Concrete Pavement Mixture Design and Analysis (MDA):

Evaluation of Foam Drainage Test to Measure Air Void Stability in Concrete

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Technology Center

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Peter Taylor, Xin Wang, Xuhao Wang

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National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
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16. Abstract

The stability of air bubbles in fresh concrete can have a profound influence of the potential durability of the system, because excessive losses during placement and consolidation can compromise the ability of the mixture to resist freezing and thawing. The stability of air void systems developed by some air entraining admixtures (AEAs) could be affected by the presence of some polycarboxylate-based water reducing admixtures (WRAs). The foam drainage test provides a means of measuring the potential stability of air bubbles in a paste. A barrier to acceptance of the test was that there was little investigation of the correlation with field performance.

The work reported here was a limited exercise seeking to observe the stability of a range of currently available AEA/WRA combinations in the foam drainage test; then, to take the best and the worst and observe their stabilities on concrete mixtures in the lab.

Based on the data collected, the foam drainage test appears to identify stable combinations of AEA and WRA.

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CONCRETE PAVEMENT MIXTURE DESIGN AND ANALYSIS (MDA):
EVALUATION OF FOAM DRAINAGE TEST TO MEASURE AIR VOID STABILITY IN CONCRETE

Technical Report
March 2015

Principal Investigator
Peter Taylor, Associate Director
National Concrete Pavement Technology Center, Iowa State University

Authors
Peter Taylor, Xin Wang, and Xuhao Wang

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A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103 / Fax: 515-294-0467
www.cptechcenter.org

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EXECUTIVE SUMMARY

The total air content of a mixture is normally measured before concrete is placed into its final position and consolidated. This practice is acceptable only if the air void system is stable. A test that assesses the stability of air void systems was reported by Cross et al. (2000), and reviewed by Taylor et al. (2006a). While the test showed promise, little correlation with field performance was available and it has not found much traction.

The aim of the limited work reported here was to continue to evaluate the test using paste systems in use today. Based on the data collected, the foam drainage test appears to identify stable combinations of air entraining admixtures (AEAs) and some polycarboxylate-based water reducing admixtures (WRAs).

INTRODUCTION

Traditionally, the air content of a fresh concrete mixture is measured only before concrete is placed into its final position and consolidated. Because the air void system was generally stable, this practice was acceptable, but recent changes in the chemistry of the paste system have been leading to reported changes in the concrete during handling (Freeman, 2012). Concrete measured to contain 5 to 6% air at the truck has been observed to contain anywhere between 3 and 13% in-situ, leading to potential poor freeze thaw resistance or loss of strength, respectively.

A test that assesses the stability of air void systems was reported by Cross et al. (2000), and reviewed by the Taylor et al. in 2006a. While the test showed promise, little correlation with field performance was available and it has not found much traction.

The aim of the limited work reported here was to continue to evaluate the test using paste systems in use today.

BACKGROUND

The stability of air bubbles in fresh concrete can have a profound influence of the potential durability of the system, because excessive losses during placement and consolidation can compromise the ability of the mixture to resist deterioration caused by freezing and thawing. This is increasing critical in the light of work by Freeman (2012) that indicated that stability of air void systems developed by some air entraining admixtures (AEAs) could be affected by the presence of some polycarboxylate based water reducing admixtures (WRAs).

A test method called the foam drainage test provides a means of measuring the potential stability of entrained air bubbles in a paste was reported by Cross et. al. (2000) . A barrier to acceptance of the test was that there was little investigation of the correlation with field performance.

The original aim of the work reported here was to investigate that correlation. This was challenging because owners and contractors are unwilling to allow researchers to interfere with construction in progress, or to use combinations that are unstable and so increase the risk of premature failure of their pavements. An attempt was made to tie laboratory foam drainage data with a field-based project being carried out by Ram et al. in Wisconsin (2013). The data collected from unreported laboratory tests did indicate that several of the admixture combinations used in the field had a high risk of instability, while the field data reported showed losses through the paver between 0 and 2% air content by volume. The findings, therefore, were somewhat inconclusive.

The work reported here was a limited exercise seeking to observe the stability of a range of currently available AEA/WRA combinations in the foam drainage test; then, to take the best and the worst and observe their stabilities on concrete mixtures in the lab.

LABORATORY WORK

The bulk of the work was in the form of foam drainage tests on a range of AEA and WRA combinations.

Cementitious Materials

A single source of Type I/II cement was used for all mixtures and the chemical composition is shown in Table 1.

Table 1. Chemical composition of cement

Chemical Composition	Type I/II Cement
SiO_2	20.10
Al_2O_3	4.44
Fe_2O_3	3.09
SO_3	3.18
CaO	62.94
MgO	2.88
Na_2O	0.10
K_2O	0.61
P_2O_5	0.06
TiO_2	0.24
SrO	0.09
BaO	-
LOI	2.22

Chemical Admixtures

- Air entraining admixtures: 5 products were obtained from 2 manufacturers – 2 vinsol based, 2 rosin, and 1 synthetic.
- Water reducing admixtures: 5 polycarboxylate-based products were obtained from one manufacturer.

Aggregates

Crushed 1 in. limestone coarse aggregate was used with a natural river sand in the concrete mixtures.

Tests

Foam Drainage tests were conducted in accordance with the method published in a Federal Highway Administration (FHWA) report (Taylor et al. 2006b). Tests were conducted on mixtures with and without cement. The matrix of combinations is shown in Table 2. Limited availability of some products meant that a complete matrix could not be completed.

Table 2. Test matrix

	None	WRA 1	WRA 2	WRA 3	WRA 4	WRA 5
Syn 1	X					
Vinsol 1	X					
Vinsol 2	X	X	X	X	X	X
Rosin 1	X	X	X	X	X	X
Rosin 2	X	X	X	X	X	X

The foam drainage test comprises preparing a mixture of paste ingredients, and agitating in a blender to create 1,000 mL of foam. This foam is poured into a graduated cylinder, and the rate at which fluid collects at the bottom of the cylinder is then monitored over 60 minutes. Plot V_d versus 1/t. The data are modeled to estimate the long-term volume (V_0) of fluid collected (Equation 1). Decreasing V_0 indicates systems that may be considered more stable and less likely to collapse in the field.

$$V_d = V_0 - 1/(k \times t) \qquad \text{Equation 1}$$

Where

V_d = Volume of water at time t

V_o = Volume of water at time ∞ (Calculated)

t = time

k = slope of the V_d vs 1/t plot

Two combinations were selected for testing in concrete mixtures, one stable and one unstable, in order to assess whether there is a correlation between mixture stability and that reported by the foam drainage test. The combinations are highlighted in Table 2. The same mixture was used in both cases using proportions typically used in pavement construction. AEA dosages were fixed at the middle of the manufacturers recommended range.

Mixture proportions are shown in Table 3.

Table 3. Concrete mixture proportions

	Weight (SSD)
Cement, lbs/cy	593
Water, lbs/cy	254
Fine Aggregate, lbs/cy	1520
Coarse aggregate, lbs/cy	1520
w/c	0.43

Six cylinder samples were taken from each mixture: two after initial mixing, two after “typical” vibration (6 seconds using a 1-in. pencil vibrator) and 2 after “over vibration” (additional 12 seconds). Cylinder samples were later examined in accordance with ASTM C 457.

Results

The results of the foam drainage tests on mixtures without cement are shown in Figure 1 and Table 4.

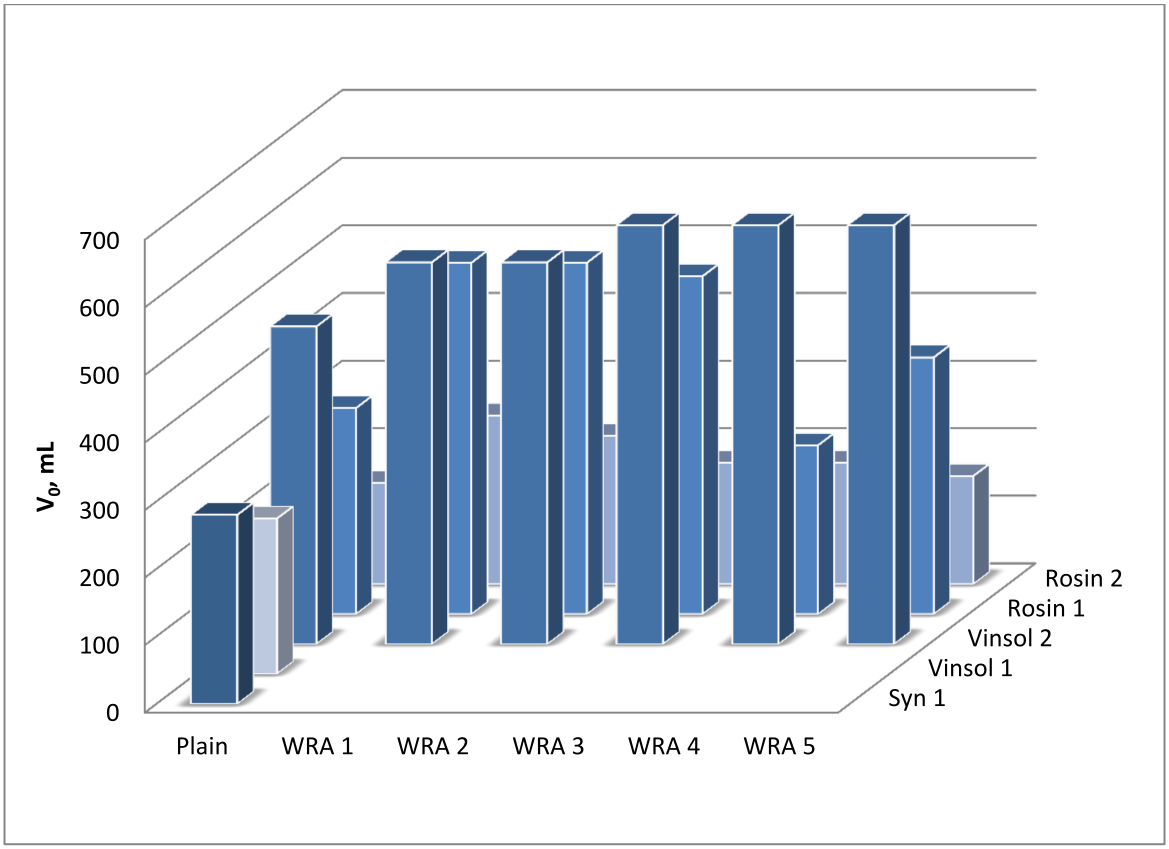

Figure 1. V_0 (mL) for mixtures without cement

Table 4. V_0 (mL) for mixtures without cement

	Plain	WRA 1	WRA 2	WRA 3	WRA 4	WRA 5
Syn 1	280					
Vinsol 1	230					
Vinsol 2	470	565	565	620	620	620
Rosin 1	305	520	520	500	250	380
Rosin 2	150	250	220	180	180	160

The results of the foam drainage tests on mixtures with cement are shown in Figure 2 and Table 5.

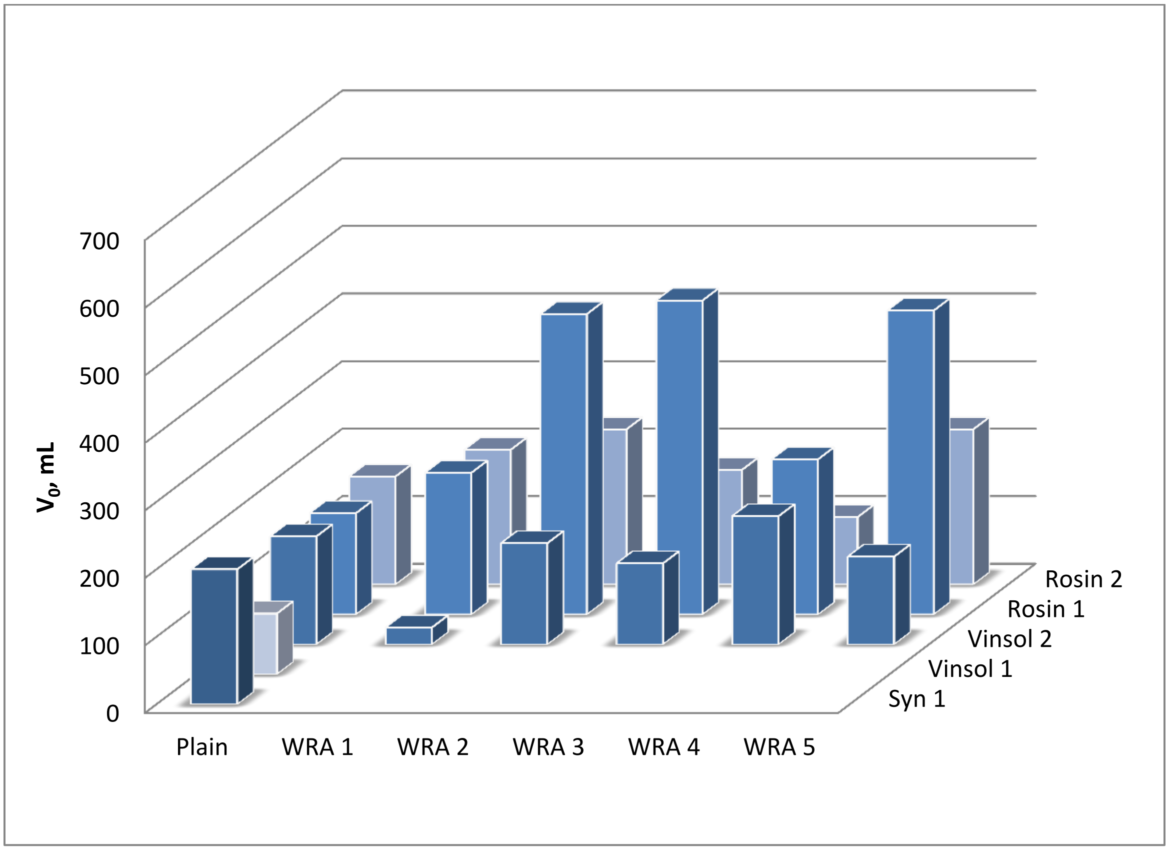

Figure 2. V_0 (mL) for mixtures without cement

Table 5. V_0 (mL) for mixtures with cement

	Plain	WRA 1	WRA 2	WRA 3	WRA 4	WRA 5
Syn 1	200					
Vinsol 1	90					
Vinsol 2	160	25	150	120	190	130
Rosin 1	150	210	445	465	230	450
Rosin 2	160	200	230	170	100	230

The spacing factors for the two concrete mixtures are shown in Table 6 and Figure 3.

Table 6. Spacing factor data, mm (average of two samples)

	Rosin 1 and WRA 1 (A)	Vinsol 2 and WRA 3 (B)
After mixing	0.10	0.12
After normal vibration	0.20	0.17
After excess vibration	0.26	0.20

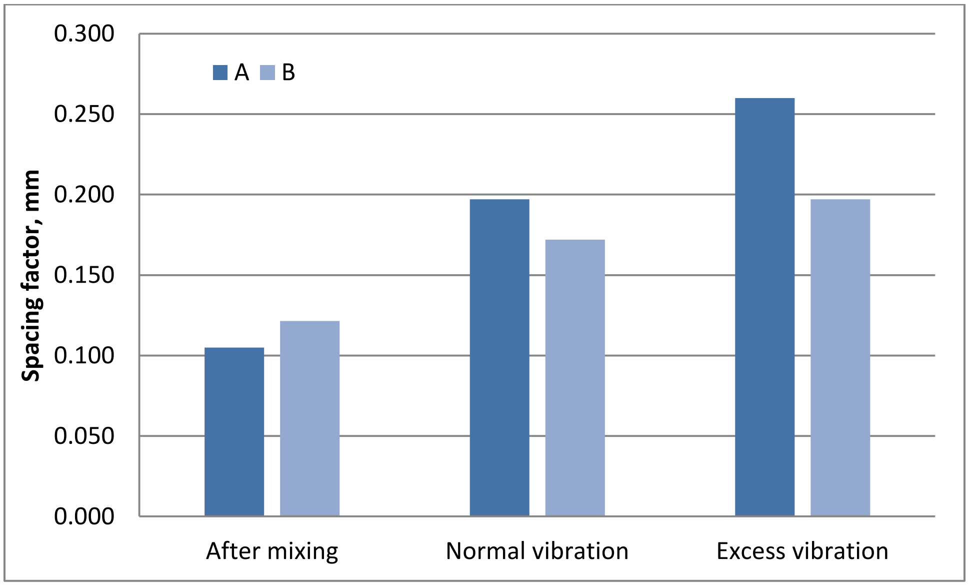

Figure 3. Spacing factors for admixture combinations after vibration (A = Rosin 1 and WRA 1, B = Vinsol 2 and WRA 3)

Discussion

Several observations can be drawn from the data presented. Firstly, it is clear that stability of air-void systems is dependent on the presence of cementitious materials. In particular the Vinsol 2 appeared to perform poorly in the mixtures without cement but well in mixtures with cement. This is consistent with previously reported trends (Taylor et al. 2006a). Tests should therefore be conducted using the ingredients intended for use in the field. Some work had been conducted as part of this effort in which dosages of the admixtures were varied, but this merely resulted in difficulty in making enough foam to run the test and the data were meaningless. Therefore, proportions used for testing should be those set out in the method.

From the tests on mixtures containing cement, it can be seen that all of the AEA products performed well without WRAs present. However, the Rosin 1 product was significantly affected with some of the WRA products. This is consistent with observations reported by Freeman (2012) and helps to explain reports from the field that, despite quality assurance (QA) systems in place, some pavements are observed to have air void contents less than 4% in the hardened concrete.

The spacing factors presented in Table 6 and Figure 3 are derived from ASTM C 457, the linear traverse method. The data from the two concrete mixtures are consistent with the foam drainage results, namely that the stability of the air in the system containing a lower V_0 combination was better than that of the higher V_0 combination.

CONCLUSIONS

Based on the data collected, the following conclusions may be drawn:

- The foam drainage test appears to identify stable combinations of AEA and WRA.
- Air void stability in concrete appears to be consistent with output from the foam drainage test.

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