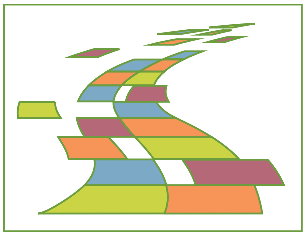
CP ROAD MAP
shaping the future of **concrete pavement**



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ROAD MAP TRACK 7

“Moving Advancements into Practice”

MAP Brief January 2015

Describing promising technologies that can be used now to enhance concrete paving practices

Producing Freeze-Thaw Durable Concrete

PROJECT TITLE
Producing Freeze-Thaw Durable Concrete

TECHNICAL WRITERS
Tyler Ley
Oklahoma State University

EDITOR
Sabrina Shields-Cook

SPONSOR
Federal Highway Administration

MORE INFORMATION
Tyler Ley
Oklahoma State University
tyler.ley@okstate.edu
405-744-5257

Introduction

When concrete is in a wet environment and exposed to freeze-thaw (F-T) cycles, tensile stresses develop within the concrete. Localized damage to the surface of concrete can also occur when deicing salts are used. Concrete is most at risk for this type of damage when it is close to being saturated. This can lead to damage in just a few F-T cycles.

Why do we entrain air in concrete?

To protect concrete from F-T damage, a soap or surfactant, called an air entraining admixture (AEA), is added while the concrete is mixing. An AEA helps stabilize air voids that are spherical and typically between 0.0005 in. and 0.05 in. in diameter. After the concrete hardens, these voids can reduce damage from freezing. In addition, entrained air also improves the workability of fresh concrete and can reduce segregation and bleeding.

Entrained air will reduce the strength of the concrete mixture. Typically, every 1% increase in air content causes a reduction in the compressive strength of about 500 psi. While entrained air is important to the F-T durability of concrete, it is also critical to use F-T durable aggregates and a cement paste that is strong and moisture resistant.

What kind of air-void system do we need?

The ideal air-void system consists of small and well-dispersed bubbles. This is why bubble size and spacing are the two most important parameters in determining the effectiveness or the quality of the air-void system (Powers 1949). Because these two parameters are historically difficult to measure in fresh concrete, most specifications instead require a certain volume of air in the concrete. Most modern specifications require an air content of 6% +/- 1.5%. These specifications are a simplification of research done over 60 years ago by Klieger (1952, 1956). Recent research has shown that using total volume of air is conservative for some mixtures and not satisfactory for others. Modern concrete mixtures use very different admixtures, cements, and construction practices than those used when Klieger’s original research was completed.

For example, concrete mixtures with modern AEAs have been shown to need only 3.5% air in the concrete to provide satisfactory air-void systems and sufficient performance in rapid F-T testing in paving mixtures (Felice 2012; Felice, Freeman, and Ley 2014). However, when combinations of AEAs and water reducers (WRs) were investigated, they were found to produce bubble systems that were larger and of lower quality at a given volume of air. This means that higher air contents were needed in order to achieve the same F-T durability (Saucier et al. 1991, Saucier et al. 1990, Freeman 2012, Felice 2012).

Research has found that mixtures with air contents as high as 7% did not perform well in the F-T testing when certain WR and AEA combinations were used. This MAP brief highlights how specifications that use total air volume to specify air content can be inadequate and indicates that air-void quality is more representative of F-T performance.

How do we get a good air-void system?

Obtaining a consistent air-void system in concrete can be challenging because there are a large number of variables that im-

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Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The January 2015 MAP Brief provides information relevant to Track 7 of the CP Road Map: 7.Concrete Pavement Maintenance and Preservation.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefJanuary2015.pdf.

pact the volume and quality of an air-void system in fresh concrete. Some of these variables include the following: type and length of mixing, chemistry of the cementitious materials, combinations of admixtures, gradation of the aggregates, and temperature. Additionally, construction practices such as placement by a paver, pumping, and surface finishing can further modify the air-void system.

It is best to design concrete mixtures to minimize their sensitivity to fluctuations of admixture dosage, mixing, and construction conditions. This can be done by having concrete mixtures that are not overly reliant on admixtures to meet performance requirements. Once concrete production has successfully begun, close attention should be paid to observing how changes in construction practices impact the air-void system. It is also helpful to measure the concrete at a number of different points in the construction process and specifically to measure the material at the point it is placed in the structure.

How do we know we have a good air-void system?

The most widely used method to measure the quality of the air-void system is ASTM C457, “Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete.” In this test, hardened concrete is cut, polished, and inspected with a microscope using a standardized method to measure the void sizes and spacing. This test reports the total volume of air as well as a parameter called the spacing factor. The spacing factor was developed by Powers (1949) and is recognized as the primary measurement of air-void system quality. Rapid laboratory F-T testing found that a spacing factor of approximately 0.008 in. was needed to provide F-T durability (Backstrom et al. 1958).

One challenge with the ASTM C457 test is that it takes weeks to obtain the results. The test is also expensive and requires specialized equipment and personnel. As discussed previously, most specifications rely on the measurement of the total volume of air with AASHTO T 152 (ASTM C231), “Test for Air Content of Freshly Mixed Concrete by the Pressure Method;” AASHTO 196 (ASTM C173), “Standard Method of Test for Air Content of Freshly Mixed Concrete by the Volumetric Method;” or AASHTO 121 (ASTM C138), “Standard Method of Test for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.” Because these tests only measure the air-void volume, their results are not always a good indicator of air-void quality.

Figure 1 shows two concrete mixtures with different air contents and the impact different air contents have on the spacing factor. Notice that the mixture with just AEA needs about 5.5% air to meet the suggested spacing factor while the mixture with AEA and WR requires 9% air. This again shows that it is critical to know the air-void system quality and not just the air content of a mixture.

Recent research at Oklahoma State University has led to the development of a new testing device that is able to measure the quality of the air-void system in fresh concrete. This device has been named the Super Air Meter (SAM) and is shown in Figure 2. The device and sample preparation have many similarities to the AASHTO T 152 (ASTM C231) pressure meter, but the SAM test method uses higher pressures and a larger number of pressure events to determine the volume and quality of the air-void system in fresh concrete (Ley and Tabb 2014, Welchel 2014). The test takes less than 10 minutes to run, and the meter provides both the air content as determined by AASHTO T 152 (ASTM C231) and a new measurement called the SAM number that correlates with the void spacing or the spacing factor.

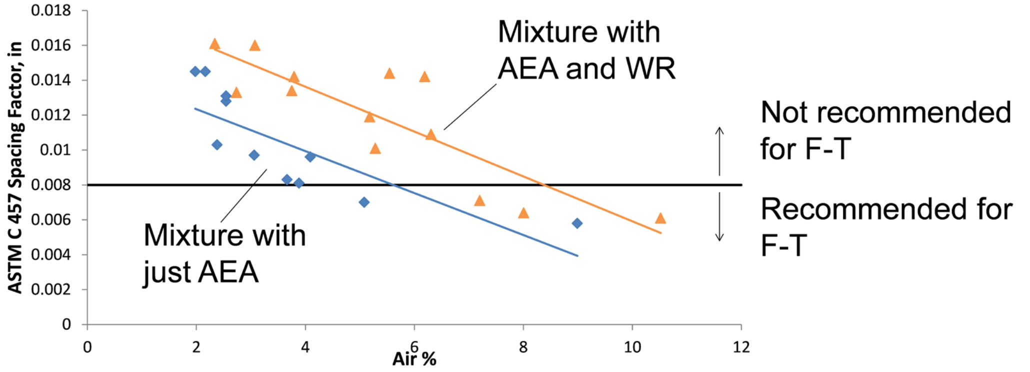

Figure 1. Air content versus spacing factor for concretes with different admixture combinations. The data shows that just using air content as a measure of air-void quality can be miss leading.

Figure 2. The Super Air Meter (SAM)

The SAM test method is currently being used in 20 different states, and an AASHTO provisional test method has been prepared to be balloted in February 2015. Results from over 300 different concrete mixtures by two different research groups from the laboratory and the field is shown in Figure 3. These mixtures varied in slump, water to cement ratio, cement content, AEA type, and combinations of admixtures. Over 90% of the time, a SAM number of 0.20 has been shown to correctly determine whether the spacing factor is above or below the 0.008 in. limit based on the laboratory and field testing. Results are also shown in Figure 4, which compares the SAM number to performance in rapid F-T testing (ASTM C666). A SAM number of 0.20 seems to be a good indication of performance.

The SAM is beneficial because it can be used to measure the air-void quality in the fresh concrete before the concrete has hardened. This allows for changes to be made to the mixture or the construction practices to provide concrete with increased F-T resistance. More details can be found at www.superairmeter.com.

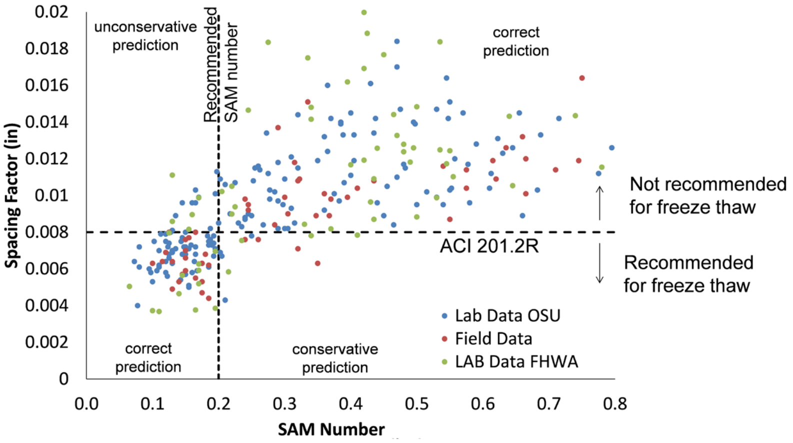

Figure 3. A comparrison of SAM number versus spacing factor for over 300 mixtures from two different labs with both lab and field concrete

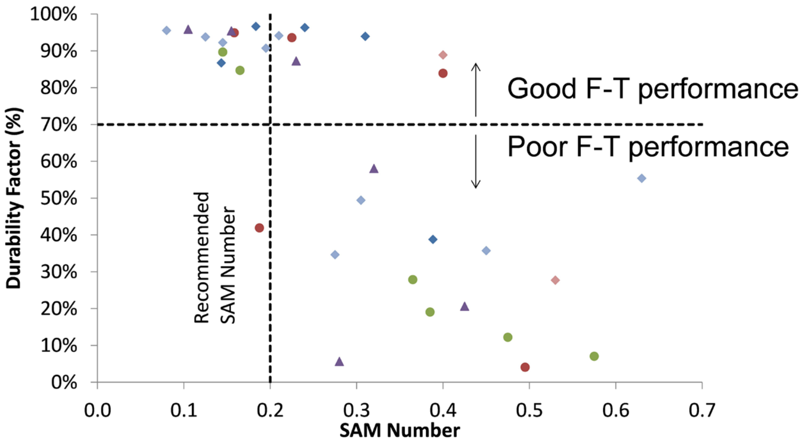

Figure 4. The SAM number versus the durability factor from rapid F-T testing

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