Concrete Property Test

Other 6-2: Material Incompatibilities

National Concrete Pavement Technology Center
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Purpose – Why Do This Test?

Portland cement concrete mixtures for paving are complex systems. There have been many examples of premature pavement distresses caused by a material incompatibility issue (*20*). If no effort is made to identify potential material incompatibilities in a laboratory environment, then field problems may lead to project delays and/or modified construction methods that only temporarily mask the problem.

Laboratory analysis of mixtures for potential incompatibilities consists of a testing protocol that involves preparing paste, mortar, and/or concrete containing different combinations of materials and considers the effect of temperature on potential incompatibilities.

Principle – What is the Theory?

Research conducted by the CTL Group for the FHWA provides the background for utilizing an incompatibility testing protocol. *Identifying Incompatible Combinations of Concrete Materials: Volume I – Final Report* states the following:

"Lack of compatibility among various cementitious materials and admixtures can lead to early stiffening, which could account for many other problems. The tendency to early stiffening may be attributed not only to the individual cementitious materials, but also to interactions among the various cementitious materials and the chemical admixtures. Early stiffening may be caused by excessive calcium sulfate in the form of hemihydrate (plaster) in the cement (false set) or the uncontrolled early hydration reactions of the tricalcium aluminate (C_3A) (flash set). False set may be overcome by continued mixing of the concrete. Early stiffening is not reversible and leads to loss of workability. When concrete is hard to place, it is likely water will be added, which reduces both strength and durability and increases the potential for shrinkage and cracking. The addition of some admixtures improves workability without these negative effects, but the admixtures also add considerably to the cost of the concrete, and they may retard setting.

Early stiffening depends on several factors, including C_3A content and reactivity; alkali content; and the form, content, and distribution of sulfates in the cement. C_3A hydrating in the presence of sulfate ions forms ettringite on its surface. The ettringite acts as a barrier, further limiting reactivity. If supplementary cementing materials, particularly Class C fly ash, contain aluminate phases, and the sulfate is not well distributed in the cement paste, the concrete may experience early stiffening. A balance among the ions in plastic concrete is necessary to prevent early stiffening. Some chemical admixtures, particularly Type A water reducers, may disturb this balance.

Early stiffening can be deleterious to pavement performance. If the concrete cannot be thoroughly consolidated, loss of strength and durability can result, as well as early development of cracking and pavement failures.(2) If extraordinary consolidation efforts are used to achieve the required concrete density, the entrained air-void system may be altered, leading to decreased freeze-thaw durability.(3,4)

Cracking in concrete can also be caused by a host of factors. Shrinkage can occur in fresh or hardened concrete. The major cause of plastic shrinkage cracking is thought to be the tensile stress developed as water evaporates from the surface of the concrete, leaving the capillaries partially filled and creating a disjoining pressure caused by surface tension effects. The risk of cracking may be higher in concretes that exhibit early stiffening because the mix does not remain fluid long enough to allow a layer of bleed water to remain on the surface. While bleeding is generally thought of as detrimental to concrete, bleeding may also have some benefit with relation to the potential for plastic cracking: drying of the surface cannot occur if it is covered with bleed water. Precautions to prevent plastic shrinkage cracking include (1) strict adherence to specifications regarding evaporation rates and cessation of concrete placement if relative humidity is low and temperatures and wind speeds are high, (2) use of fog sprays, and (3) use of evaporation retarding admixtures during and immediately after finishing.

Cracking can also occur because of autogenous shrinkage, drying shrinkage, thermal effects, and external loads. Cracking occurs when and where the maximum principal tensile stress exceeds the tensile strength of the concrete.

A number of paving projects have experienced problems related to use of synthetic air-entraining agents resulting in accumulations (coalescence) of air voids around the aggregate particles. In addition to this problem, the quality of the air-void system in the hardened concrete continues to be

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a matter of concern. The spacing factor and specific surface are the main parameters of the concrete air-void system that indicate the ability of the concrete to resist the damaging effects of frost. In recent years, it has been observed that marginal air-void systems may result from incompatibility between certain water reducers and air-entraining agents." (*20*)

Note: A complete incompatibility testing protocol can be found in *Identifying Incompatible Combinations of Concrete Materials: Volume II – Test Protocol*. Please refer to this publication for test procedures/methods, test apparatus, and guidance on interpreting test data.

Construction Issues – What Should I Look For?

The following construction issues may be caused by material incompatibilities:

- Early stiffening.
- Flash set.
- False set.
- Retarded strength gain.
- Unstable air entrainment.
- Low strength due to coalescence of air voids around aggregate particles.

The most common adaptations to counteract these material incompatibilities are as follows:

- Reduce the dosage of supplementary cementitious materials (SCMs).
- Adjust the temperature of the concrete mixture.
- Delay the introduction of water-reducing admixtures in the batching sequence.

APRIL 2008

ctre
Center for Transportation Research and Education

Iowa State University

This test summary is one of a set of summaries originally published in chapter 7 of the *Testing Guide for Implementing Concrete Paving Quality Control Procedures* (Fick, G., Iowa State University, Ames, Iowa, 2008). The testing guide is a product of a 17-state, Federal Highway Administration pooled-fund project, Material and Construction Optimization for Prevention of Premature Pavement Distress in PCC Pavements, TPF-5(066). The project was managed by the National Concrete Pavement Technology Center at Iowa State University.