National Concrete Pavement Technology Center

CP Tech Center

Two-Stage Mixing

tech transfer summary

Optimal two-stage mixing procedures can improve concrete production rates while maintaining durability and quality.

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RESEARCH PROJECT TITLE
Improving PCC Mix Consistency and Production Rate through Two-Stage Mixing

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The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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Objectives

- Investigate effective methods for coating aggregate particles with cement slurry, study the effect of the two-stage mixing procedure on concrete properties, and characterize the pastes produced
- Optimize mixing energy, mixing time, and production rates for homogeneous cementitious materials

Problem Statement

Concrete ingredients must be thoroughly mixed to produce a homogeneous mixture with sufficiently hydrated and uniformly distributed cement particles. Moreover, the mixing operation must properly coat the aggregates with paste to eliminate undissolved cement particles. However, modern concrete increasingly contains fine cementitious materials, low water-to-binder ratios, and high binder contents. This allows fine cementitious particles to agglomerate, prevents cementitious materials from hydrating uniformly, and reduces concrete workability.

Two-Stage Mixing

Responding to this challenge, the two-stage mixing process divides the mixing operation to improve both the paste uniformity and the aggregate coating. The first stage prepares the paste by premixing water, cement, and additives to create a slurry of cementitious materials. Thus, the cement and additives can chemically combine with water and the undissolved cement and additive particles cannot easily attach to the aggregate and agglomerate. The second stage then adds the slurry to the fine and coarse aggregate and coats the aggregate with the paste. This produces concrete.

Other industries use high-intensity mixing to prepare cement paste, and this technology could be applicable to the portland cement concrete used in highway construction. This pre-mixing process may help disperse cementitious material and improve cement hydration, concrete homogeneity, and the interfacial transition zone (ITZ) between aggregate and paste.

Research

Phase I studied the interaction between cement hydration, cement paste formation, and different mixing methods. Variables included two mixers (high-shear and low-shear), varying mixing times and speeds, and various pastes made with different binder combinations of cement, fly ash, and slag. Fresh and cured paste samples were tested.

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Phase II investigated the effect of two-stage mixing on concrete properties. Combinations of cement, fly ash, and slag were selected tested, and concrete made using a conventional dry batch process was compared with two samples made using the two-stage process (30- and 60-second mix times). Fresh concrete samples were tested for tested for slump and air content, and hardened concrete samples were tested for strength, permeability, and air voids.

Phase III included two field studies—one in Illinois and one in Minnesota. Two different two-stage mixing techniques were investigated. Fresh concrete was tested for slump and air content, and hardened concrete was tested for strength, air voids, and permeability.

Key Findings

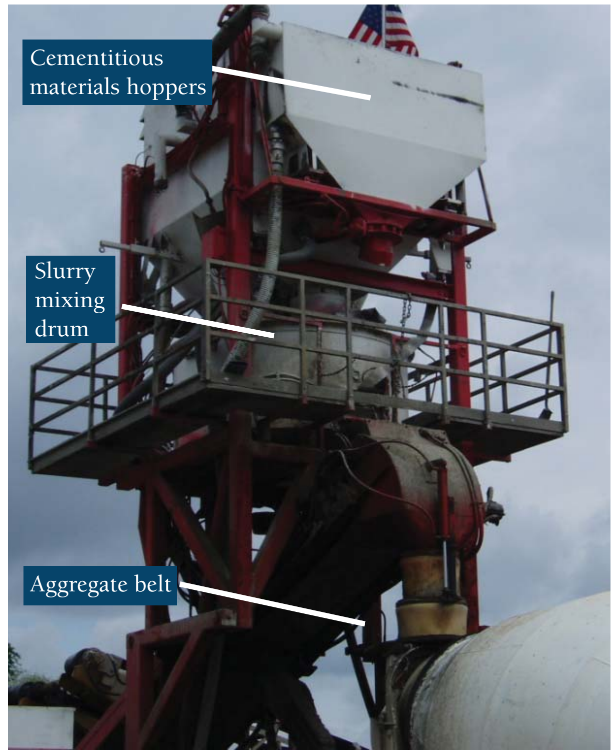
- Increasing mixing energy during two-stage mixing produces a more thoroughly mixed slurry. Pastes containing fly ash generally require lower mixing energy to reach optimum uniformity than pastes containing only cement.
- High-shear mixing produces a slightly greater degree of hydration than normal mixing, and high-shear mixing produces the earliest hydration reactions.
- High-shear mixing reduces the unhydrated cement particles as mixing time increases. Degree of hydration decreases when supplementary cementitious materials (SCMs) are added.
- Two-stage–mixed concrete has a lower permeability than conventionally mixed concrete.
- Air entrainment is less effective in two-stage mixing when the air-entraining admixture (AEA) is added in the slurry.
- For a given AEA type and dosage, concrete produced using two-stage mixing contains lower air content than concrete mixed conventionally.
- A mixture's air void spacing factor generally increases as total air content decreases. Air content further decreases when two-stage mixing is used for concrete with SCMs.

Implementation Benefits

- Based on this research, two-stage mixing can significantly improve concrete uniformity.
- Due to increased mixing time (from the time the cement contacts water to the end of mixing), two-stage mixed concrete generally shows a reduced slump.
- Two-stage mixing may increase concrete strength 5%–10% over conventionally mixed concrete. Laboratory results show an 8%–10% increase, field results show a 5%–10% increase, and a literature review shows a 10%–20% increase.

Implementation Readiness

- Two-stage mixing at 30 seconds is recommended as the optimal mixing process.
- Additional research is needed to verify the strength and uniformity conclusions, to investigate the effects of AEA in two-stage mixing, and to study the effect of two-stage mixing on ternary combinations.



Components of the two-stage mixing tower at the Minnesota research site

Two-stage mixing tower at the Minnesota research site