Progress Report
May 2005

FHWA POOLED-FUND PROJECT NUMBER: ***TPF5-(075)***

TITLE: Extending the Season for Concrete Construction and Repair – Phase II, Defining Engineering Parameters

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OBJECTIVE: To define the effect of the antifreeze admixtures developed in Phase I on the freeze-thaw durability of portland cement concrete. Develop guidance for using admixtures to enhance the service life of concrete in northern climates.

REPORTING PERIOD: 01 February 2004 through 01 May 2005

ITEMS IN THIS ISSUE:

- Progress since last report
- Phase I condition survey
- ASTM/ACI/USAF developments
- New report available
- Looking ahead
- Phase III to be proposed

Progress since last report: Freeze-thaw testing of the initial set of beams cast from six concrete mixtures representing a range of w/c ratios and cement factors was completed in April. Two additional sets of beams were made and are being freeze-thaw tested to confirm our preliminary analysis of the data that the freeze-thaw durability of concrete increases with admixture concentration, except at the higher concentrations where durability begins to decline (Fig.1). It appears, as mentioned in the last report, that the higher concentrations of admixtures, which are based on the amount of water in the concrete mix, may be overloading the pore structure in hardened concrete. We say this because concretes made with lower w/c ratios seem to show fewer declines in frost resistance as a function of admixture concentration than do concretes made with higher w/c ratios. In effect, lowering the w/c ratio increases pore volume in relation to admixture volume. More on this in later reports as the data is still being reduced. At this point, the laboratory results are demonstrating that the freeze-thaw resistance of concrete can be improved with admixtures.

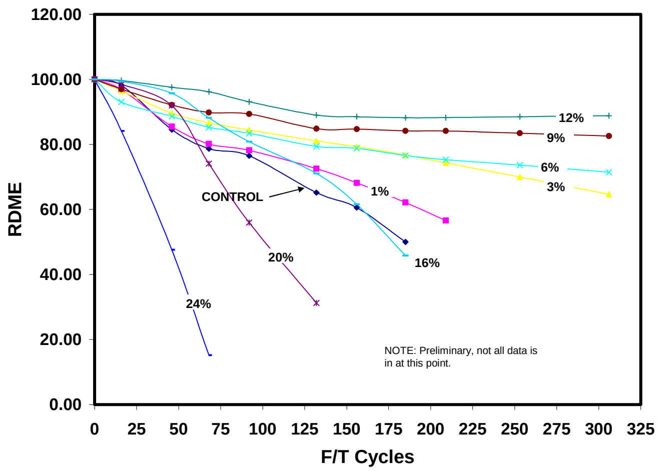

Figure 1. Sample of Phase II freeze-thaw results where admixture concentrations up to at least 12% (wgt of dry chemical to wgt of water) dramatically improve durability. The Phase I concretes contained between 12 and 16% concentration of admixture, which were shown to not adversely affect durability.

The dilation testing is approximately half way done. The preliminary results suggest that admixtures affect the length change of concrete as it is cycled from room temperature to –60°C and back again. Figure 2 shows that concrete made without admixtures (control) expands much more than does a comparable antifreeze concrete. On cooling between 20 and –5°C both concretes contract. Between –5°C and –20°C, the control concrete expands greatly whereas the antifreeze concrete barely expands. At –40°C the control concrete expands again while the antifreeze concrete contracts. On warming, both beams expand with the control concrete expanding more than the antifreeze concrete. As both concretes fully thaw, they attempt to return to their original length at 0°C. Thereafter, both beams exhibit normal thermal expansion. Interestingly, though both concretes exhibit residual expansion, the control exhibits more. Concrete, when frozen, is considered to be susceptible to frost damage if it dilates and to be immune to frost damage if it does not dilate. Because the control concrete had more residual dilation than did the antifreeze concrete, it should be more susceptible to frost damage. The freeze-thaw data seems to bare this out. It will be interesting to see if this trend continues as more dilation testing is done.

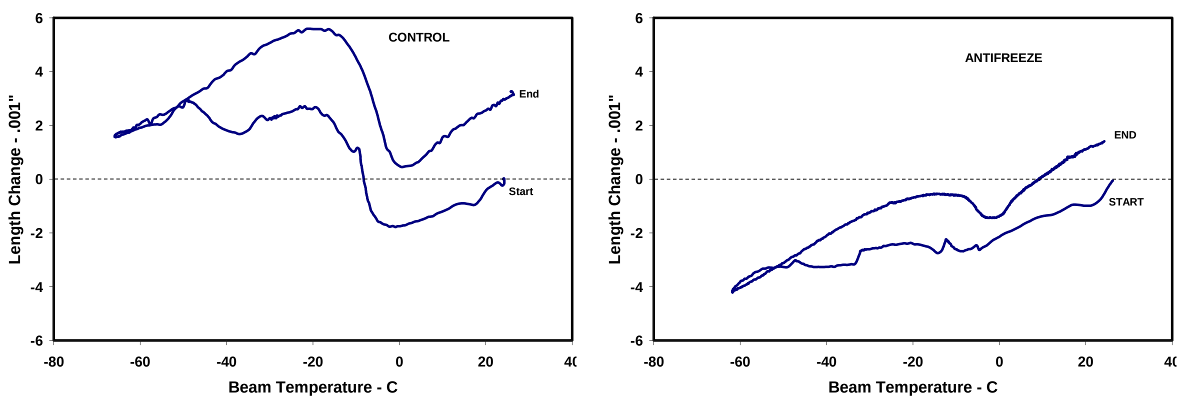

Figure 2. Length change as a function of temperature. Both concretes were water-saturated and made with the same w/c ratio and cement factor.

Phase I Condition Survey: Because the bridge repairs done in West Lebanon, NH (Phase I) have both a control and an antifreeze section, we have been visually monitoring this bridge since December 2002. Recall that both sections were repaired under mid-winter conditions using the same concrete mix design except that the antifreeze section employed antifreeze chemicals. The control section used a heated shelter to protect the concrete while it cured. Up until just recently, both sections seemed to be performing equally well. However, as Figure 3 shows, the control section has started to deteriorate, whereas the antifreeze section continues unchanged. This good outcome was not anticipated at the start of Phase I but, when coupled with the encouraging findings from Phase II, it appears that not only can the construction season be extended; the service life of concrete probably can also be extended. The amount of admixture needed to achieve both of these functions need not be great and probably shouldn't be based on developing results.

Figure 3. After two winters, the control concrete (left) is beginning to spall while the antifreeze concrete is unchanged.

ASTM/ACI/USAF developments: The new Cold Weather Admixture Systems (i.e., Antifreeze Admixtures) specification was placed on the main committee ballot of ASTM Section C09, Concrete and Concrete Aggregates, in March 2005. Ballot results will be addressed at the June 2005 meeting.

ACI 306, Cold Weather Concreting, has re-drafted its guidance on cold weather concreting. The goal of this committee, which I chair, is to present new report to ACI for approval within the next year. The new version will address the state-of-art of antifreeze admixture technology.

ACI 212, Chemical Admixtures for Concrete, is updating its guidance. I presented new chapter covering cold weather admixtures to this committee in April 2005. The goal is to have a new report drafted within two years.

The US Air Force is considering publishing an Engineering Technical Letter (ETL) later this year based on our Phase I results.

These developments should help pave the way for admixture companies to market antifreeze admixtures that are tech-supported. Thanks to all of you for being a part of this developing success.

New Report Available: A report on the results from the Grand Forks Air Force Base, ND, job has been posted on our website at < http://www.crrel.usace.army.mil/techpub/CRREL_Reports/reports/TR05-9.pdf >.

Looking ahead*:* The plan is to complete all freeze-thaw and dilation testing by mid-summer. The data should be analyzed and a report drafted this coming fall.

Phase III to be proposed: The following two findings from the Phase I and II work suggest that we could be smarter about using antifreeze admixtures.

1. A –5°C concrete may not always be necessary. Where air temperatures have dropped to –20°C lesser amounts of admixture probably would have sufficed.
2. Freeze-thaw durability of concrete increases with admixture concentration right up to the amounts we used in Phase I. Interestingly, lesser amounts seem to produce more durable concrete, which goes along with the first bullet above.

Therefore, a guide for tailoring admixture dosages to a given jobsite condition is needed. A series of tables that allows one to select admixture dosage based on air temperature, mix design, thickness of concrete, and boundary condition would be a practical improvement to how we now design antifreeze concrete. These tables could be incorporated into the March 2004 Guide we produced for you, which would give us essentially a manual for cold-weather concrete. We will send out a draft Phase III proposal as early as next week to get your feedback.