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CONCRETE

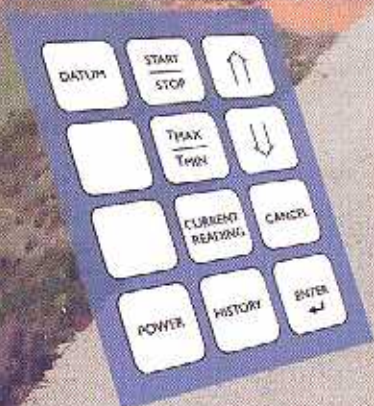
MAGAZINE

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Finding
a (pervious)
concrete
solution



Plus!
Lesson 4
from the TDOT/TCA/ACPA Maturity Project

Lesson 4:

New Maturity Technology 101

By L. K. Crouch and T. Adam Borden



Figure 1. Maturity Reader

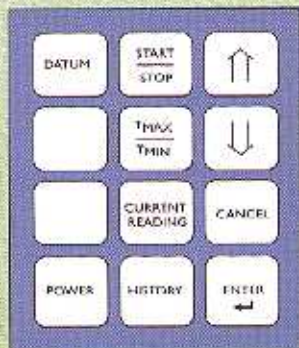


Figure 2. Close-up of Reader Keypad

Introduction

The recent TDOT/TRMCA/ACPA Evaluation of New PCC Maturity Technology Project generated a large quantity of data. The data generated can be analyzed to provide valuable lessons about PCC behavior. This paper is the fourth in a series of technology transfer articles. The authors appreciate the financial support of TDOT and TRMCA. We hope you find the information presented helpful in better understanding PCC behavior. In the fourth article, new maturity technology equipment and operations are discussed.

Equipment

The new maturity technology virtually eliminates the problems of vandalism, theft, and accidental damage associated with traditional field maturity meters. The new maturity technology uses an independent embedded microprocessor (logger) that requires no permanent external connection. The logger calculates a new 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, but it may only store two hundred data sets at one time. Logger data transferred to the reader can be downloaded to a personal computer in two formats: text and secure [1].



Figure 3. Maturity Logger



Figure 4. Embedded & Hooked To Reader



Figure 5. System Operation [1]

Generating a Compressive Strength-Maturity Correlation Plot



Step 1



Step 2



Step 3



Step 4



Step 5

1. Sample PCC (field preferred, lab acceptable) – must use exact materials and proportions, correlation plots are PCC mixture specific.
2. Cast 20 6x12 cylinders [2, 3].
3. Install a maturity logger in 2 of the cylinders.
4. Activate maturity loggers – as soon as the cylinders are cast.
5. Initial curing of the cylinders [2, 3].
6. Transport cylinders to the lab – if cast in the field.
7. Cure the cylinders in the lab – use standard conditions.
8. Measure the maturity – just before breaking a pair of cylinders, measure and record the maturity of the two cylinders containing loggers (never break the cylinders containing loggers).
9. Determine compressive strength development – break a pair of cylinders at 1, 2, 3, 4, 7, 10, 14, 28, and 56 days [4].



Step 6



Step 7



Step 8



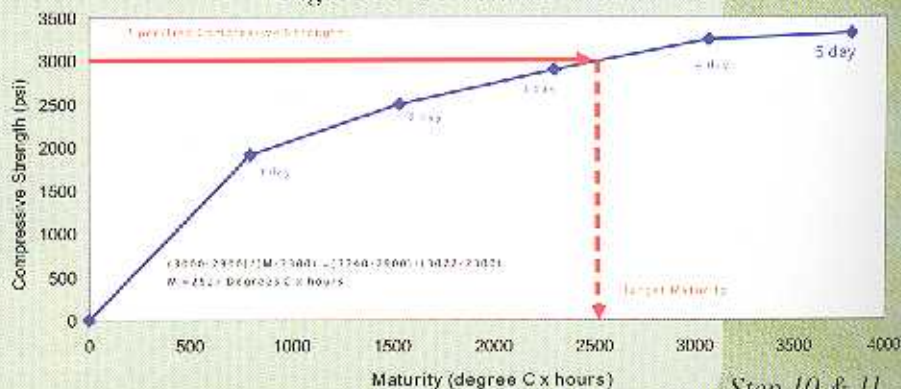
Step 9

10. Construct the compressive strength-maturity correlation plot – plot compressive strength (y axis) vs. measured maturity (x axis). Connect the points with straight lines.

11. The target maturity is determined as follows:

- On the compressive strength-maturity correlation plot locate the first day the required compressive strength is exceeded. Label the maturity for that day M_1 and the compressive strength for that day S_2 .
- On the compressive strength-maturity correlation plot locate the last day the compressive strength measured was below the required compressive strength. Label the maturity for that day M_2 and the compressive strength for that day S_1 .
- Call the required compressive strength S .
- Call the target maturity TM .
- $(S - S_1)/(TM - M_1) = (S_2 - S_1)/(M_2 - M_1)$
- An example for $S = 3000$ -psi is shown in the Step 10 & 11 of Figure 6

Figure 6. Correlation Procedure



Step 10 & 11

Field Operations for the First Twelve Times Maturity is Used for Acceptance of Each PCC Mixture Design

1. Sample PCC in the field.
2. Cast 4 or more field-cured 6x12 cylinders and cure in close proximity to the structure [3].
3. Install maturity loggers in PCC structure – see AASHTO TP 52-95 [5] for guidance on the number and location of loggers.
4. Activate loggers – as soon as structure is cast.
5. Monitor maturity index in the structure.
6. Between 100 and 110 percent of target maturity:
 - a. Take a maturity reading;
 - b. Predict compressive strength with compressive strength-maturity correlation curve;
 - c. Break a pair of field-cured 6x12 cylinders.

7. Determine required maturity index for acceptance. To accept the PCC as meeting specifications, the one-sided confidence limit is [6]:

$$S_M > (LL + K)$$

where:

S_M = predicted strength near target maturity

LL = specified lower limit (required compressive strength)

$$K = 1.645 (\Sigma (S_M - S_{MTM})^2 / 2n)^{0.5}$$

K = measure of variability between predicted and measured strengths

1.645 = confidence coefficient for a 5% probability of accepting material with a strength below LL.

S_{MTM} = measured strength near target maturity

n = number of paired (S_M and S_{MTM}) values used in the analysis



Step 1



Step 2



Step 3



Step 4

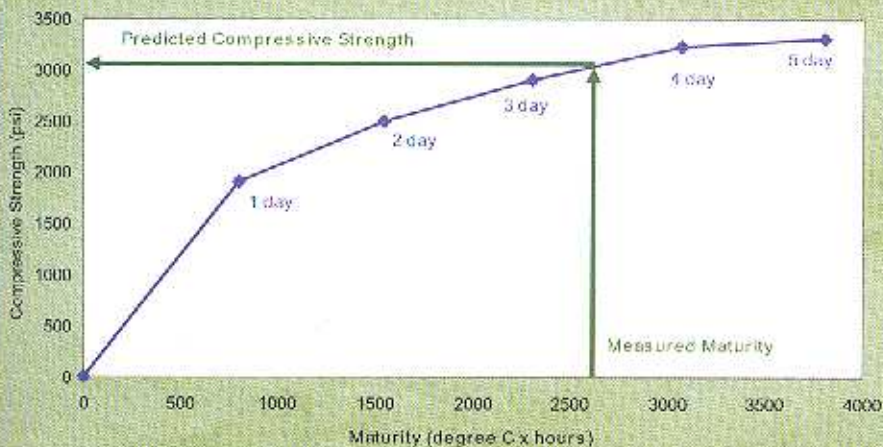


Step 5



Step 6

Step 7



The required maturity index for acceptance is the maturity index corresponding to $S_M - K$ is established using at field-cured cylinders and maturity predictions from the first twelve times the maturity index used for acceptance of a particular PCC mixture design. Prior to establishing K, the PCC in the structure can be accepted in one of three ways:

- Accept the PCC with a 95% confidence level that no compressive strength in that lot was less than required compressive strength when the maturity index corresponding to S_M was read on the loggers for the lot (assuming $K = 1200$ -psi, a very conservative assumption), or
- Using the compressive strength from a pair of field-cured cylinders, or
- Using cores cut from the structure [7].

Field Operations After K is Established (Batch Number 13+)

- Install maturity loggers in the PCC structure – see AASHTO TP 52-95 [5] for guidance on the number and location of loggers.
- Activate loggers – as soon as structure is cast.
- Monitor maturity index in the structure.
- Accept the PCC with a 95% confidence level that no compressive strength in that lot was less than required compressive strength when the maturity index corresponding to S_M was read on the loggers for the lot.

Additional Guidance on Field Operations

- At the discretion of the engineer, additional pairs of field-cured cylinders may be required to refine K. K values greater than or equal to 800-psi indicate high variability and require further refinement / investigation.
- At the discretion of the engineer, a new compressive strength maturity correlation plot may be required. A new compressive strength-maturity correlation plot should be considered when S_M is greater than $1.10 * S_{MTM}$.
- After the first 12 batches, it is prudent to periodically check the maturity predictions with field-cured cylinders.

Figure 7. Field Operations Prior To Establishing K

Example of Acceptance Calculations

Assume the required compressive strength is 3000-psi. Table 1 shows assumed data. Table 2 shows example calculations.

Table 1. Assumed Data

S_{MTM}	2482	3498	3234	3235	3494	3064	3024	3053	3181	3610	3762	3708
S_M	3010	2958	3034	3025	3030	3056	3264	3266	2974	2998	2985	2976

Table 2. Calculations

Parameter	Value (psi)
$(\sum (S_M - S_{MTM})^2 / 2n)^{0.5}$	324.7
K	534.1
LL	3000
LL + K	3534

The PCC could be accepted with a 95% confidence level that no compressive strength in that lot was less than 3000-psi when the maturity index corresponding to 3534-psi was read on the loggers for the lot.

New Maturity Technology Logistics

The recent TDOT / TRMCA / ACPA study showed the new maturity technology to be robust and reliable enough for field or laboratory use.

Recommendations

1. When information on in-place PCC strength is required, use field-cured cylinders cured in close proximity to the structure for jobs requiring less than 30 batches of the same PCC mixture.
2. When information on in-place PCC strength is required for job with 30 or more batches of the same PCC mixture, use field-cured cylinders in conjunction with the new maturity technology.

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