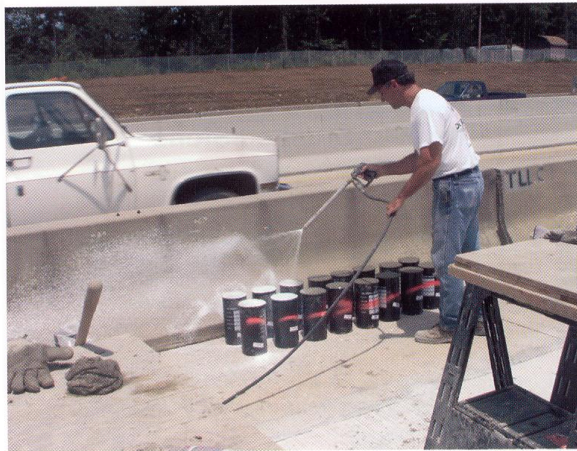


## Lesson 2: Field-cured Cylinders: Are They the Right Choice

By L. K. Crouch and T. Adam Borden



*A rebound hammer can indicate relative concrete strengths but cannot directly measure compressive strength in the field.*



*A worker applies curing compound to field-cured cylinders to replicate field curing conditions as closely as possible.*

### 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 second 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 second article, several methods for determining in-place PCC are discussed.

### In-place PCC Strength

Many construction applications such as form removal, opening a new pavement to traffic, removal of shoring and placement of additional PCC on recently placed PCC require a measure of the strength of the PCC in the structure. A variety of procedures are available for determining/estimating the in-place strength of PCC. However, data from the recent project includes only 6x12 lab-cured cylinders [1, 2], 6x12 field-cured cylinders [1, 2], 4x8 cores [3], a new maturity technology and the rebound hammer [4]. Table 1 enumerates the advantages and disadvantages of each test method used in the recent maturity project. Advantages are highlighted in light blue and possible disadvantages are highlighted in yellow.

### Lab-cured Cylinders

Lab-cured cylinders [2] are used to evaluate the potential compressive strength of the PCC mixture using standard curing procedures, not the compressive strength of the PCC placed in a structure. Table 1 shows that lab-cured cylinders have a standard curing temperature and moisture history. The standard temperature and moisture history is often very different from the actual temperature and moisture history of the structure in question. Two of the primary purposes of lab-cured cylinders are quality control and evaluation of the adequacy of mixture proportions for strength [2].

## Cores

Cores cut from the structure are probably the best measure of the in-place PCC strength. As seen in Table 1, cores have the correct consolidation, curing temperature history and moisture history. However, obtaining and testing PCC cores can be difficult, time consuming and expensive. Therefore, a superior method would determine in-place compressive strengths similar to cores and have better logistics.

### Selecting the Most Appropriate Method(s) for Determining In-place PCC Strength

Table 1 indicates that field-cured cylinders, the new maturity technology and the rebound hammer all have logistics superior to coring. However, method accuracy is also a very important criterion for selecting the most appropriate method for determining in-place PCC strength. Method accuracy will be determined by comparing method strength to core compressive strength. Figures 1, 2, 3 and 4 show field-cured cylinder strengths, maturity predicted strengths and rebound hammer correlation strengths as a percentage of core compressive strength using data from the recent TDOT/TRMCA/ ACPA Project. Rebound hammer data for I-65 Nashville at 28 days was not available. Table 2 shows mean values of field-cured cylinder strengths, maturity predicted strengths, and rebound hammer correlation strengths as a percentage of core compressive strength.

Table 2 shows that all three methods were able to predict core compressive strength within ten percent on average. Field-cured cylinders produced the best predictions of core compressive strength with a mean deviation of only 3.1 percent. In three of four cases, field-cured cylinders predicted core compressive strengths within one percent. The new maturity technology produced the worst predictions of core compressive strength on average. Further, the new maturity technology was not able to predict core compressive strength within ten percent at either age for I-75 Chattanooga. The rebound hammer over-estimated core compressive strength in all cases.

Attributes	Lab-cured Cylinders	Field-cured Cylinders	Cores	New Maturity Technology	Rebound Hammer
Mixture	Correct	Correct	Correct	?	Correct
Consolidation	Standard	Standard	Correct	Irrelevant	Correct
Temperature History	Standard	Close	Correct	Correct	Correct
Moisture History	Standard	Close	Correct	Correct	Correct
Measures	Compressive Strength	Compressive Strength	Compressive Strength	Time and Temperature	Rebound Number
Correlation Required	No	No	No	Yes	Yes
Information Availability	Limited, depends on number of cylinders fabricated	Limited, depends on number of cylinders fabricated	Virtually Unlimited	New Maturity calculated every 15 minutes	Virtually Unlimited
Information Acquisition	Laboratory	Pickup at Jobsite, test at Lab	Cut at Jobsite, test at Lab	Jobsite	Jobsite
Obtaining Information Logistics	Very Good	Good	Poor	Excellent	Good
Risk of Vandalism	Low	Dependent on location	None	Very Low	None
Sensitive to Batch-to-Batch Variability	No	No	No	Yes	No

Table 1. Attributes of Strength Test Methods Used in the Recent TDOT/TCA Project

Location	Age (days)	Mean Field-cured Cylinder Strength as a Percentage of Mean Core Strength	Mean Maturity Predicted Strength as a Percentage of Mean Core Strength	Mean Rebound Hammer Strength as a Percentage of Mean Core Strength
I-65	4	99.0	91.8	106.2
	28	99.3	91.8	Not Available
I-75	4	100.3	89.5	106.0
	28	110.4	112.1	112.1
Mean Percentage Deviation from Core Strength		3.1	9.8	8.1

Table 2. Mean Values of Percentage of Core Strength for the Field-cured Cylinders, Maturity Predictions, and the Rebound Hammer

### Maturity Limitations

The new maturity technology measures time and temperature and calculates a maturity index. The calculated maturity index is the area between the time-temperature plot and the datum temperature (14°F in this study). The maturity index is correlated to compressive strength development of a specific PCC mixture, which requires approximately 2 months. The new maturity technology assumes that the PCC mixture being evaluated in the field is identical to the PCC mixture used for the correlation. The new maturity technology requires assistance in determining if the PCC mixture being evaluated is the same as the correlation PCC mixture. Further, the previously mentioned assumption makes the new maturity technology sensitive to PCC batch-to-batch variability. AASHTO T 276-97 [5] provides a means to protect the specifying agency from the effects of high batch-to-batch variability. The evaluation requires a comparison of measured and predicted compressive strengths. The Texas Department of Transportation [6] recommends field-cured cylinders to characterize the effect of batch-to-batch variability on maturity predictions.

### Maturity Advantages

Information availability and ease of retrieval are distinct advantages of the new maturity technology. Table 1 indicates that information is available at the jobsite, updated every 15 minutes and can be obtained quickly and easily. Further, the risk of vandalism is very low with the new maturity technology.

### Rebound Hammer Limitations

Mindess, Young, and Darwin [7] report that the following factors other than compressive strength that effect rebound number results:

1. Surface finish of the concrete being tested
2. Moisture content of the concrete
3. Temperature
4. Rigidity of the member
5. Carbonation
6. Direction of the impact

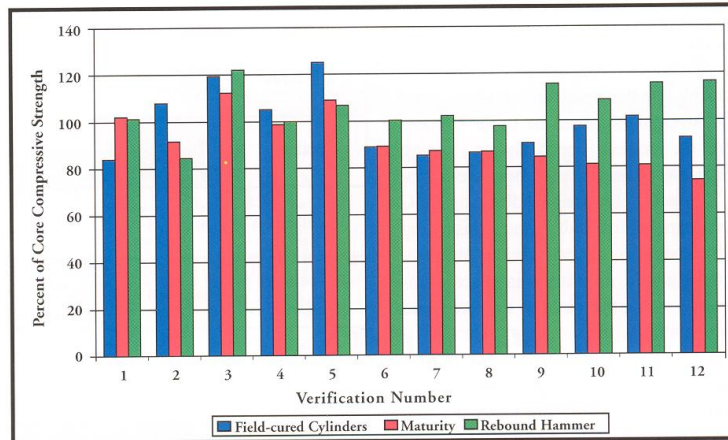


Figure 1. Comparison of Field-cured Cylinder, Maturity Predicted and Rebound Hammer Strengths with Measured Core Strengths for I-65 Nashville at 4 Days

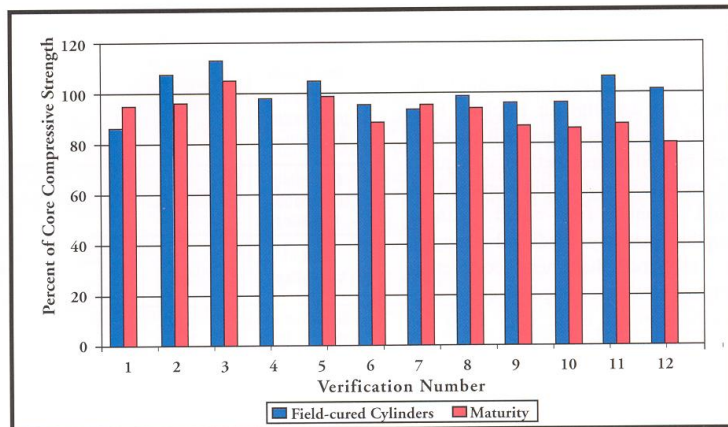


Figure 2. Comparison of Field-cured and Maturity Predicted Strength with Core Compressive Strength for I-65 Nashville at 28-days

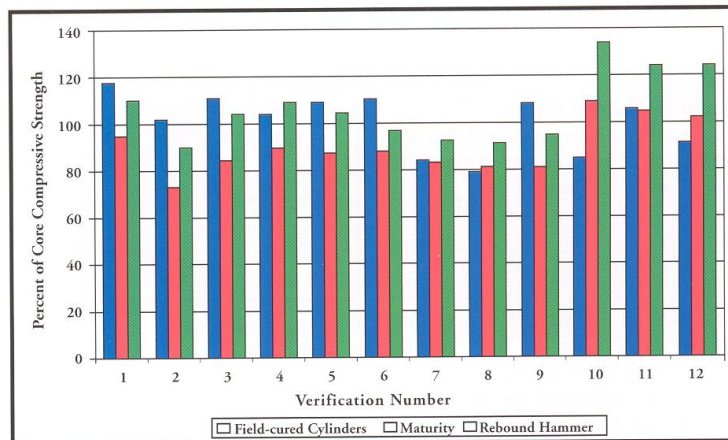


Figure 3. Comparison of Field-cured Cylinder, Maturity Predicted and Rebound Hammer Strengths with Measured Core Strength for I-75 Chattanooga at 4 Days

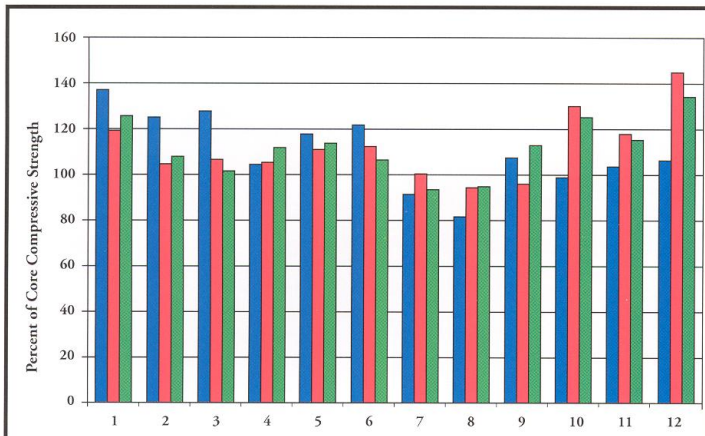


Figure 4. Comparison of Field-cured Cylinder, Maturity Predicted and Rebound Hammer Strengths with Measured Core Strength for 1-75 Chattanooga

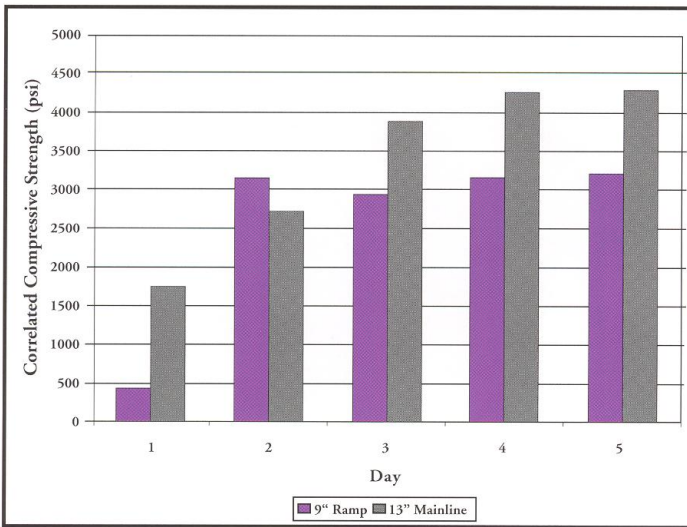


Figure 5. Effect of Pavement Thickness on Rebound Hammer Correlated Strength for 1-65 Nashville

Figure 5 shows that the effect of Factor 4 can be substantial. Further, ASTM C 805 [4] requires ten rebound hammer readings at each location. Finally, periodic calibration of the hammer and a PCC mixture specific correlation between readings obtained and PCC compressive strength specimens (cylinders or cores) is required by ASTM C 805 [4].

#### Are Field-cured Cylinders the Right Choice for Determining In-place PCC Strength?

##### Field-cured cylinders have the following advantages:

1. Better accuracy at predicting core compressive strengths in this study;
2. Temperature and moisture history is very similar to that of the PCC in the structure, unlike lab-cured cylinders which experience standard moisture and temperature conditions;

3. Do not require extensive correlation procedures;
4. Fewer limitations than the rebound hammer;
5. Easier and cheaper than cutting and testing cores;
6. Accuracy is not susceptible to PCC batch-to-batch variability;
7. The PCC mixture in field-cured cylinders is the PCC mixture used in the structure. This may not be the case with the new maturity technology;
8. Ideal for characterizing the difference in measured and predicted compressive strengths for the AASHTO T 276 evaluation;
9. Making, transporting, and testing cylinders is already common and familiar to most concrete industry and government personnel;
10. Recommended by Texas DOT to access maturity prediction accuracy.

##### Field-cured cylinders have the following disadvantages:

1. Possibility of vandalism;
2. In some situations it is difficult to locate the "level, rigid, horizontal surface free from vibration and other disturbances" required by AASHTO T23-02 [2].
3. Specimens must be fabricated by certified, experienced personnel to adequately characterize the PCC being tested. Improper casting, curing, or transportation results in an observed compressive strength lower than the actual compressive strength of the PCC.
4. Obtaining information is more difficult and time consuming compared to the new maturity technology;
5. The quantity of information (the frequency of new information availability) depends on the number of field-cured cylinders fabricated and thus is inferior compared to the new maturity technology, the rebound hammer, and coring.

Based on the available data, the following conclusion can be drawn. The advantages of field-cured cylinders clearly outweigh the disadvantages. Field-cured cylinders are the right choice for determining in-place PCC strength.

**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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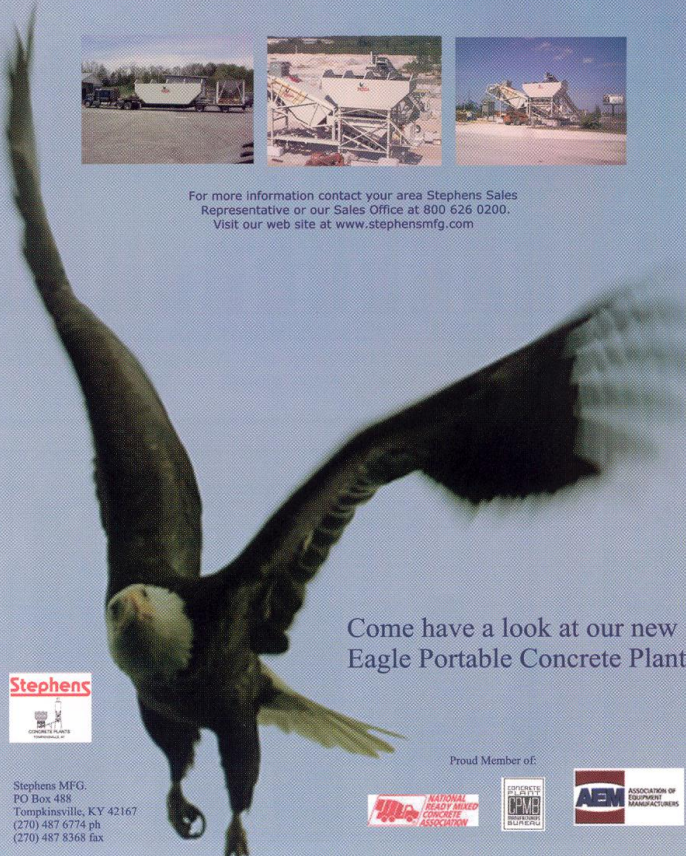
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