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16. Abstract

A two-stage mixing process for concrete involves mixing a slurry of cementitious materials and water, then adding the slurry to coarse and fine aggregate to form concrete. Some research has indicated that this process might facilitate dispersion of cementitious materials and improve cement hydration, the characteristics of the interfacial transition zone (ITZ) between aggregate and paste, and concrete homogeneity.

The goal of the study was to find optimal mixing procedures for production of a homogeneous and workable mixture and quality concrete using a two-stage mixing operation. The specific objectives of the study are as follows: (1) To achieve optimal mixing energy and time for a homogeneous cementitious material, (2) To characterize the homogeneity and flow property of the pastes, (3) To investigate effective methods for coating aggregate particles with cement slurry, (4) To study the effect of the two-stage mixing procedure on concrete properties, (5) To obtain the improved production rates. Parameters measured for Phase I included: heat of hydration, maturity, and rheology tests were performed on the fresh paste samples, and compressive strength, degree of hydration, and scanning electron microscope (SEM) imaging tests were conducted on the cured specimens. For Phases II and III tests included slump and air content on fresh concrete and compressive and tensile strengths, rapid air void analysis, and rapid chloride permeability on hardened concrete.

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IMPROVING PORTLAND CEMENT CONCRETE MIX CONSISTENCY AND PRODUCTION RATE THROUGH TWO-STAGE MIXING

Final Report
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EXECUTIVE SUMMARY

A two-stage mixing process for concrete involves mixing a slurry of cementitious materials and water, then adding the slurry to coarse and fine aggregate to form concrete. Research has indicated that this process might facilitate dispersion of cementitious materials and improve cement hydration, the characteristics of the interfacial transition zone (ITZ) between aggregate and paste, and concrete homogeneity.

The goal of the study was to find optimal mixing procedures for production of a homogeneous and workable mixture and quality concrete using a two-stage mixing operation. The specific objectives of the study are as follows:

1. To achieve optimal mixing energy and time for a homogeneous cementitious material
2. To characterize the homogeneity and flow property of the pastes
3. To investigate effective methods for coating aggregate particles with cement slurry
4. To study the effect of the two-stage mixing procedure on concrete properties
5. To obtain the improved production rates

This study is divided into three phases: (1) laboratory investigation of the interaction between cement hydration and mixing methods and times for the formation of cement paste, (2) laboratory investigation of concrete, and (3) field investigation of concrete.

In the Phase I study, two mixers (a high shear mixer and a low shear mixer) were used, with varying mixing times and speeds for slurry mixing. Pastes made with different binder combinations of cement, fly ash, and slag were tested. Heat of hydration, maturity, and rheology tests were performed on the fresh paste samples. Compressive strength, degree of hydration, and scanning electron microscope (SEM) imaging tests were also conducted on the cured specimens.

The Phase I study results indicate that increasing the mixing energy (mixing speed and time) produces a more workable and uniform slurry. This conclusion is supported by the results from degree of hydration and rheology tests of paste. After mixing energy reaches a certain level, rheological properties of a given paste may show little or no significant change with increased mixing time. For a given mixing time, a high shear mixer generally produces pastes with higher early-age strengths than those produced using a normal mixer. Based on these tests, an optimal mixer and mixing time were recommended for the Phase II study on the two-stage mixing process of concrete.

In the Phase II study, the laboratory concrete study results showed that air entrainment was difficult when the air entraining agent was added in the slurry. A weak relationship exists between the total air content and the spacing factor as determined by the rapid air void analyzer. The 28-day compressive strengths were 10 percent stronger for the two-stage mixed concrete.

In the Phase III field study, two sites (Jordan, MN and Highland, IL) were visited using two different two-stage mixing techniques. A suitable location for a field site in Iowa was not able to

be achieved. Tests included slump and air content on fresh concrete. Hardened concrete tests included compressive and tensile strengths, rapid air void analysis, and rapid chloride permeability. The two-stage field test results from two projects showed that two-stage mixed concrete performed better overall when compared to conventional ready-mixed concrete. Two-stage mixed concrete was generally more resistant to chloride penetration with increased tensile strengths. The analysis of tensile strength results showed a more homogeneous concrete.