Joint Transportation Research Program

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SPR-3212 2012

Compatibility of Cementitious Materials and Admixtures

Introduction

The process of selection of both the constitutive materials and the proportions of modern concrete mixtures is becoming more complex due to the increasing pressure to meet various durability and performance requirements. As a result, modern concrete mixtures frequently contain numerous mineral and chemical ingredients, combinations of which may lead to so-called incompatibility problems. The term “incompatibility” has been applied to various types of abnormal performance of concrete in both plastic and hardened concrete, including:

- Setting and strength gain problems
- Excessive slump losses
- Increased water demand to achieve the desired slump
- Problems with the generation and stability of the air void system

These irregularities adversely influence workability, placing, consolidation and finishing characteristics, along with durability of concrete mixtures. Based on the extensive literature review conducted as a part of this study, the main incompatibility problems were found to be due to one or more of the following phenomena:

- Cement driven incompatibility problems
- Incompatibility due to the type and the amount of supplementary cementitious materials (SCMs) in the mixture
- Incompatibility problems related to the usage of chemical admixtures in the mixture
- Problems due to other reasons and substandard practices

An extensive summary of literature findings on the incompatibility problems is presented in Appendix A of this report.

Findings

- Even though all (except for one) cements were initially selected to result in potential incompatibility problems, only 45 out of the 70 mixtures (combinations) tested in the sub-phase I of Phase I did so, while the remaining 25 mixtures were identified as compatible. The observed signs of incompatibility included rapid stiffening of the mixtures, significant changes in set behavior and/or in the hydration process.
- In general, cements with high C_3A content and low sulfate content were more prone to incompatibility problems. It was also observed that mixes with Type A water reducer (WR), W1, had a higher tendency for rapid stiffening than mixes with PC type superplasticizer (SP). The addition of W1 to high C_3A content and low sulfate content fly ash cementitious systems resulted in significant changes to the hydration process. Increased replacement of cement by class C ashes often aggravated the rapid stiffening and abnormal setting behavior of the mixtures. Also, in most of the cases, other factors (amount of admixture or the timing of addition) further aggravated the problem of incompatibility.
- Fly ash content and the type of admixtures present in the mixture significantly influenced both the generation and the stability of the air void system. The air entraining agents (AEA) requirement increased with the increase in the class F ash content. Mixtures prepared with W2 and AEA were found to be more unstable than mixtures prepared with other admixture combinations.

- Various incompatibility problems observed during the concrete testing were consistent with the findings from the corresponding paste and mortar experiments. Concrete mixtures prepared with high (60%) volumes of class F ash exhibited poor strength development.

Implementation

Based on the findings from the present work, the last section of the report, titled "Recommendations to Avoid Incompatibility Problems," presents practical, implementable guidelines with respect to minimizing potential incompatibility problems in the field.

The recommendations to avoid potential early stiffening and abnormal setting problems were developed using findings from mini slump, Vicat's set time and semi-adiabatic calorimeter experiments. Foam drainage, foam index and air content in mortars tests were used to develop guidelines to prevent air void related incompatibility problems.

Figure 6.1 of the report presents the list of incompatible combinations of materials and can be used as a practical field aid for the quick check of potential problems, especially in cases when materials source change occurred during the construction.

Two other factors (increased addition levels of WRAs and delayed addition of admixtures) resulted in mixed results. Both of these practices accelerated the set time in some mixes but had no effect on other mixes. Hence, it is recommended not to use either of these practices during construction. If it is imperative to use either of these practices, then it is recommended to perform a preliminary study as outlined in Figure 6.2. Various test methods and the corresponding limiting criteria to identify potential incompatibility problems are listed in Table 6.1. This table can also serve as a practical field guide.

Recommended Citation

Olek, J., and C. Paleti. *Compatibility of Cementitious Materials and Admixtures*. Publication FHWA/IN/JTRP-2012/30. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: 10.5703/1288284315025.

View the full text of this technical report here:
http://dx.doi.org/10.5703/1288284315025

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