INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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The Influence of Curing Conditions on Strength Properties and Maturity Development of Concrete

Introduction

The main objectives of this project were to establish a correlation between maturity development and degree of hydration of cement and to establish equivalent curing methods for concrete specimens that can accurately represent the curing conditions of concrete in pavement. To achieve these objectives, the following tasks were performed.

1. The maturity development of cement in relation to cement hydration was evaluated.
2. The influences of different specimen curing conditions and specimen types on the flexural strength, compressive strength, and maturity development of pavement concrete were evaluated.

Findings

Based on the research results presented in this document, the following conclusions were drawn from the study.

1. There existed a good correlation between maturity development of cement paste and the degree of hydration of cement. This correlation was valid only if sufficient moisture was available for continuous hydration of the specimens. The maturity-degree of hydration correlation could also be extended to concrete since the maturity development in cement paste and concrete was found to be similar.
2. With respect to flexural strength of the specimens, curing specimens in the lime bath or in the sandpit produced specimens with equivalent flexural strengths. Air curing of specimens did not produce specimens with a strength equivalent to the strength of specimens cured in either the lime bath or sandpit.
3. The temperature-matched curing technique was able to produce specimens with strengths within 10 percent of the flexural strength required for opening the pavement to traffic. This result was repeated in the field based on maturity values.
4. With respect to compressive strength, the specimens cured in the sandpit and the specimens cured in air were the most similar. The strengths of the specimens cured in the lime bath were different than the strengths of the specimens cured in the other two curing conditions.
5. The ambient temperature in which the concrete was cured had a significant influence on the maturity development of the concrete. The sandpit-cured specimens most accurately matched the maturity development of the pavement in the field study (within 6 percent). The lime-bath, sandpit and air-cured specimens all matched the maturity of the pavement to within 14 percent. The temperature-match cured specimens matched the maturity development in the pavement to within 1 percent in laboratory studies.

6. It appears that there was no difference between the maturity development in beam specimens and cylinder specimens. Air curing of specimens has a greater effect on the maturity-strength relationship of beam specimens than on cylinder specimens. Also, the temperature match-cured specimens validated the maturity curve for the concrete.

Implementation

Currently INDOT specifies two different types of field curing: lime bath and sandpit curing. Lime bath curing is used for QC/QA pavement construction for specimens made to determine the 7 day flexural strength of the concrete. Sandpit curing is used for estimating opening-to-traffic strengths of the pavement concrete. The constant temperature of the lime bath provides a uniform curing environment that should provide repeatable results (based on maturity) from batch to batch. However, due to the inability of the lime-bath-cured specimens to adjust to environmental conditions these specimens may not always provide an accurate representation of the strength of the pavement concrete. Thus, it is not recommended that the lime-bath-cured specimens be used for opening-to-traffic purposes. Specimens cured in the sandpit have the ability to adjust to the temperature of the environment, as does the concrete in the pavement. Therefore, these specimens are more appropriate for opening-to-traffic purposes. Thus, current INDOT specifications are appropriate.

Temperature match curing has the ability to provide specimens with an accurate representation of the maturity of the pavement. However, most commercial systems are costly. Less expensive in-house systems can be developed that would provide satisfactory results, however, the TMCB system developed in this study needs more development before it could be implemented. Further, sandpit curing provides results that are statistically equivalent to the maturity of the pavement. Thus, INDOT needs to determine if the extra expense of TMC systems is worth the increase in accuracy when current methods provide satisfactory results.

A method for converting between the strength of specimens cured in a given curing condition to the strength of the pavement is needed. An attempt was made to perform a regression analysis of the maturity data obtained in this study to develop such a relationship. However, the ANOVA results indicated that the trial (field trials T1-T3) was a significant factor. Since it was significant, the trial would have to have been included in the regression equation. Thus the use of the equation would have been limited to these three field studies.

To develop an equation with a broader range of uses, a greater number of trials need to be conducted. This experimental setup would remove the effect of the trial on the maturity development. Thus, the equation developed would be based only on the different curing conditions. Also, to base this equation on the strength of the pavement, cores of the pavement concrete should be taken and evaluated. The proposed form of the equation is shown in the following equation.

$$\ln(MOR) = a_0 + a_1C1 + a_2C2 + a_3C3$$

MOR = Modulus of Rupture
C1 = Curing Condition 1 Indicator Variable
C2 = Curing Condition 2 Indicator Variable
C3 = Curing Condition 3 Indicator Variable
a_n = Constant

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