

New PCC Maturity Technology: Five Questions

By L. K. Crouch and T. Adam Borden

Background

The Winter 2002 issue of *Tennessee Concrete* on concrete testing contained excellent articles by Mote and Marasa (1), Brown (2), and Lobo (3) on the pros and cons of PCC cylinder testing. Is there an alternative method for evaluating PCC curing progress? Yes, concrete maturity.

PCC gains strength and durability from reactions between Portland cement, supplementary cementing materials and water. The continuation of the chemical reactions is commonly termed curing. Curing progress is most commonly measured with compressive strength development. Curing progress is a function of time, temperature, and moisture conditions. Provided that adequate moisture is available, curing progress is a function of time and temperature. The maturity index is a function of time and temperature. Nurse and Saul performed some of the early research on the maturity concept. AASHTO T 276-97 (4) recommends the Plowman equation based on the earlier work of Nurse and Saul.

$$M = \sum_{0}^{t} (T - T_0) \Delta t$$

where:

M = maturity index

T = average concrete temperature during time Dt

T₀ = datum temperature (usually -10°C (14°F))

t = elapsed time hours

Δt = time interval (hours)

Just as depressing the accelerator on a vehicle makes the vehicle speed up, increasing the curing temperature makes the chemical reactions in PCC speed up. To continue the analogy, the maturity index measures the

progress of curing like mile markers on an interstate measure the distance the vehicle has traveled. The maturity index is simply an alternative to compressive strength development for measuring the progress of PCC curing.

The advantage of the maturity concept over casting, transporting, curing, capping, and testing PCC cylinders is logistical. Casting, curing, transporting, capping, and testing PCC cylinders requires considerable time and effort and affords many opportunities for mistakes that most often reduce observed compressive strength (see *Tennessee Concrete* Winter 2002).



Figure 1
New Concrete
Maturity System

QUESTION 1:

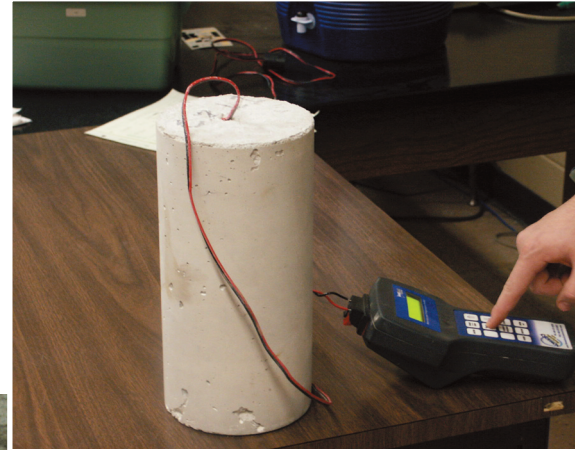
How does the new maturity technology differ from previous technology?

The new concrete maturity system is not a theoretical breakthrough; it uses the same maturity concepts that have been available since the 1950s. However, it is a technological leap forward. The new system virtually eliminates the problems of vandalism, theft, and accidental damage associated with traditional field maturity meters. The new concrete maturity system (shown in Figure 1) uses an independent embedded microprocessor (logger) that requires no permanent external connection. The logger calculates the maturity index every 15 minutes. The reader unit downloads maturity index values as well as maximum and minimum temperatures when connected to a logger. One reader unit can be used in conjunction with an unlimited number of independent embedded loggers.

QUESTION 2:

Does the new system eliminate PCC cylinders?

No, the maturity method requires a correlation curve based on PCC cylinder compressive strengths. A pictorial summary of how to develop a compressive strength maturity correlation plot is shown in Figure 2. However, it does not require cylinders to be cast, transported, cured, capped, or tested after the initial correlation plot is developed for that PCC mixture. Fewer opportunities are available for mistakes, less labor is required, and the maturity index can be measured nearly continuously rather than at discrete points like compressive strength.



Measure Maturity



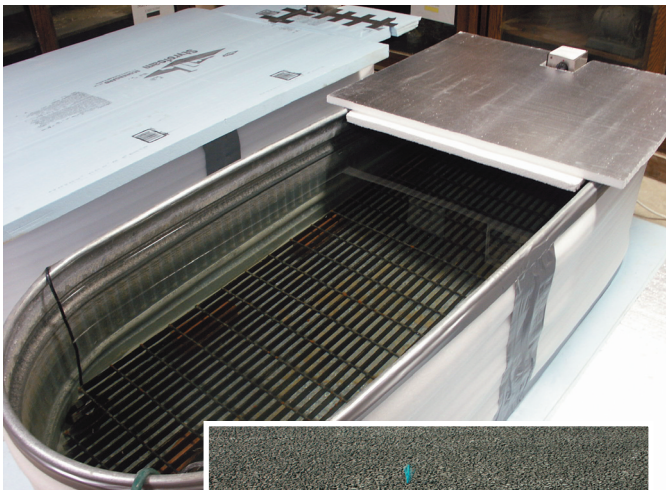
Install Maturity Loggers



Cast Cylinders



Measure Compressive Strength



Cure



Initial Curing



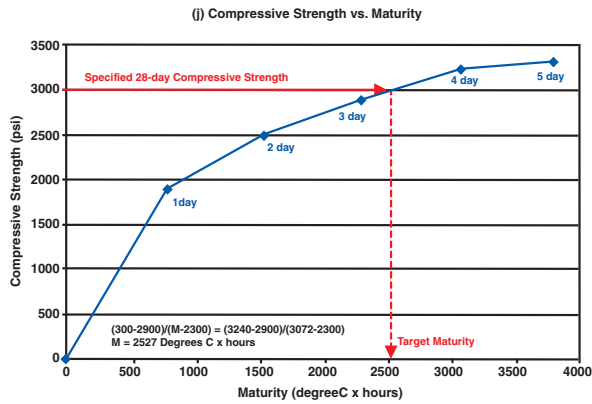
Sample PCC



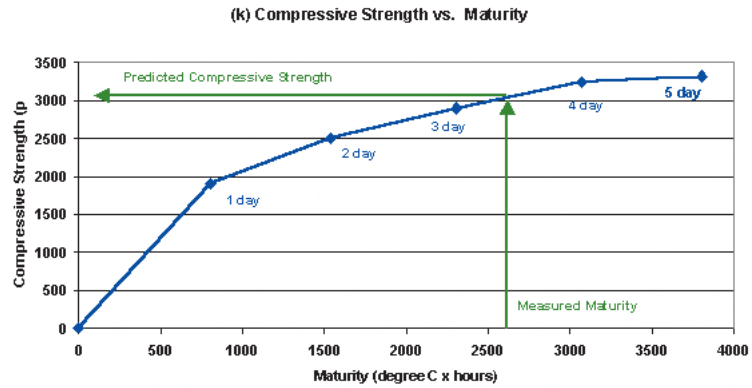
Figure 2.1(d) Turn Loggers On



Fig 2.1 (f) Transport to Laboratory



Construct plot and determine target maturity



Predict compressive strength

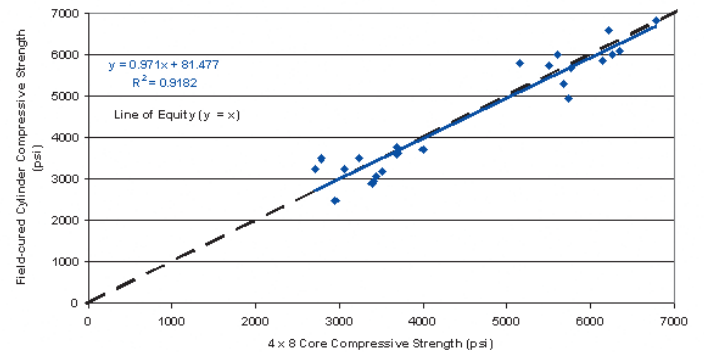
QUESTION 3: Is the new system rugged, precise, and accurate?

This question is being investigated in a project jointly sponsored by TDOT and TRMCA at Tennessee Technological University. The project began in August 2002 and is scheduled to conclude in December 2003. The project uses a dual approach to evaluate the new maturity technology. In the laboratory, 120 6x12 cylinders from the same batch of Class A TDOT PCC are divided into four groups of thirty cylinders each. Each group is subjected to a curing temperature regime. Sets of cylinders from each curing regime are broken at pre-determined maturity values to determine the validity of the maturity concept. In the field, two compressive strength-maturity correlation plots are constructed using field mixtures for actual Tennessee PCC pavements. The compressive strength-maturity correlation plots are used to predict compressive strength development of later placements of the same PCC mixture on the same job. The accuracy of these predictions are determined by comparing predictions with measured compressive strengths using lab-cured 6x12 cylinders, field-cured 6x12 cylinders, 4x8 pavement cores, rebound hammer measurements, and Windsor Probe data. One field evaluation was performed at the I-65 / SR 155 (Briley Parkway) interchange. A second field evaluation is planned for I-75 near Hamilton Place Mall in Chattanooga in July 2003.

Rugged? Early indications are that the new system is adequately rugged and durable for field use.

Precise? Multiple readers and loggers are showing excellent agreement in the laboratory and the field.

Figure 3. Comparison of Field-cured Cylinder and 4 x 8 Core Compressive Strengths



Accurate? To determine accuracy, a standard or true compressive strength is required. The research team selected field-cured 6x12 and 4x8 cores as the best estimate of actual PCC pavement compressive strength. The samples for these two strength evaluations techniques have experienced the same curing regime as the PCC in the pavement and therefore should provide the best estimate of in-place PCC strength. Lab-cured 6x12 cylinders measure

potential compressive strength rather than in-place strength due to a superior curing regime. Fortunately for the research team, the two estimates of in-place compressive strength from I-65 agreed very well as shown in Figure 3.

Agreement between average predicted and average measured compressive strengths for I-65 field project is shown in Table 1. Percent difference is calculated by the following formula:

$$\% \text{ Difference} = ((\text{Predicted} - \text{Measured}) / \text{Measured}) * 100$$

Table 1.
Percent Difference in Predicted and Measured Average Compressive Strengths at the I-65 Field Evaluation

	75% Target Maturity	100% Target Maturity	125% Target Maturity	28-day	Method Average Difference
Rebound Hammer	-16.2	-16.0	-8.0	N/A	-13.4
Lab-cured 6x12 cylinders	-18.6	-21.6	-18.9	-25.6	-21.2
Field-cured 6x12 cylinders	-1.2	-6.5	-4.2	-8.0	-5.0
4x8 Cores	-9.5		-8.7	-9.1	

QUESTION 4:

What is the cost of the new system?

A starter kit containing a reader, case, software, and twenty-five loggers costs \$ 1500. Additional loggers (not reusable) are \$ 25 each.

QUESTION 5:

Should the new system replace PCC cylinders for opening new PCC pavements to traffic?

TDOT Materials & Tests Division is currently considering this question. The information generated in the current project will assist TDOT in making the decision. With the project only about forty percent complete, it is too early for conclusions or recommendations. However, Table 2 summarizes the new system's advantages and disadvantages compared to traditional cylinder tests for opening new PCC pavements. ■

Table 2.
Comparison of Lab-cured cylinders and the new maturity system

	Lab-cured PCC Cylinders	New Maturity System
Information availability	How many pairs of cylinders did you make?	New maturity value calculated every 15 minutes
Representative of jobsite conditions?	Standard curing temperature (Sometimes too cool, sometimes too warm)	Yes, actual jobsite temperatures
Require correlation curve?	No	Yes
	Advantage	Disadvantage

References

1. Mote, Rick and Marasa, Mike, "Variable Affecting Concrete Compressive Strength", Tennessee Concrete, Vol. 16, No.3, pp.11-12.
2. Brown, Heather, "Getting the Most Out of your Cylinders", Tennessee Concrete, Vol. 16, No.3, pp.13-14.
3. Lobo, Colin. "Acceptance Testing of Concrete", Tennessee Concrete, Vol. 16, No.3, pp.15.
4. AASHTO T276-97 "Standard Method of Test for Developing Early-Age Compression Test Values and Projecting Later-Age Strengths", Standard Specifications for Transportation Materials and Methods of Sampling and Testing Part 2 –Tests, Twenty First Edition, 2001, American Association of State Highway and Transportation Officials.

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Author Information

L. K. Crouch, Ph.D., P.E. is a professor of Civil Engineering at Tennessee Technological University.

T. Adam Borden, E.I. is a graduate research assistant pursuing a Master of Science in Civil Engineering at Tennessee Technological University.