Maturity Value Determination for Fast Track Paving

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MATURITY VALUE DETERMINATION
FOR
FAST TRACK PAVING

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ABSTRACT

The two major exit ramps to Interstate 5 in downtown Seattle, Washington needed to be reconstructed. High volume of traffic and high incident of accidents required less closure time for construction. Therefore, paving was conducted with fast track concrete mix and maturity was monitored to determine opening strength for concrete.

Both maturity and fast track has been around for some time now however, the idea of concrete maturity to determine the opening strength for pavement is a relatively new concept. Prior to the field application of fast track concrete mix and concrete maturity, numerous tests were conducted. Tests included the maturity value determination for an opening flexural strength of 400 psi and the insulating factor needed for fast track paving.

Test results showed that a maturity value of 400 °C-hour is needed for a flexural strength of 400 psi. And also, an insulating factor of 3 (R=3) is sufficient to obtain the opening flexural strength of 400 psi in eight to twelve hours after placement of concrete. With this test information, paving was performed at the ramps of the Albro St. and Spokane St. exits. Pavement achieved the required opening strength of 400 psi in eight to eleven hours after placement of concrete. Reconstruction of the ramps were completed in two days with fast track paving.

INTRODUCTION

Maturity concept has been around since 1904. Concrete maturity is defined as the extent of cement hydration in the concrete mixture. Provided there is sufficient moisture, maturity at a given concrete age is primarily a function of the temperature history. Maturity is evaluated from the recorded temperature history of the concrete by computing the temperature time factor of the concrete. Maturity has been extensively used in the past for investigation of failure of concrete structures since early 1970's. However, in recent years maturity has been used to determine concrete strength for early opening to traffic.

Fast track paving has been in use since 1986 and most of the experience has been in Iowa. Experiences with fast track paving which uses conventional equipment and techniques have shown that it is a viable construction alternative for certain locations. Fast track paving utilizes a special concrete mix with high cement factor and insulating blankets in the initial cure process.

Two project sites selected for the application of fast track paving and maturity concept were the ramps on the Spokane street and Albro street exits in Seattle, Washington. High volume of traffic and high incident of accidents in this area concerned the construction office. Project plans for construction of these ramps during an extended period of partial closure were judged too accident prone. An acceptable alternate was the total closure of the ramps for a short term over the weekend. They wanted a solution which would have minimum impact to the traffic during construction which meant less closure time. Therefore, fast track concrete was considered. The ramps would be closed from Friday night till Monday morning. This would provide sufficient time for the contractor to set up traffic control, prepare for paving and open to traffic.

Before the field application of fast track and maturity concept tests were conducted to determine the minimum maturity value needed for flexural strength of 400 psi, the amount of insulation needed for fast track paving, and the strength comparison between beam specimens and pavement.

OBJECTIVE

This study had several objectives which are as follows :

a) Evaluate a specific concrete mix for its characteristic ability to attain the flexural strength within the restricted time.

b) Determine the minimum maturity value needed to obtain flexural strength of 400 psi.

c) Determine the amount of insulation needed for fast track paving.

d) Use fast track paving to obtain early opening strengths.

PROJECT DESCRIPTION

The project sites were the two major exit ramps (Albro street and Spokane street exits) from Interstate 5 at Seattle, Washington as a part of construction of HOV lanes in the area. The work involved widening by replacing the 26 year old pavement with .35ft of asphalt treated base (ATB) and 10" P.C.C. pavement on the two exit ramps. Pavement sections placed were approximately 850ft in length and 4.5ft to 21ft in width at Albro street and 1015ft in length and 5.5ft to 15.5ft in width at Spokane street. Figure 1 shows the project sites. The amount of fast track concrete placed was 1022 sq.yds. at Albro street and 1050 sq.yds. at Spokane street.

Current traffic on the northbound on ramp from Albro st. is 7415 yearly ADT and 19,165 yearly ADT on the northbound off ramp to Spokane st. Paving with the conventional concrete mix would have required sixteen days of closure time while with the fast track concrete mix, the ramps were open to traffic in two days for each installation.

MATERIALS AND CONSTRUCTION

MATERIALS

Fast track concrete mix consisted of the following materials :

Cement (Ashgrove Type III)	- 752 pounds
Coarse Aggregate (Stoneway A-338)	- 1802 pounds
Fine Aggregate (Stoneway A-338)	- 1140 pounds
Air Entraining Agent (Daravair) (W. R. Grace & Co.)	- 2.5 oz
Water Reducer	
(WRDA - 79) Normal Range (Type A)	- 3.0 oz
(WRDA - 19) High Range (Type A/F)	- 10.0 oz
(W. R. Grace & Co.)	

Conventional concrete pavement mix consists of 565 pounds of Type II cement with a design flexural strength of 650 psi at 14 days. Fast track concrete mix contains 752 pounds of Type III cement achieved a flexural strength of 400 psi at 8 to 11 hours. Refer to Table 1 for fast track concrete mix proportions.

CONSTRUCTION

The project was contracted out to David A. Mowat of Seattle, Washington for an original contract amount of $24 million however, additional change orders have brought the contract up to $31 million. General weather condition during paving was clear and warm with daytime highs in the 80's - 70's and night time lows in mid-50's.

Placement of fast track concrete was done under a change order modifying the traffic control plans and had a net increase cost of $ 124,000. Paving on the ramps of Albro street and Spokane street exits took place on a Saturday night July 18th and September 12th 1992. Paving started at 7:00 PM and was done by 3:00 AM next morning. Cooler temperatures in September did affect the temperature and strength gain.

Concrete for the paving was supplied from local ready mix plant (Stoneway Concrete) four miles from the project site. Due to the variation in width of pavement, and for less inconvenience for the paving operation, the contractor was allowed to use a screed and handheld vibrators for placement of concrete. Delivered concrete temperature for the ramps were 85°F at Albro st. and 76°F at Spokane st.. After placement, concrete was cured with white pigmented curing compound then covered with an insulating blanket with an insulating factor of 3 (R=3).

Insulating blankets were placed 1 to 2 hours after placement of the concrete in order to avoid marring of the surface. The transverse and longitudinal pavement joints were sawed as soon as the pavement had sufficient strength to support the equipment and the sawing operation did not dislodge any aggregate. The insulating blankets were only removed in the vicinity of the sawing operation and replaced as soon as the sawing for a joint was finished. After the cure blankets were removed, the joints were sealed with the hot pour material.

TESTING

Fast track concrete mix was tested for the following :

a) To determine the minimum maturity value needed for flexural strength of 400 psi.

b) Measure the effectiveness of different cure environment by varying the amount of insulation (R=0 value to R=8).

c) Strength testing to compare beam and pavement for strength development.

d) Field application of fast track concrete mix and maturity.

At the Ashgrove cement plant in Seattle, Washington on June 24,1992 testing was conducted on fast track concrete mix. A slab (20' X 20' X 10") and twenty beams (6" X 6" X 21") were cast. The concrete was batched at Stoneway's batch plant at east marginal way Seattle, Washington and delivered to the plant site.

Concrete was delivered to the test site in two loads of about four cubic yards each. To simulate actual placement conditions, each load of concrete was held in the truck at the test site for approximately 15 to 20 minutes which was the anticipated travel and set up time to discharge. Mix adjustment for slump and entrained air were made after the designated waiting period. All of the first load delivered was used in the test panel. After the designated waiting period, about two wheelbarrow loads of the second load was discharged into the test panel and then the sample for making all the test specimens was taken.

Maturity was monitored on beams and test slab. Beam specimens were cured under different cure environments.

Unprotected specimen	- Cured under normal condition.
Protected specimen	- Cured on ground with moisture retention covering and cure blanket (R value of 3).
Insulated specimen	- Cured on insulated board with moisture retention covering and cure blanket (R value of 8).

Maturity meter used to monitor the concrete temperature was an M-meter (M-3004) from James Instruments Inc. It is primarily a battery operated microprocessor-based system which reads temperature and records hourly the temperature sensed by the sensor. M-meter (maturity meter) takes readings at 0.1 hour and uses a -10°C as the datum temperature. Therefore, these factors should be taken into consideration for concrete maturity value calculation. When using the M-meter, the maturity value is based on °C-.1 hour.

Two M-meters were used on this study. A low temperature meter which read up to 40°C and a high temperature meter which read up to 80°C. During the monitoring of concrete temperature at the test site, the maturity meter (M-meter) went inactive, this is mainly due to the use of a low temperature M-meter which only read up to 40°C. For the actual pavement work, a high temperature M-meter was used.

Test slab was cured with moisture retention covering and cure blanket (R=3). Beams for flexural testing were cured at R=3. Specimens were tested for flexural and compressive strengths starting six hours after specimens were made and then were tested at two hour intervals. At each test, two specimens were tested and the test results, temperature and maturity was recorded.

At the two exit ramps, fast track concrete mix was used for paving with insulating blanket, and was monitored for maturity. Based on the test results the pavement gained strength in 8 to 11 hours for a flexural strength of 400 psi.

The test results are listed in Table 2,3,4 and shown graphically in Figures 2 and 3. Figure 3 was used to determine the required maturity level to attain the necessary flexural strength. It was developed by plotting maturity values against strength for the samples cured at an R value of three - Modulus of rupture and Channel 2 maturity from Table 4.

SUMMARY AND CONCLUSION

Maturity value of beam and pavement were not similar. Comparison of the maturity values between pavement and beam show a higher value for pavement. This is due to the massive amount of concrete in pavement versus the beam which has a significant affect on the heat of hydration and temperature generated. Therefore, the temperature and strength gain is higher for pavement when compared to the beam. Based on test results and observations beam strengths are not good indicators of pavement strengths. However, a maturity value based on beam strength is a conservative value.

Maturity value of 400 °C-hour was reached at the two exit ramps at 7 to 8 hours at Albro st. and in 10 to 11 hours at Spokane st.. Temperature and maturity gain in the pavement at Spokane st. exit ramp was gradual. This gradual increase is due to cooler air temperature, wind chill and improper placement of insulating blanket. The two exit ramp pavements obtained a maximum temperature of 150°F at Albro st. and 120°F at Spokane st..

Based on the test results the following can be concluded :

1. A flexural strength of 400 psi was obtained at an maturity value of 400 °C-hour with insulating factor of 3 (R=3).

2. Beam strengths are not good indicators of pavement strengths.

3. A insulation factor of 3 was sufficient to obtain the required strength and maturity. A higher insulation factor did not have a significant affect on the temperature or maturity.

4. Fast track concrete mix did attain the required maturity for opening of 400 °C-hour in 8 to 11 hours.

5. Fast track is a pratical alternative for certain critical situation especially in urban areas.

RECOMMENDATIONS

1. Fast track concrete pavements at the two exit ramps should be monitored for performance.

2. Concrete maturity for fast track concrete mix should be further evaluated for structural applications.

3. Further studies should be conducted on maturity so that concrete strength can be determined based on maturity versus compressive or flexural strength.

4. A simple electronic temperature recorder could be used instead of M-meter to monitor concrete temperature. The datum temperature for reference purposes can be considered to be 0°C since a relative maturity value will be sufficient for determining concrete strength.

ACKNOWLEDGEMENT

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TABLE TITLES

TABLE 1

FAST TRACK CONCRETE MIX

Cement (Type III)	752 pounds
Fine Aggregate	1140 pounds
Coarse Aggregate	1802 pounds
Water	270 pounds
Air Entraining Agent	2.5 oz
Water Reducer	
Normal Range (Type A)	3.0 oz
High Range (Type A/F)	10.0 oz
Water / Cement Ratio	0.36
Air	5 +/- 1.5 %
Slump (maximum)	5 inches

TABLE 2

MATURITY TEST RESULTS

AGE (HRS)	BEAM	TEST SLAB	PAVEMENT ALBRO ST.	PAVEMENT SPOKANE ST.
1		26	78	29
2			117	58
3		71	156	89
4			201	121
5	137	183	258	155
6			320	192
7	209	276	385	233
8			452	279
9	284	390	521	331
10				387
11	379	504		445
13	489	618		
15	577	732		
17	668	846		
19	761	960		
21	847	1,074		
23	931	1,184		
25	1,013	1,292		

TABLE 3

PAVEMENT TEST RESULTS

AGE (HRS)	ALBRO ST.		SPOKANE ST.	
	TEMP. °C	MATURITY	TEMP. °C	MATURITY
1	29	78	19	29
2	29	117	19	58
3	29	156	21	89
4	35	201	22	121
5	47	258	24	155
6	52	320	27	192
7	55	385	31	233
8	57	452	36	279
9	59	521	42	331
10			46	387
11			48	445
13				
15				
17				
19				
21				
23				
25				

TABLE 4

BEAM TEST RESULTS

AGE (HRS)	* MODULUS OF RUPTURE (PSI)	TEMPERATURE °C				MATURITY			
		CHAN.1 PLASTIC	CHAN.2 BLANKET R = 3	CHAN.3 BLANKET R = 8	CHAN.4 BLANKET R = 8	CHAN.1 PLASTIC	CHAN.2 BLANKET R = 3	CHAN.3 BLANKET R = 8	CHAN.4 BLANKET R = 8
5	16.75	29	29	28	27	136	137	134	134
7	135.14	35	34	34	34	206	209	203	200
9	270.44	38	41	40	40	278	284	273	271
11	378.33	36	40	40	40	367	379	368	366
13	484.94	33	39	39	40	465	489	476	476
15	566.58	32	38	39	40	541	577	546	566
17	549.50	31	37	39	40	619	668	657	661
19	583.64	29	36	38	39	699	761	753	759
21	538.65	27	35	37	38	771	847	844	851
23	675.62	27	34	37	37	841	931	933	941
25	708.46	28	34	35	35	911	1,013	1,020	1,028

* CENTER POINT LOADING

FIGURE CAPTIONS

PROJECT SITES

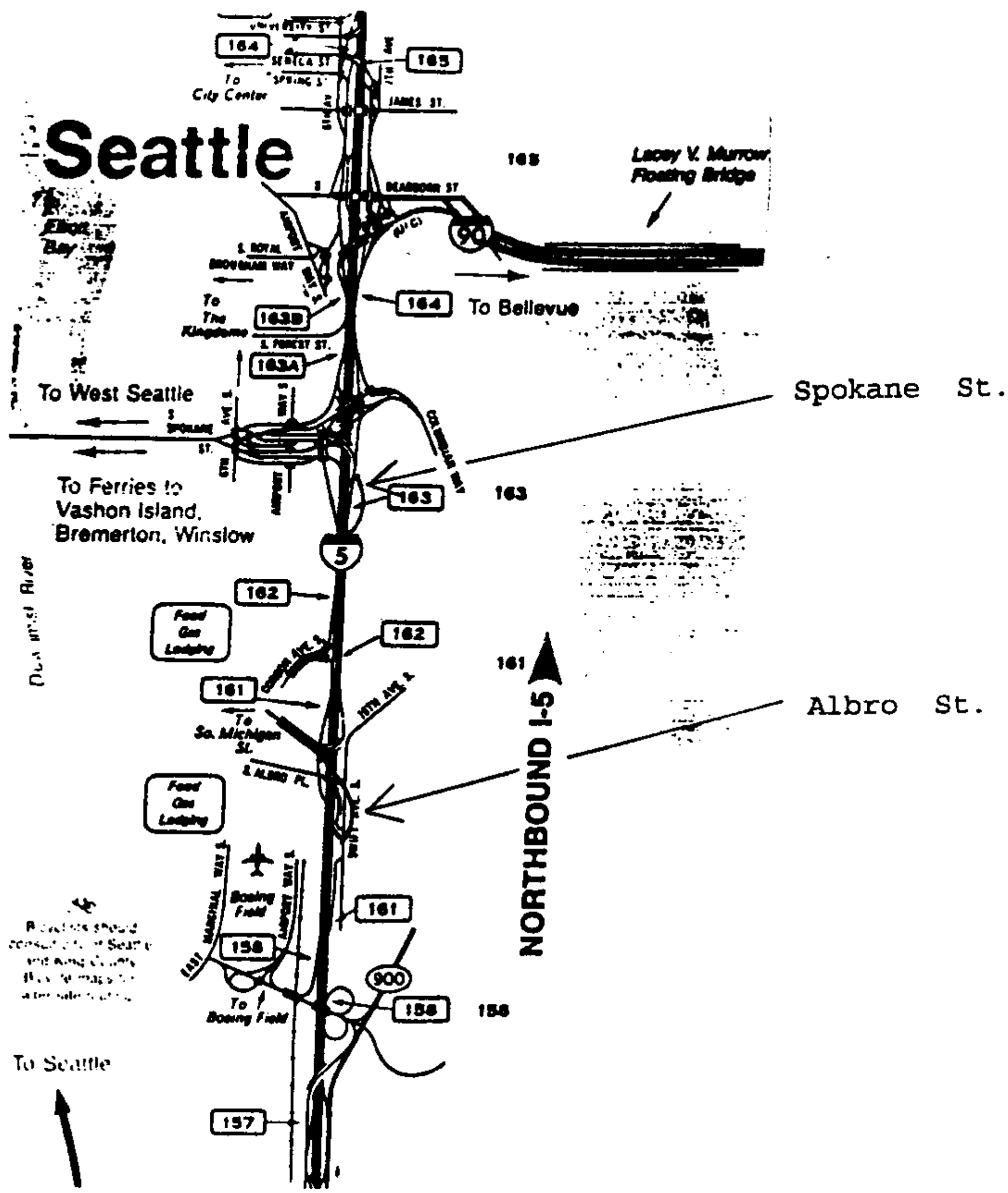

FIGURE 1

TIME VERSUS MATURITY

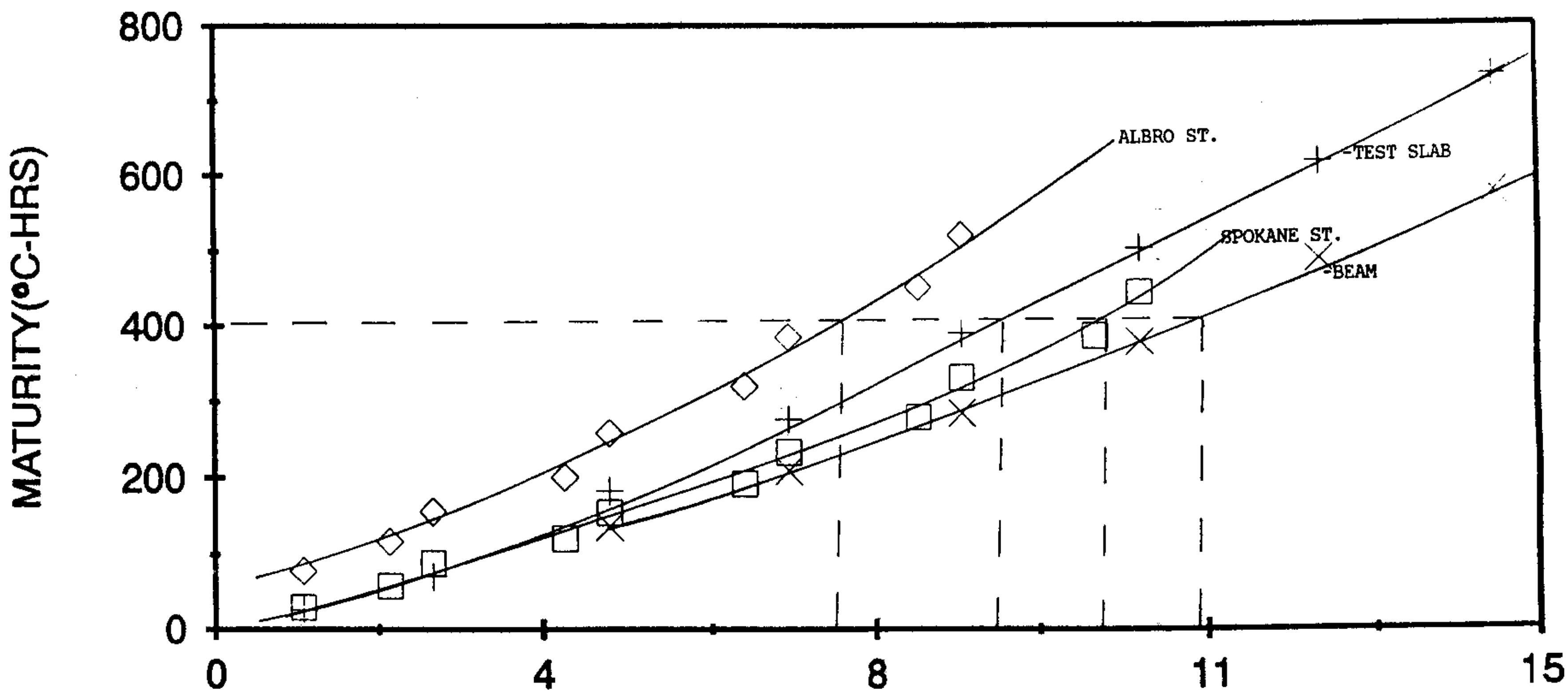

FIGURE 2

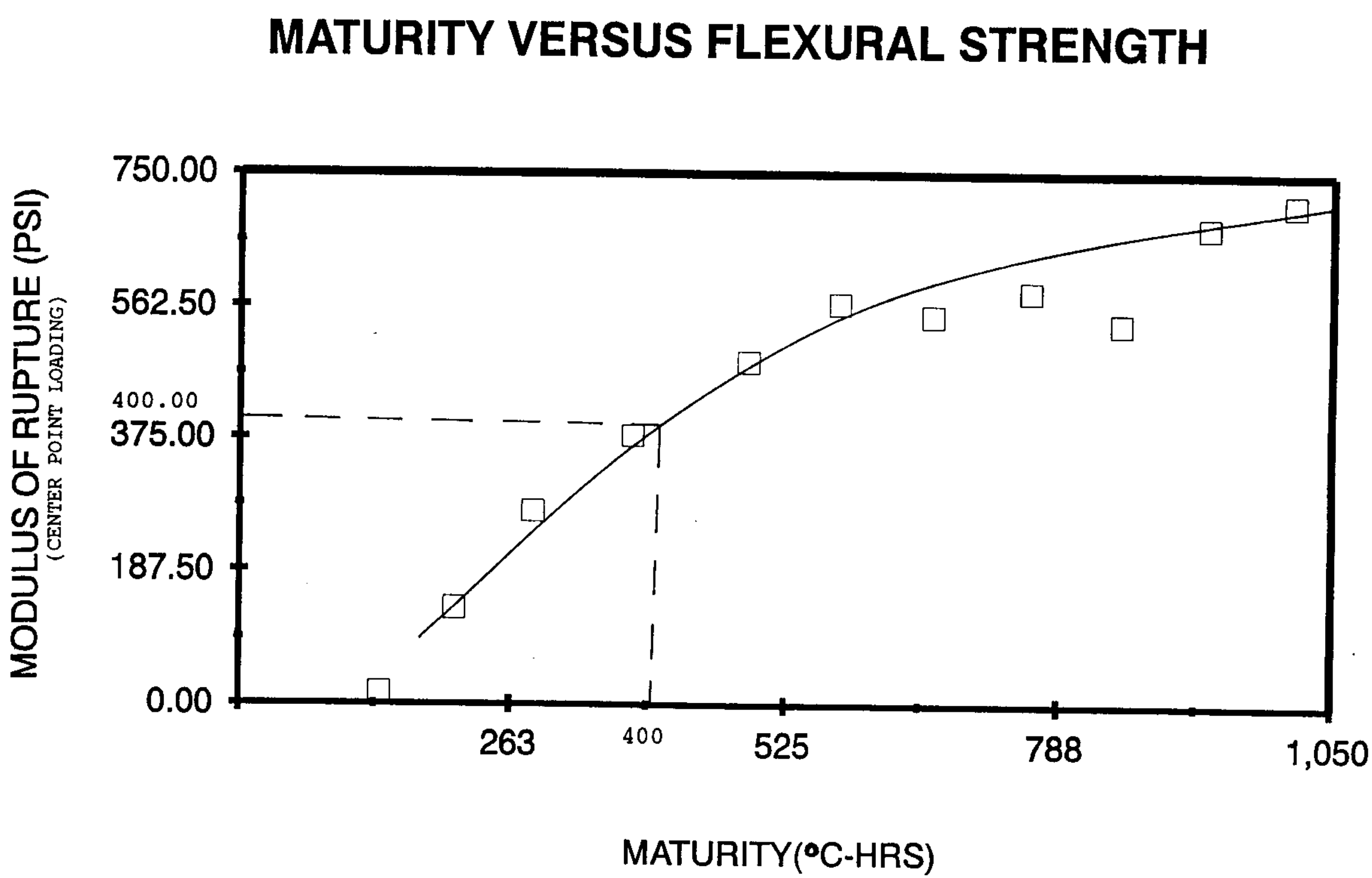
MATURITY VERSUS FLEXURAL STRENGTH
750.00
562.50
400.00
375.00
187.50
0.00
MODULUS OF RUPTURE (PSI)
(CENTER POINT LOADING)
263
400
525
788
1,050
MATURITY(°C-HRS)

FIGURE 3