DHT 50

Effect of Permeability on ASTM C 1260/1567 Testing

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By

Andy Naranjo, P.E. – TxDOT Cement Laboratory Supervisor
&
Rachel Cano – TxDOT Cement Laboratory, Summer Intern

Introduction

ASTM C 1567, "Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate[1]," also known as the Accelerated Mortar-Bar Test (AMBT), is currently used by numerous agencies as a method to determine the minimum dosage of supplementary cementing material needed to mitigate alkali-silica reaction in concrete[2-6]. There appears to be an empirical relationship between this test and performance of actual field structures[2]. However, since the mechanisms occurring in this test and in actual concrete are far from the same, the relationship is largely coincidental.

The reduced expansion when SCMs are used in the AMBT is generally considered to be an effect of the permeability reducing capability and/or the alkali binding properties of the SCMs[7]. It has yet to be determined what the impact of permeability and alkali binding ability of the fly ash have on the expansion results. Others[8, 9] have also found that differences in cement alkalinity can have large effects on the results of the AMBT when testing fly ashes, with higher alkali cement mixtures having lower expansion results. It was suggested that higher alkali cements tend to promote more pozzolanic and cementitious reactions thus resulting in less permeable mortar, which slows the ingress of alkali hydroxides into the sample[10] and retards expansion.

In this study, mortar mixtures with and without fly ash were tested to determine the effect the initial permeability has on the final expansion of the AMBT. Additionally, two cements with slightly varying alkali contents were used to determine the test's sensitivity to cement alkalinity.

Materials

Two cements (C1 & C2) with different alkali contents were used in this study to determine if the alkali contents of cements affect permeability or expansion results. Four Class C fly ashes (F1-F4) and one Class F fly ash (F5) were also used in this study. The chemical composition of these materials is listed in Table 1.

One reactive siliceous fine aggregate from southwest Texas was used in all mortar mixtures. The aggregate was sieved into individual sizes, washed, dried, and recombined according to ASTM C 1260[11] gradation requirements.

Table 1
Chemical Composition of Portland Cements and Fly Ashes (% mass)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Na_2Oe
C1	19.87	4.25	3.69	62.72	0.56	3.75	0.04	0.60	0.43
C2	20.53	4.97	3.63	63.14	1.05	2.72	0.14	0.35	0.37
F1	33.94	18.47	6.80	25.00	5.29	1.46	1.16	0.31	1.36
F2	32.00	17.46	6.27	25.18	5.65	2.52	1.28	0.26	1.45
F3	36.16	19.62	5.50	23.44	4.34	0.86	1.22	0.36	1.46
F4	28.96	17.09	5.75	27.67	8.06	2.69	1.20	0.18	1.32
F5	54.32	22.97	4.88	9.69	1.73	0.32	0.19	1.01	0.85

Test Methods

Mortar bars were prepared in accordance with ASTM C 1260/1567. The mixture proportions were increased in order to cast eight mortar bars and two 2-inch diameter permeability samples from the same batch. Mixtures with fly ash F1-F4 had 40% of the cement replaced with the respective fly ash. Mixtures containing fly ash F5 had 20% of the cement replaced with fly ash.

In order to determine the effect of permeability, two curing methods were used. After molding, the mortar bars and permeability specimens were cured in a moist cabinet for 24 hours and then demolded. The first set of mortar bars (four bars) and one permeability specimen were tested in accordance to ASTM C 1260/1567. However, the permeability sample was tested after the second curing day.

The additional four mortar bars and permeability specimen were placed in a container with saturated calcium hydroxide solution and stored in a 38°C oven for 28 days. This curing method was an attempt to make these specimens less permeable than the ones that were cured according to ASTM C 1260/1567. The mortar bars were then tested in accordance to ASTM C 1260/1567.

The permeability specimens were tested in accordance with ASTM C 1202, except that it was necessary to run the test at 30 volts instead of 60 volts. This is similar to the method used to test permeability of post-tensioned grout materials. Thus, the permeability values are only used as a relative degree of permeability.

Results

Figure 1 shows the permeability results for all the mortar mixtures tested in this study. These values represent the permeability of the mortar bars prior to being submerged in sodium hydroxide solution and stored at 80°C for fourteen days.

The permeability of the mixtures containing only cement and cured according to ASTM C 1260/1567 slightly varied from each other. Mixtures containing cement and fly ash that were cured according to ASTM C 1260/1567 had a substantial reduction of permeability in all but one mixture when compared to the control mixtures. Mixtures containing cement C2, the lower alkali cement, had less permeability reduction than mixtures containing cement C1.

The permeability results of the mixtures cured at 38°C for 28 days are also shown in Figure 1. As with the other set of control mixtures, there was little difference between the permeability of the two control mixtures. The addition of fly ash substantially reduced the permeability of the mixtures compared to the control mixtures. Again, there was a difference between mixtures containing fly ash and the two cements, with the mixtures containing the lower alkali cement being more permeable.

When comparing the permeability of the specimens cured according to ASTM C 1260/1567 to the ones cured for 28 days at 38°C, the specimens cured for 28 days had substantially lower permeability. Mixtures containing cement C1 that were cured for 28 days had permeability values 43% to 70% lower than their counterpart mixtures cured according to ASTM C 1260/1567. Mixtures containing cement C2 that were cured for 28 days had permeability values that were 17% to 53% lower than their counterpart mixtures cured according to ASTM C 1260/1567. There is a substantial difference in permeability depending on which cement is used in the mixtures. The permeability data indicates that the use of the higher alkali cement has a significant impact on the permeability of the mixtures.

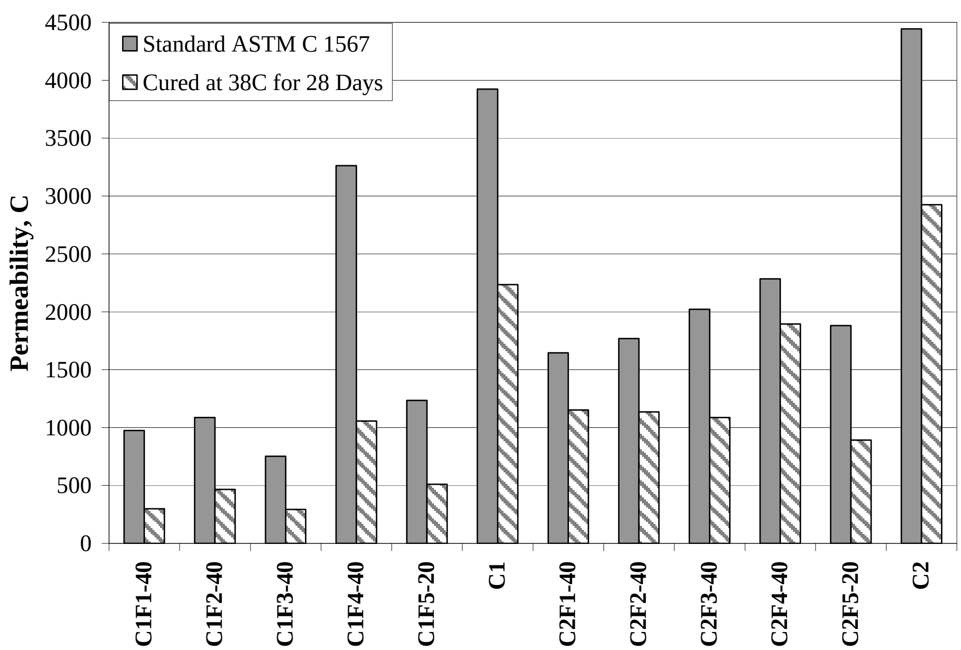

Figure 1 - Permeability Results

Figure 2 shows the ASTM C 1260/1567 expansion results of all the mortar mixtures tested in this study. The two control mixtures cured according to ASTM C 1260 resulted in similar 14-day expansions. The use of fly ash in these mixtures resulted in a decrease of expansion, which could be a direct result of the reduced permeability. The use of different cements resulted in the same trend as with the permeability. The higher alkali cement mixtures tended to have slightly lower 14-day expansions compared to mixtures that used cement C2.

Expansion values for mixtures cured for 28 days at 38°C are also shown in Figure 2. These mixtures showed similar 14-day expansions to those cured according to ASTM C 1260/1567. As previously stated, mixtures cured by this method resulted in having sustainably lower permeability compared to the mixtures cured according to ASTM C 1260/1567. From these test results, it appears that the permeability of the mixture prior to being exposed to sodium hydroxide solution has little to no influence on the 14-day expansion. As an example, mixtures C1F1-40 and C1F2-40 had more than 50% reduction in permeability, but had similar expansion results. This trend holds true for all of the mixtures tested in this study. Only one mixture, C1F5-20, had a 14-day expansion below the 0.1% limit.

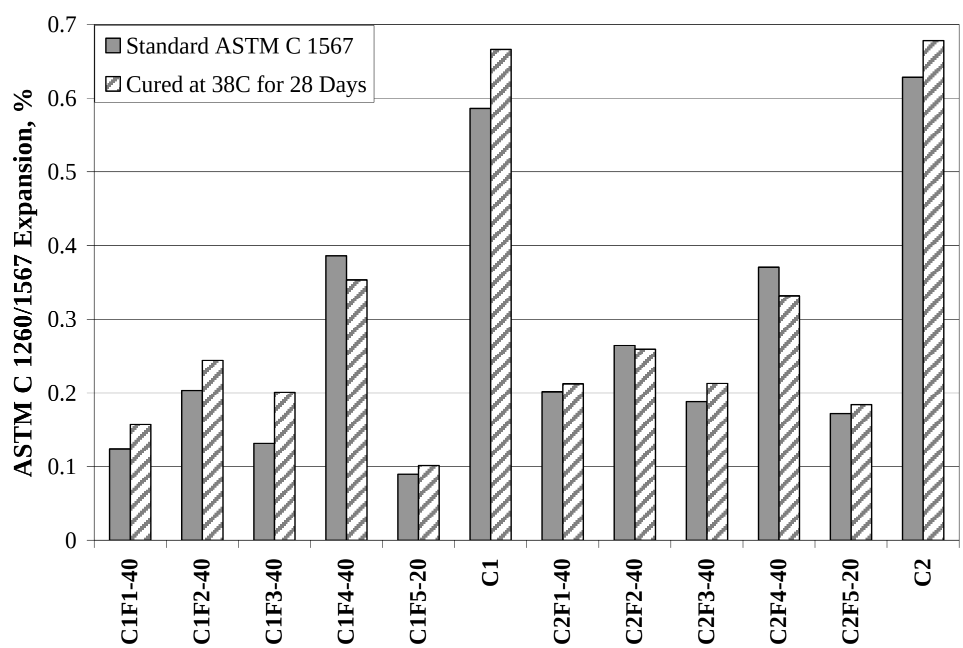

Figure 2 - ASTM C 1260/1567 Expansion Results

Figures 3 and 4 are plots of the ASTM C 1260/1567 expansions versus permeability results for each cement and curing method. These plots again illustrate that the initial permeability of the mixtures do not have an impact on the 14-day expansion results.

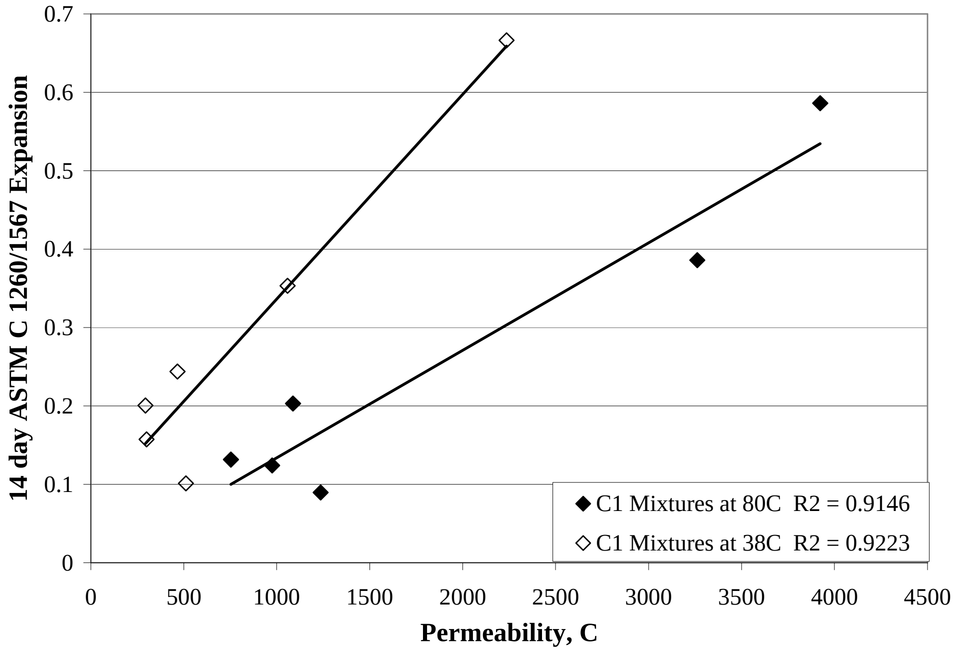

Figure 3 - ASTM C 1260/1567 Expansions vs. Permeability Results

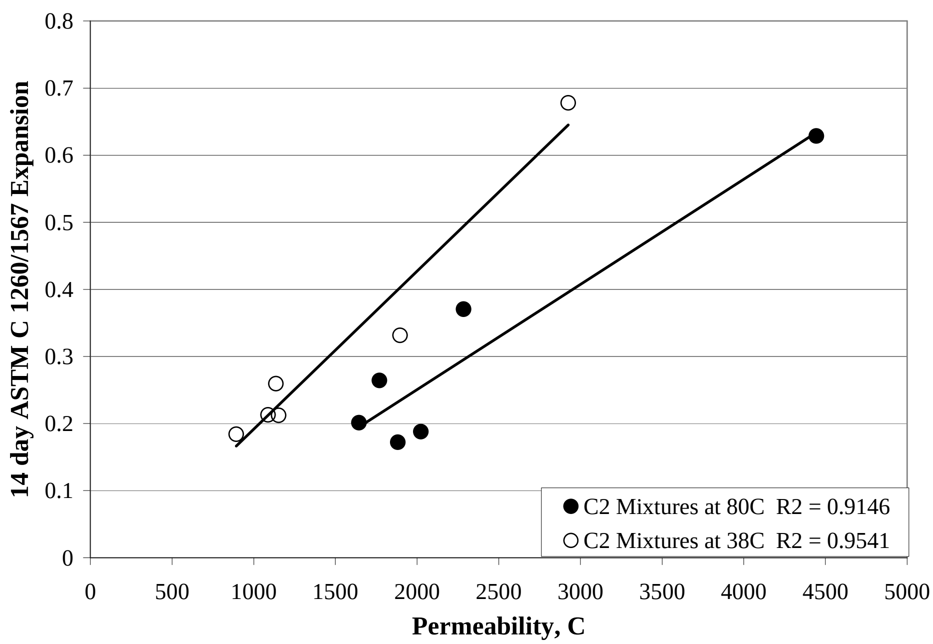

Figure 4 - ASTM C 1260/1567 Expansions vs. Permeability Results

Conclusion

Based on the results of this study, the following conclusions can be made about the ASTM C 1260/1567 testing:

- The use of fly ash resulted in substantial reduction in the initial permeability and final mortar bar expansion compared to the control mixtures.
- The cement alkalinity has a greater effect on mixtures containing fly ash than on mixtures that contain only cement.
- The higher alkali cement mixtures with fly ash tended to result in less permeable mortars that also had lower final expansion, regardless of the curing method.
- The modified curing method used in this study resulted in further reduction of the initial permeability compared to the mixtures cured according to ASTM C 1260/1567. However, it appears that the initial permeability does not have a major impact on the 14-day expansion.

References

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