results to date are very encouraging. Three cracks full width of the old pavement were treated with debonding tape. This made a total of 6 separate one lane applications (separate NB and SB lane construction). Five of the six one lane applications are blemish free. One of the six has a small scallop shaped crack deviating from the saw cut about three inches. These results certainly warrant additional trials of this localized debonding procedure so that reflective transverse cracking is minimized.

Reflective cracking over longitudinal cracks in the old pavement has generally been controlled by using #5 x 30 inch tie bars placed across the crack at two foot intervals. The tie bars are held in place by clamps attached to the old pavement with powder driven nails. A visual inspection in September 1990 identified some longitudinal cracking.

The joint between the widening and old pavement has been examined in some detail. There is some reflective cracking over the widening joint.

SUMMARY

The last visual inspection made in September of 1990 showed that a few new cracks have developed since crack sealing had been done. They were mainly transverse cracks with some angular cracks originating at the transverse cracks. Some small sections of broken concrete were located next to transverse cracks and expansion joints. A large percentage of the foamed expansion joint material has partially or completely come out of the sawed four-inch expansion joints.

In summary, the pavement condition and performance is considered very satisfactory and is expected to give good service for an extended number of years. The concept of single lane construction to permit usage of the adjacent lane for public and construction traffic is considered viable.

Additional information and experience is needed on future projects to explore controlling reflective transverse crack by using debonding tape. If this is successful, debonding near the transverse cracks and associated multiple cracking because of elevated curing temperature will be eliminated or minimized.

An Iowa Department of Transportation review panel of design, construction and materials pavement specialists viewed this project along with 8 other bonded overlay projects in April 1987 and based on their judgment projected a service life for this project of 20 to 30 years.

CONCLUSIONS

This research on thin bonded concrete overlay with fast track concrete supports the following conclusions:

1. The bonded overlay is performing well with a projected life of 20 to 30 years.

2. Random reflective transverse cracking has been minimized with the use of debonding tape.

3. The use of fast track concrete makes it possible to open roads to the public in 24 hours.

Appendix
Figures of Sketches and Graphs

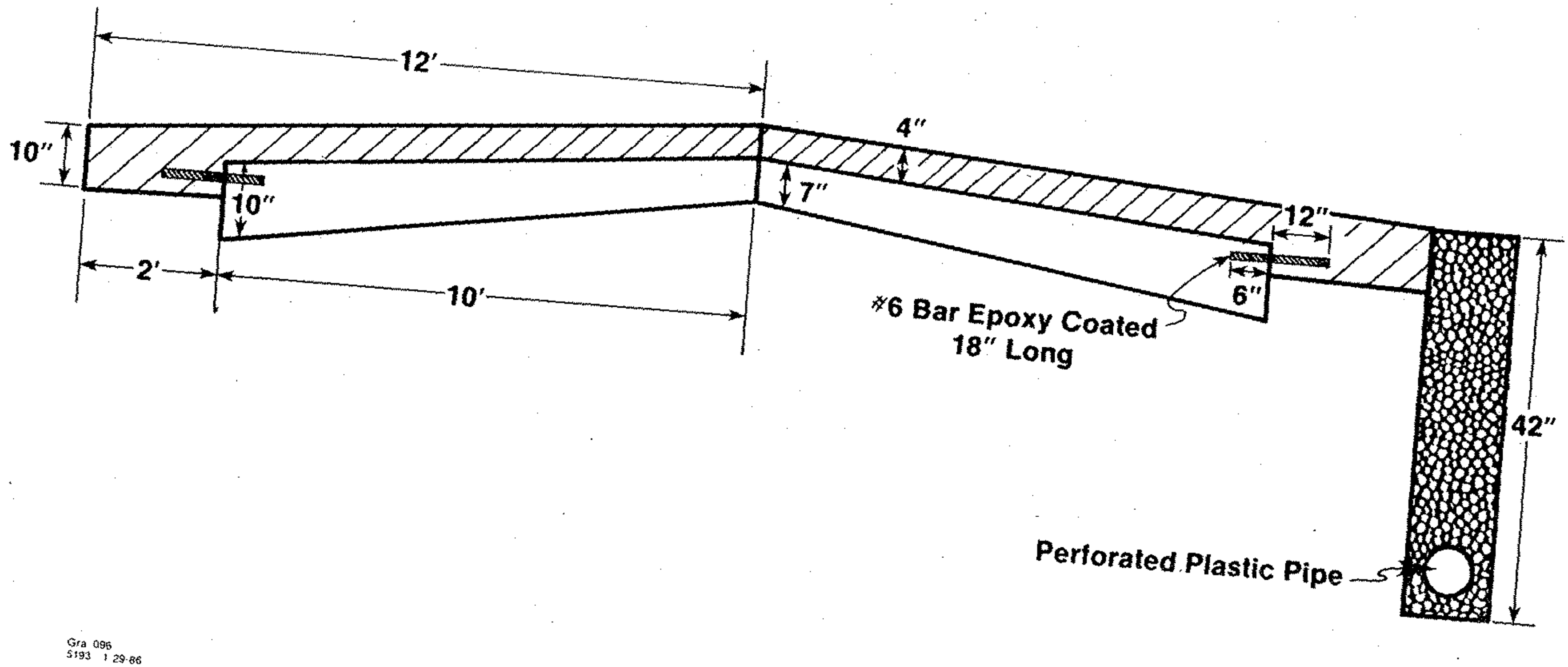


Figure I
Typical Section

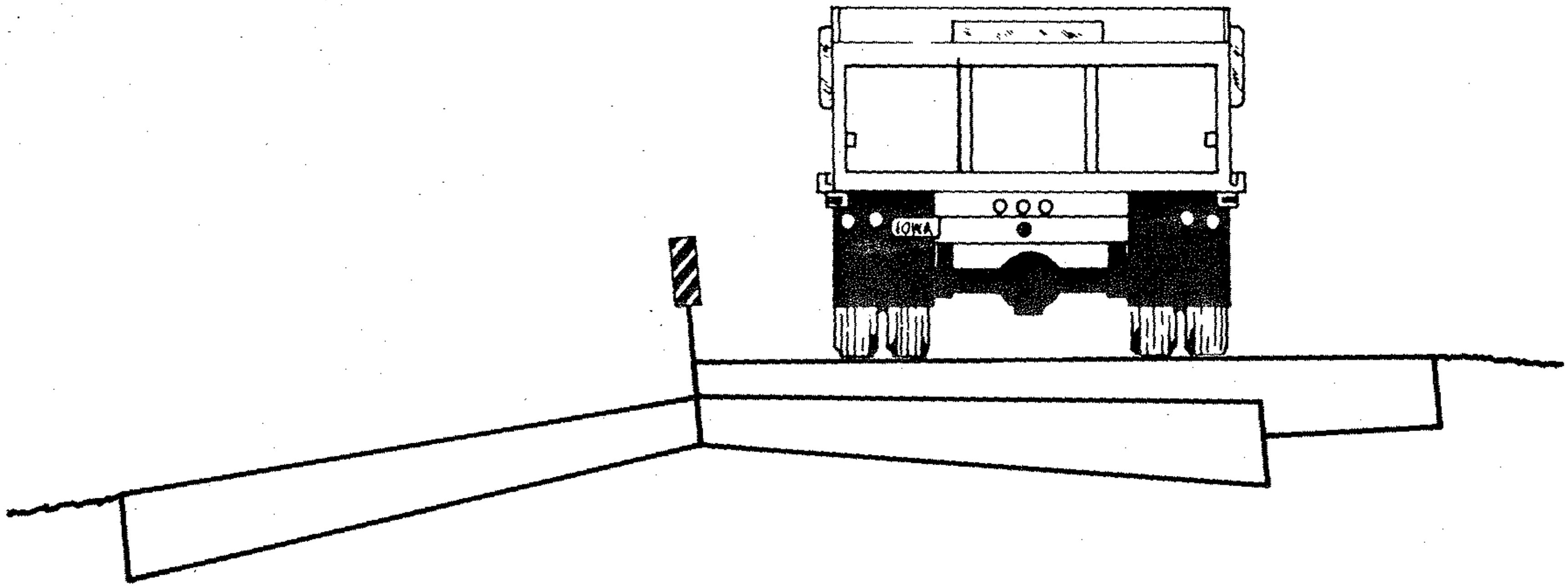


Figure II
Single Lane Construction Schematic

Figure III

IOWA FAST TRACK CONCRETE

CONCRETE MIX TEMPERATURE

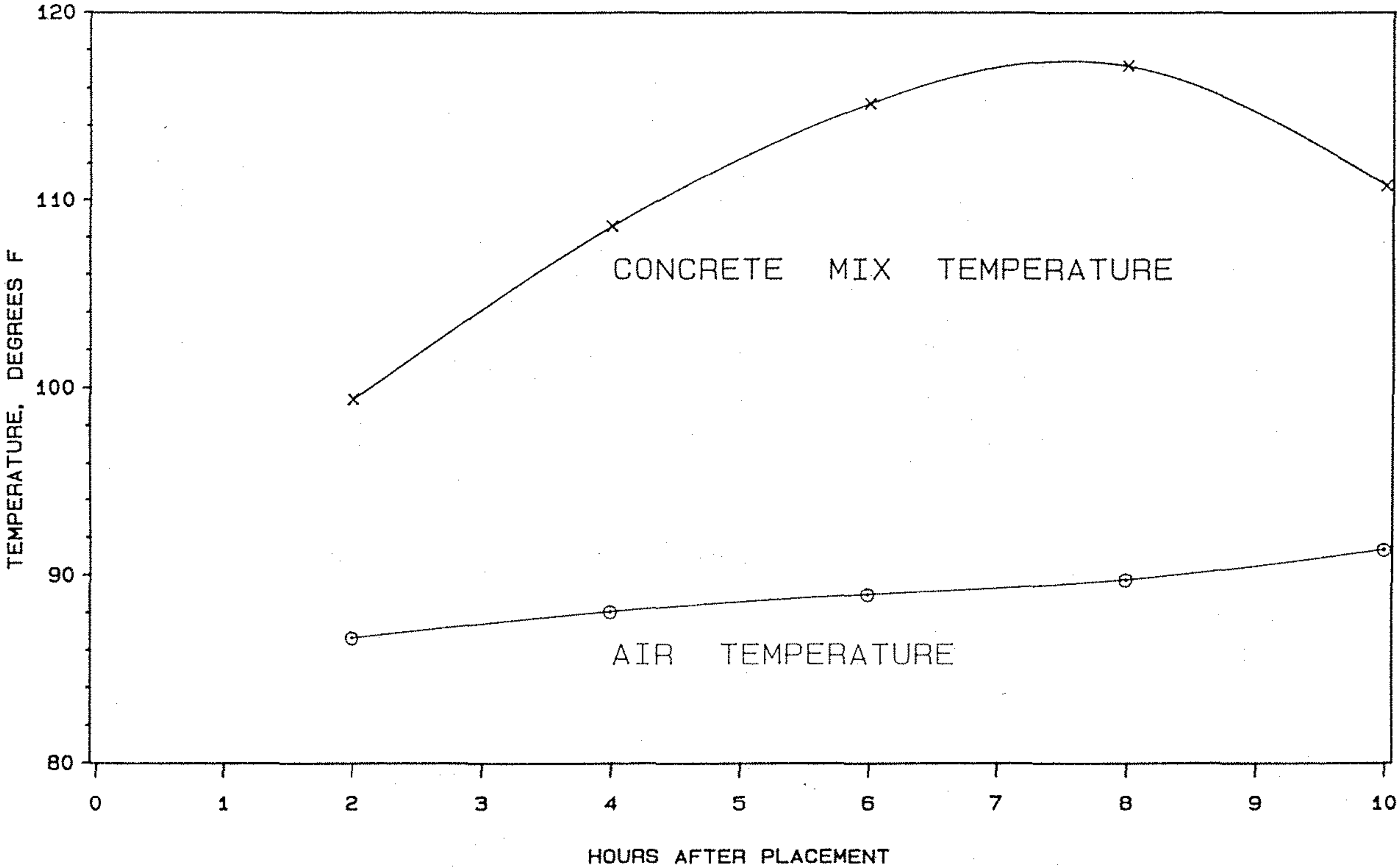


Figure IV

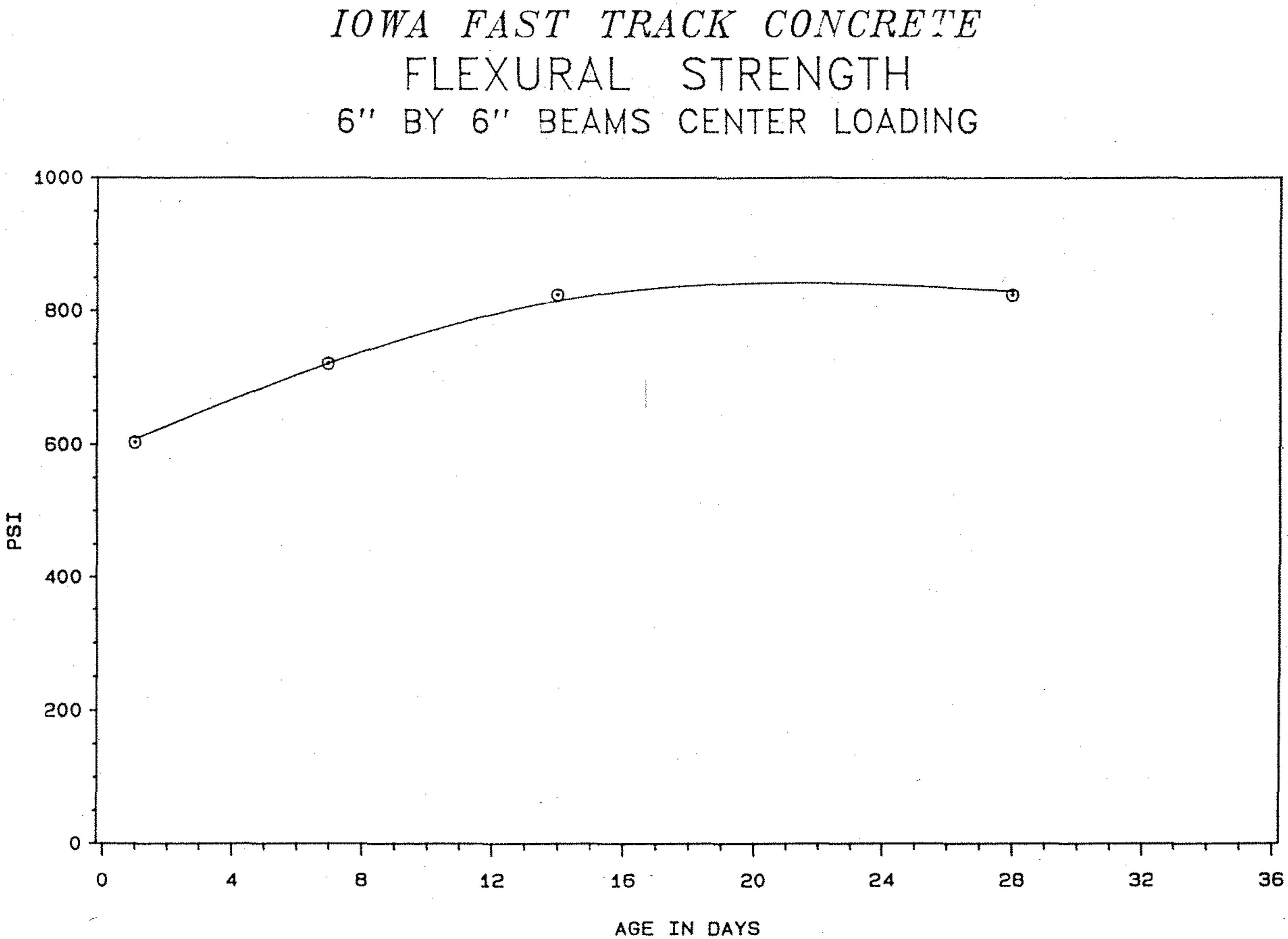

IOWA FAST TRACK CONCRETE
FLEXURAL STRENGTH
6" BY 6" BEAMS CENTER LOADING
1000
800
600
400
200
0
PSI
0
4
8
12
16
20
24
28
32
36
AGE IN DAYS

Figure V

IOWA FAST TRACK CONCRETE
FLEXURAL STRENGTH
6" BY 6" BEAMS CENTER LOADING

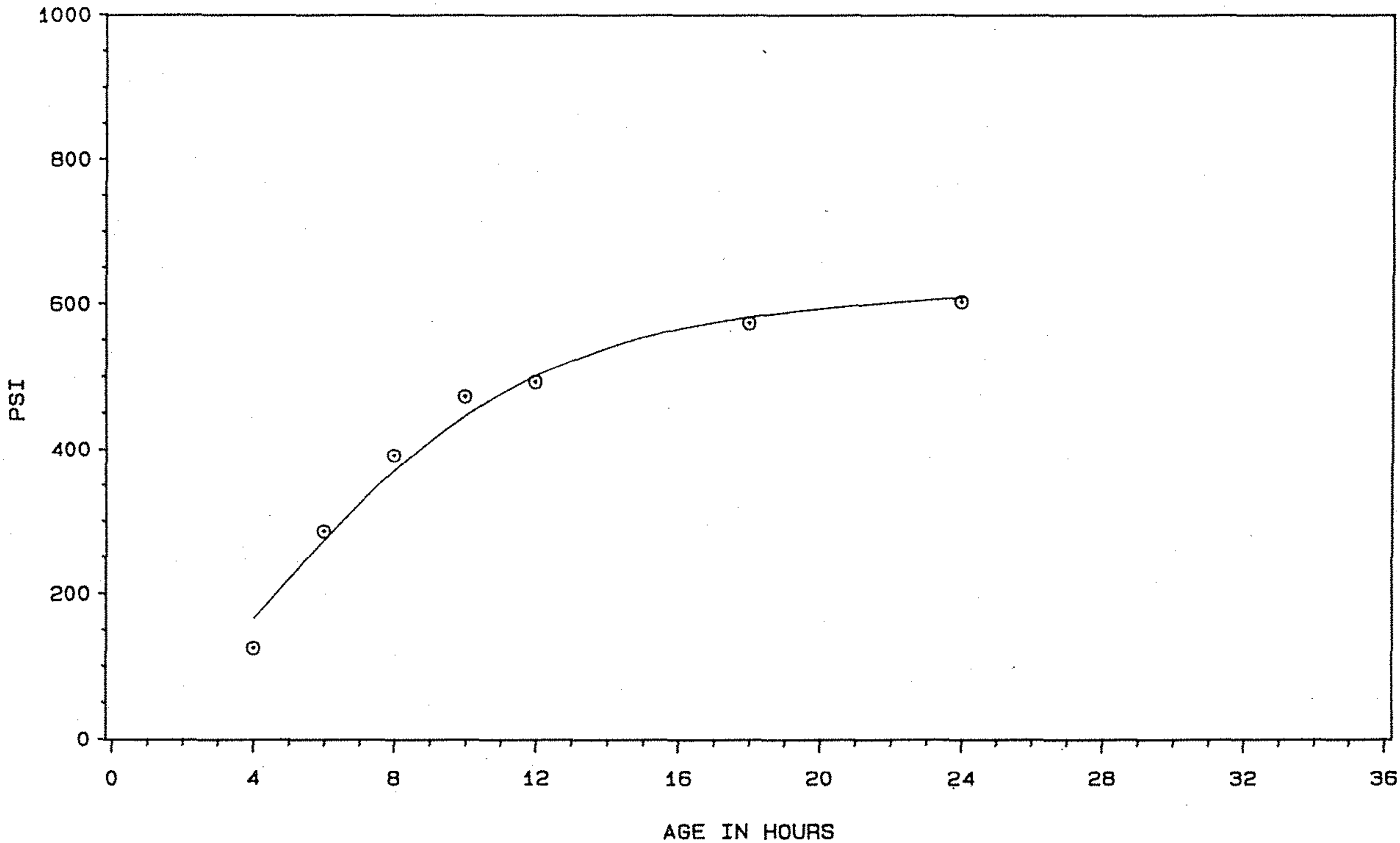


Figure VI

IOWA FAST TRACK CONCRETE

COMPRESSIVE STRENGTH

6" BY 12" CYLINDERS

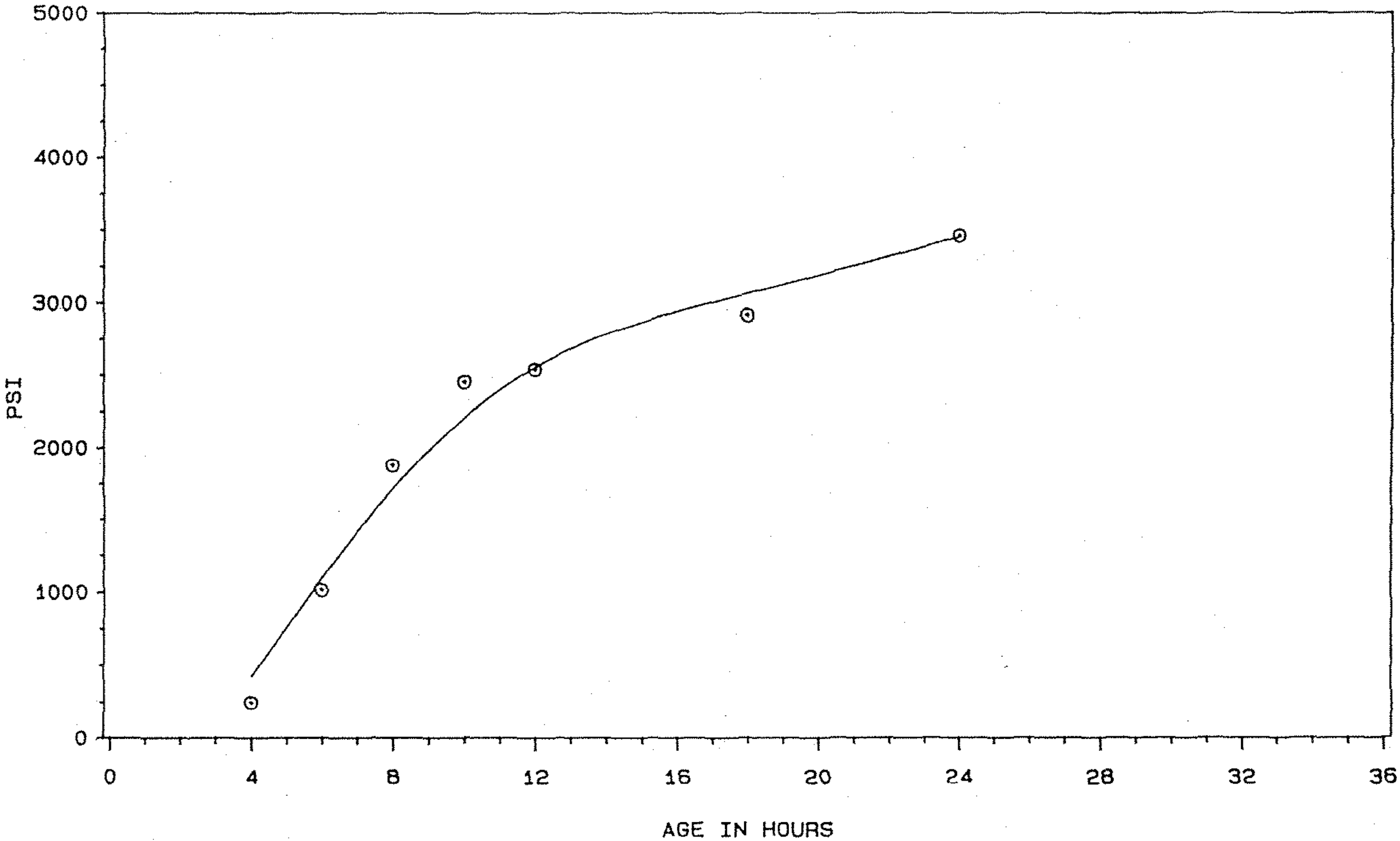


Figure VII

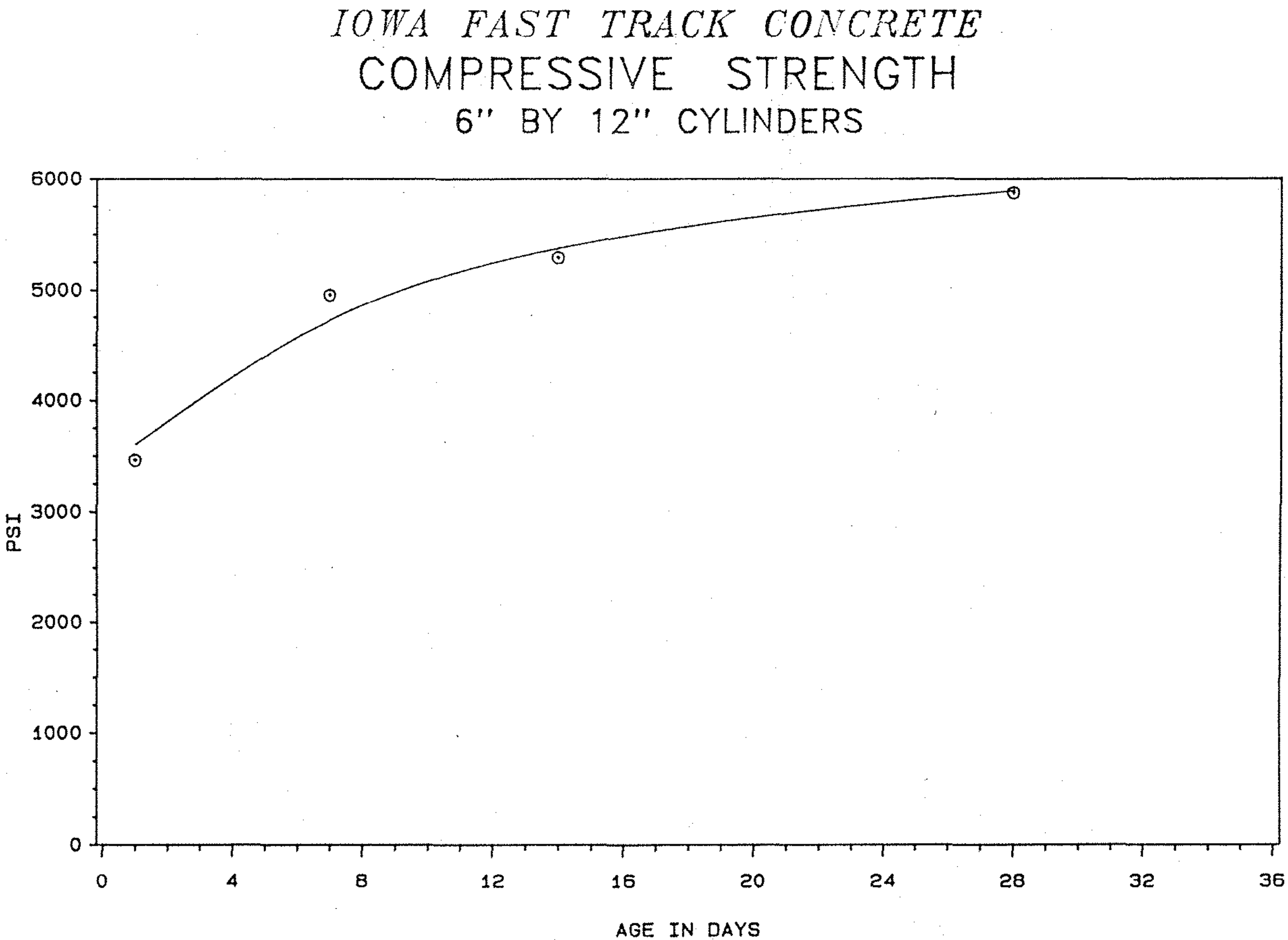

IOWA FAST TRACK CONCRETE
COMPRESSIVE STRENGTH
6" BY 12" CYLINDERS
6000
5000
4000
3000
2000
1000
0
PSI
0
4
8
12
16
20
24
28
32
36
AGE IN DAYS

Figure VIII

IOWA FAST TRACK CONCRETE
SHEAR STRENGTH
4" CORES

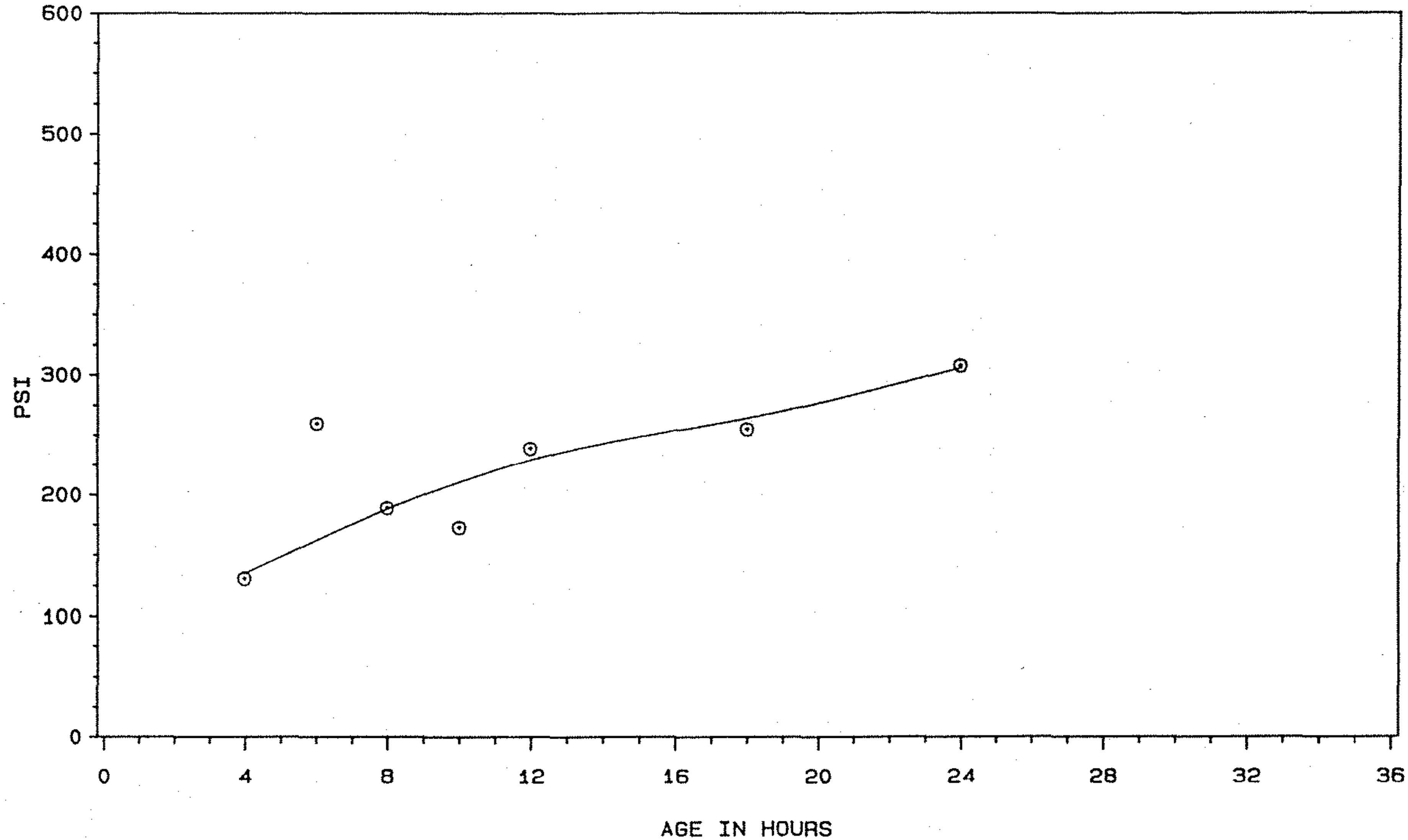
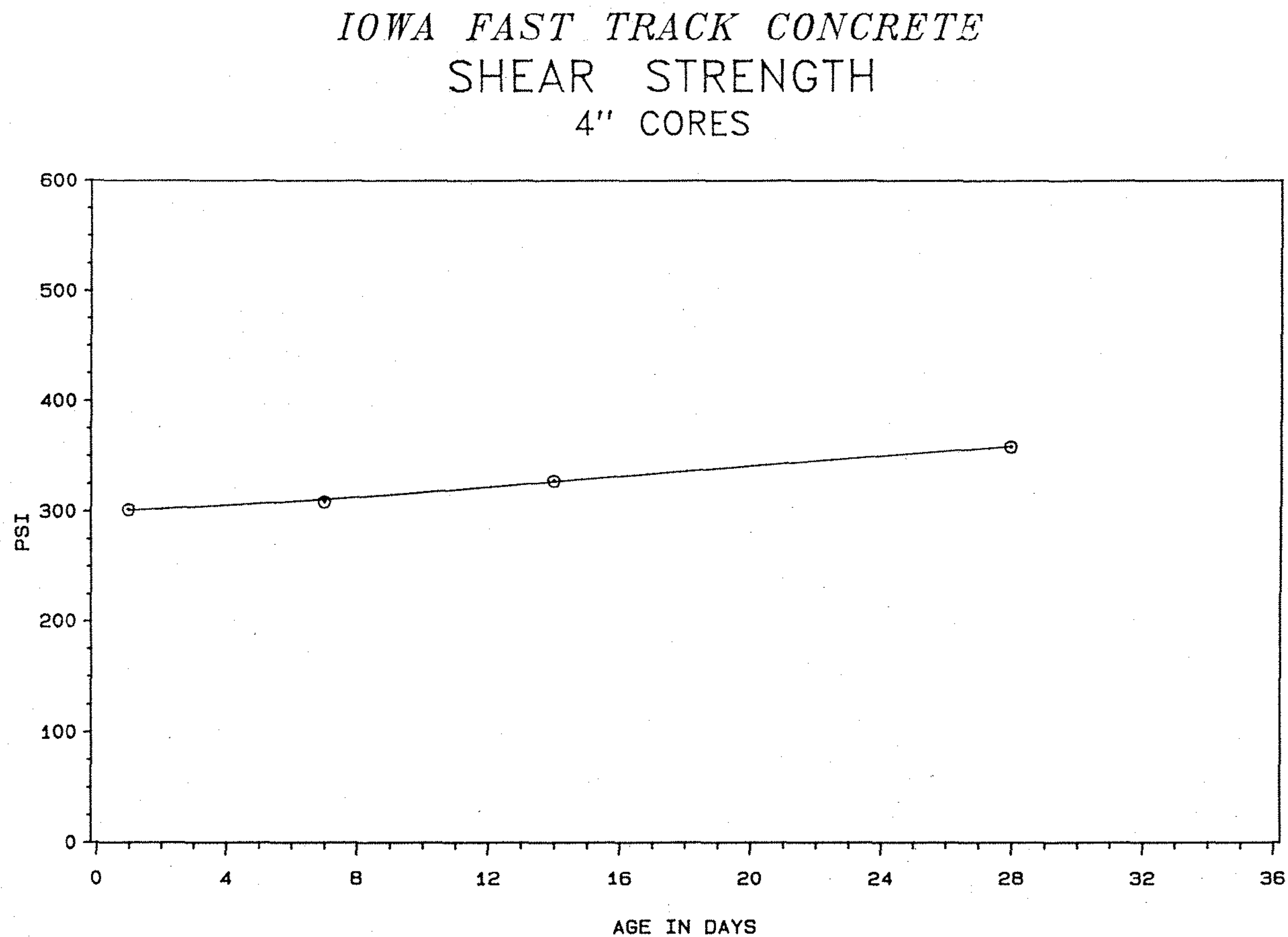


Figure IX



IOWA FAST TRACK CONCRETE
SHEAR STRENGTH
4" CORES
PSI
600
500
400
300
200
100
0
0
4
8
12
16
20
24
28
32
36
AGE IN DAYS