Louisiana Transportation Research Center

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Implementation of Maturity for Concrete Strength Measurement and Pay

by

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16. Abstract

The current construction climate continually requires a more rapid response time for concrete form removal, early age strengths, and opening strengths. This project piloted the maturity method on one structural project and one pavement rehabilitation project. As part of the implementation project, district personnel were taught about the use of maturity to determine compressive strength and trained on creating a maturity curve, placing sensors, and validating the curve. Cylinders were cast, cured, and tested in the laboratory to establish a maturity curve for the job mixtures. A total of four maturity curves were developed for this project although only two were used on field implementation projects. The two mixtures used for field implementation included a high supplementary cementitious material structural class mixture that required 3500 psi for form removal and a 4-hour 3000 psi mixture that was used for full-depth patching. The two mixtures not used in field implementation were a slip form paving mixture and an internally cured concrete mixture for use in a bridge deck. The data obtained from the curve formation was accurate but changes in the job mixtures and limited time frames to reestablish the maturity curves deemed their use impossible. Field use showed excellent correlation between the maturity curve and cast validation cylinders. This led to less cylinders having to be produced and less time waiting for form removal strengths. For the concrete rehabilitation, casting cylinders for lane opening time were eliminated and the traffic opening was allowed based solely on maturity readings. The authors recommend incorporating the use of maturity for strength measurement and pay into the standards and specifications for Departmental use.

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ABSTRACT

The current construction climate continually requires a more rapid response time for concrete form removal, early age strengths, and opening strengths. This project piloted the maturity method on one structural project and one pavement rehabilitation project. As part of the implementation project, district personnel were taught about the use of maturity to determine compressive strength and trained on creating a maturity curve, placing sensors, and validating the curve.

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IMPLEMENTATION STATEMENT

The authors recommend implementation of the maturity method for estimating concrete strength. Means and methods should be evaluated for each project but general practices should be conducted in accordance with ASTM C1074. The maturity method proves to be ideal for mass and structural elements, especially if temperature monitoring is already required. The maturity method may also show an increase in efficiency and cost savings when utilized in high early strength and pavement rehabilitation projects.

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INTRODUCTION

The use of maturity to determine concrete strength has been in use for more than four decades and the concept was conceived in the late 1940s and early 1950s *[1, 2]*. More and more state and municipal DOTs are implementing its use every year with some having used this technology as early as the mid-1980s. There are many proven benefits to the use of this method, and it has been shown to be a relatively simple and reliable approach for estimating in place strength.

Literature Review

This section will detail past research work completed on evaluating concrete strength using the maturity method. There is an extensive amount of work already completed in this area. A search on the Transportation Research Information Database (TRID) provided over 200 literary works published since 1990 on the maturity – strength relationship for concrete.

Current Standards

Several states have had specifications for using maturity to estimate strength for well over a decade. A survey of state departments of transportation (DOTs) was conducted by Tepke and Tikalsky in 2000. Forty-four states responded to the survey and thirty-two states were currently or have researched maturity and 30 percent have protocols or specifications for using the technology *[2]*. The Nurse-Saul equation was the most popular method for determining maturity. Respondents noted that maturity has been used for predicting critical strengths for opening pavement to public traffic, structural acceptance, and formwork removal for structural applications. Since this study many more states have published their own reports outlining their experiences with the maturity method.

The State Highway Administration for the Maryland Department of Transportation published a research report detailing their implementation of the maturity method. They concluded, as others have, that the maturity method is extremely sensitive to concrete mixture proportions *[3]*. The use of the method is more efficient than traditional methods though and they established a protocol for using maturity in Maryland drawing upon their experiences.

The Texas Department of Transportation's latest specification uses the Nurse-Saul temperature-time factor (TTF) maturity index. In order to develop the strength-maturity relationship, they require a minimum 4 yd^3 batch of concrete and for 20 compression or flexural samples to be produced, two containing maturity meters. Texas requires a new relationship to be established if, "Any alteration in the mixture proportions or source or type of any material, in excess of those tolerable by batching variability." The use of a logarithmic best-fit curve with an R^2 value

greater than 0.90 is required. Texas DOT requires two maturity meters per a structure and for verification samples to be produced "at the frequency specified in the pertinent work." Three samples should be produced with a corresponding sample with a maturity meter embedded. Any verification test that exceeds 10% above or below the predicted strength requires a new strength-maturity curve *[4]*.

The Iowa Department of Transportation estimates both flexural and compressive strength using the maturity method. As in Texas, Iowa uses the Nurse-Saul TTF and a datum temperature of -10°C *[5]*.

A report by Anderson et al. looked at the use of the maturity method in Washington State DOT accelerated PCCP construction projects. They found that the use of the maturity method can increase productivity, but a lack of training and understanding can quickly undermine any benefit. Overall, though, the authors concluded that the method is suited for determining strength and allowing early opening and is recommended for implementation *[6]*.

The Florida DOT completed research on using maturity meters for concrete quality assurance and the research showed that the maturity method was found to be a reliable strength measuring technique *[7]*. The Florida DOT also sponsored research to develop guidelines for slab replacement projects using maturity. The research showed that the maturity method using the Arrhenius maturity function was quite reliable and convenient for use in predicting early-age compressive strength for concrete slab replacements.

After using the method in several projects, the city of Lafayette, LA, has recently implemented a special provision outlining the use of maturity in concrete rehabilitation projects. The responsibility of the maturity curve rests with the contractor while the field testing is carried out by the department.

OBJECTIVE

The objective of this implementation project was to pilot the maturity concept on ongoing structural and paving projects. Maturity curves were developed using rapid patching material or high early strength concrete in a laboratory setting, as well as structural class concrete in the field. The project has provided assistance to districts and proof of the maturity concept to the Department.

SCOPE

To meet the objectives of this project, a review of the state-of-the-practice and state specifications was completed. Two maturity curves were developed for paving projects and one maturity curve was developed for a structural project. Of these projects, one pavement rehabilitation project and one structural project were instrumented with maturity loggers. Recommended procedures for quality control and acceptance have been established.

METHODOLOGY

Test Methods

The following test methods were used in characterization of the hardened concrete properties of internally cured concrete.

Hardened Concrete Property Test Methods

- ASTM C39 [Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens] *[8]*

Other Test Methods

- ASTM C1074 [Standard Practice for Estimating Concrete Strength by the Maturity Method] *[9]*

Strength maturity relationships were established per ASTM C1074. Since this project used the same temperature datum to establish the strength-maturity relationship as it did to determine the approximate strength of in place concrete, all tests used a temperature datum of 0°C. Pavement opening and form removal times will remain the same regardless of what datum temperature is used, as long as it is held constant *[10]*. Cylinders produced to determine the maturity relationships were produced from ready mix trucks, both on site and at the batching plant.

This project utilized intelliRock II maturity readers that LTRC loaned to the districts for the duration of the projects, shown in Figure 1. These readers offered reliable operation for quick and easy maturity readings. They are also able to store project data form numerous loggers, which could later be offloaded onto a computer. There are several different loggers available depending of the needs of the project. Two types of loggers were utilized for this project, one which logged maturity readings every hour for 28 days and one that logged every minute for 24 hours. Faster data logging times were needed for the high early strength mixture used in pavement rehabilitation.

Figure 1
intelliRock II reader and logger

DISCUSSION OF RESULTS

I-49 Pavement Construction

The use of the maturity index to determine concrete strength was first piloted on a new section of I-49, north of Shreveport, LA, as shown in Figure 2. Cylinders were cast on site for the development of a maturity curve and a maturity logger was placed in the pavement on the same day. Due to day-to-day changes in the concrete mixture design, the maturity method could not be used any further. Because strength-maturity relationships need to be established for each mixture design, communication between the contractor and the Department is an essential part to ensuring the maturity method is implemented successfully. The maturity curve deveolped with this mixture can be seen in Figure 3.

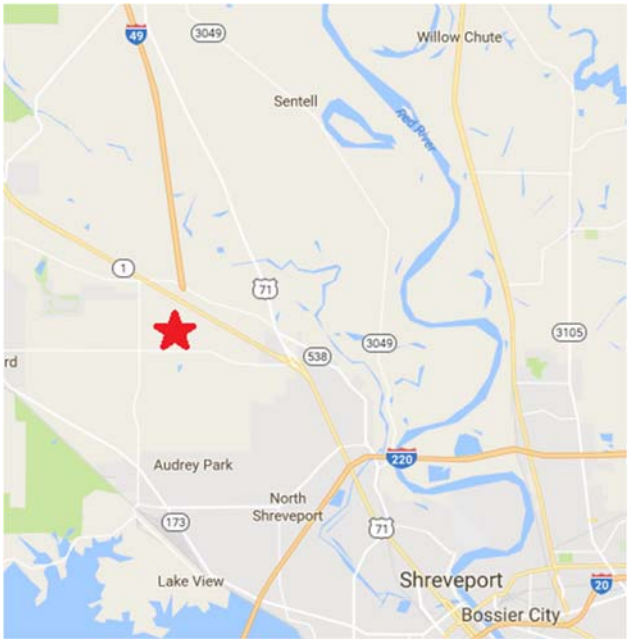

Figure 2
Location of I-49 pavement construction project

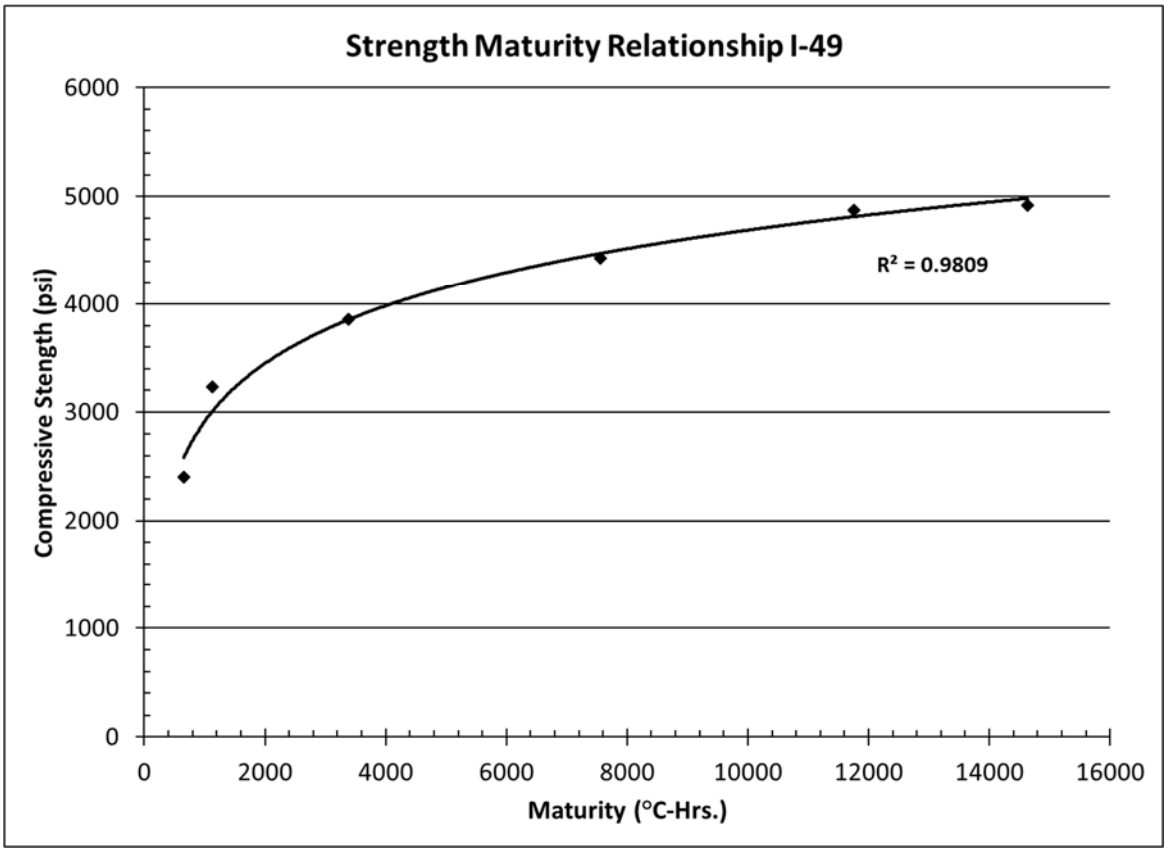

Figure 3
Strength maturity relationship for I-49

US90B MacArthur Interchange

During this project, the maturity method was utilized to determine the proper time for form removal on structural columns. This project is located in southeast Louisiana, in Jefferson Parish, as seen in Figure 4. Even though the maturity method was not implemented until after the project started, it proved to be very successful. District personnel were trained in the use of the maturity equipment and the contractor agreed to be responsible for the placement of the sensors within the structural members. A strength maturity relationship was developed on site and maturity curve validation was completed monthly. The strength maturity relationship can be seen in Figure 5 and the curve validation data can be seen in Table 1.

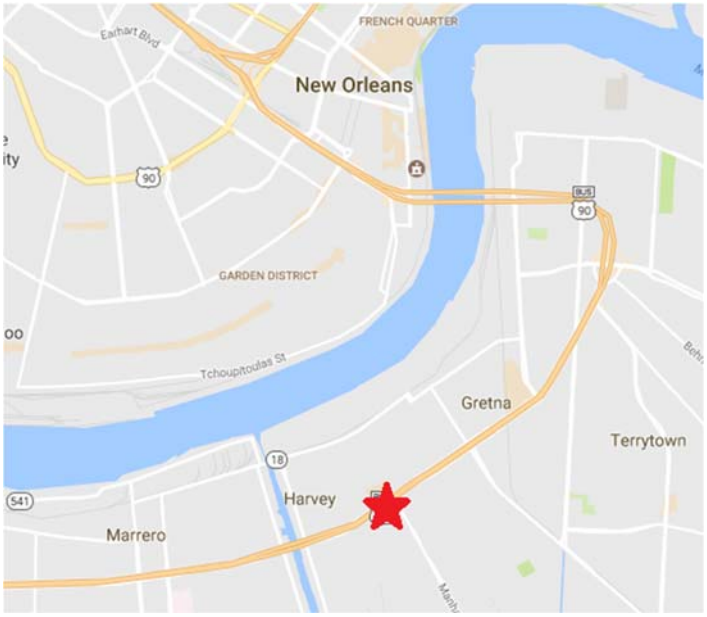

Figure 4
Project location of the US90B interchange

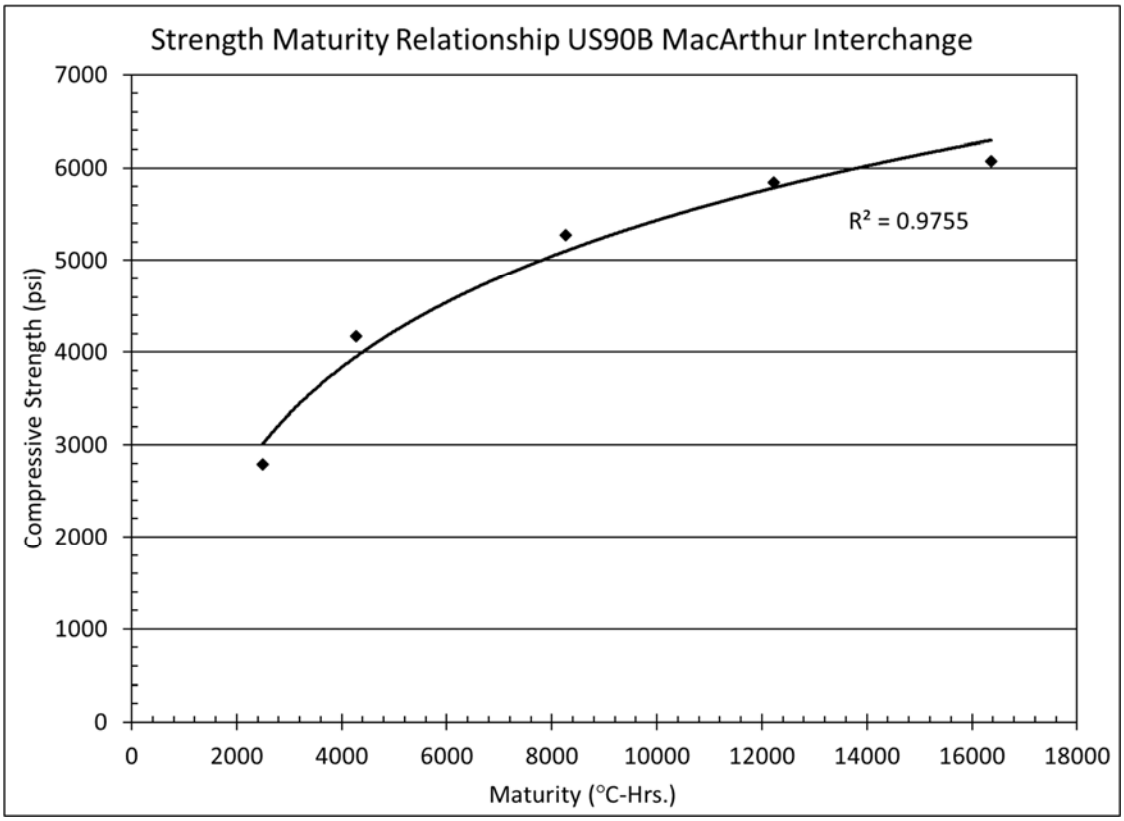

Figure 5
Strength maturity relationship for the US90B MacArthur Interchange

This project was successful due to the cooperation between the district personnel and the contractor. At the onset of this pilot, material suppliers and contractors were made aware that any change in mixture design or materials would nullify the original relationship and require 28 days to produce a new relationship between strength and maturity. District engineers noted that a good understanding of the maturity method and knowledge of mass concrete is very beneficial and should be discussed before using the maturity method in practice.

Validation samples were cast to ensure that the ability of the strength maturity index to accurately estimate concrete strength for an extended period of time. This consisted of four cylinders, including one with a logger, being cast. The compression data and the estimated strength from the original curve can be seen in Table 1. There were several occasions were the actual strength of an individual cylinder differed significantly from the estimated strength. Most of these instances showed an increase in strength and subsequent cylinders were always closer to the original relationship. Over the six sets of cylinders and more than eight months, the average percent difference between the actual strength and estimated strength was only 4%.

Table 1
Maturity curve validation data for the US90B MacArthur interchange

Date	Measured Maturity (°C-Hrs.)	Measured Strength (psi)	Predicted Strength (psi)	Difference (%)
7/20/2015	3387	3433	3545	-3.26
7/22/2015	4761	4006	4139	-3.32
7/24/2015	6327	4555	4610	-1.21
7/29/2015	9731	4968	5387	-8.43
8/6/2015	5252	4760	4310	9.45
8/7/2015	7345	5429	4898	9.78
8/11/2015	10186	5613	5467	2.60
8/23/2015	7772	5191	4995	3.78
10/26/2015	5907	4438	4516	-1.76
11/2/2015	9534	5054	5351	-5.88
12/14/2015	3630	3889	3666	5.73
12/15/2015	4180	4393	3912	10.95
12/16/2015	4641	4280	4090	4.44
12/17/2015	5196	5087	4292	15.63
2/3/2016	4676	4395	4108	6.53
2/5/2016	6051	5300	4558	14.00
2/11/2016	8326	5734	5115	10.80

CONCLUSIONS

The results of this project warrant the following conclusions. The piloted projects show that the maturity method for strength estimation is a very useful tool for the Department. The findings are in line with what has been shown in many other studies, in many other states. The maturity method, when implemented properly, can be very accurate and efficient. Personnel time and construction time can be saved with this method, while also reducing the susceptibility to error. It gives the best representation of in place concrete strength while also being a non-destructive test.

The maturity strength relationship is easy to establish, but must be completed ahead of time, illustrating that planning and communication are keys to proper implementation. District and contractor personnel need to be trained on proper use of the maturity method, noting that any changes in the PCC mixture need to be communicated.

RECOMMENDATIONS

The authors recommend incorporating the maturity method for strength estimation into the standards and specifications for Department use. ASTM C1074 should be used when creating the strength-maturity relationship and specifications should be developed for the use of maturity loggers on Department projects. The Department may find the best benefit from the maturity method when using high early strength PCC mixtures and on mass concrete pours. It provides an accurate estimation of the in-place strength, which a normally cast and cured cylinder cannot do, in most instances.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ASTM	American Society of Testing and Materials
DOT	Department of Transportation
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
in.	inch(es)
LTRC	Louisiana Transportation Research Center
PCC	portland cement concrete
pcf	pounds per cubic foot
psi	pounds per square inch
QA	quality assurance
QC	quality control

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