Progress Report
September 2002

FHWA POOLED-FUND PROJECT NUMBER: ***TPF5- (003)***

TITLE: Extending the Season for Concrete Construction and Repair

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OBJECTIVE: To develop an antifreeze admixture conforming to existing industry standards. This work will adapt recently developed knowledge about off-the-shelf admixtures to the specific conditions of highway construction. The admixture will protect concrete to 23°F (-5°C) or lower and allow concrete to gain appreciable strength while at that temperature.

REPORTING PERIOD: 01 March through 01 September 2002

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***Funding*:** A check with FHWA shows that all ten states participating in this project have contributed to its second year. Thank you for your continued support. This report serves as a reminder for the third disbursement of funds. Last year went fairly smoothly. Let us know should you encounter any difficulty with transferring funds to FHWA this year.

CERF Update: Last year, we announced that CRREL was involved with the Civil Engineering Research Foundation (CERF), Unisphere, and Concurrent Technologies Corporation (CTC) to develop a national standard for antifreeze admixtures (see http://www.crrel.usace.army.mil/concrete/Other_Initiatives.htm). We view this effort as critical to the eventual commercialization of antifreeze admixtures. The current plan is to initiate discussions with key people from ASTM at the October 2002 ACI convention in Phoenix, and to continue from there. As mentioned in previous progress reports, it is likely that this will be a several year effort from this point, as it's taken over two years to get this far. Thus, our pooled-fund project fits in quite nicely in that it will develop an antifreeze capability that should be immediately available to all until more is done in this area. Those states involved in this pooled-fund study will be in good position to take advantage of future commercial development of antifreeze admixtures.

Lab Results: Since our last progress report, we returned to the laboratory for more testing. The four admixture combinations using W.R. Grace products, tested under field conditions last winter, were tested for freezing point depression, workability, strength gain at low temperature, time of setting, plastic air, air

bubble spacing, freeze-thaw durability, maturity, and freeze protection limits. Our goal is to develop a concrete that performs as well at –5°C as does normal concrete cured at +5°C. Our data suggests we have achieved that goal in two critical areas: freezing point depression and strength development. Though freeze-thaw results are still pending, our preliminary impression is that the admixtures do not adversely affect the freeze-thaw durability of the concrete. Our tests of non-air-entrained concrete confirm this. However, it appears that some of the admixtures affect the air bubble spacing in the cement paste. We are waiting for the results from the petrography lab to make a final determination. At this point it appears that the dose of air-entraining admixture might have to be closely monitored when used with certain admixtures.

In the lab we also turned our attention to developing a second set of antifreeze admixtures using products from Master Builders. Thus far, we have been successful in finding the right combination of admixtures from this company that provides reasonable workability, freezing point depression, air content, and early-age strength gain. Field testing and further lab evaluations are required to complete this portion of the project.

Looking ahead: We plan to field-test our Master Builders admixtures this coming winter to build on the successes of last year. We issued a call in our March 2002 progress report for volunteers to conduct a winter demonstration similar to what we did in New Hampshire and Wisconsin last winter. See the urls below for a refresher on how the projects were handled then.

- *First field project, New Hampshire, December 2001:*
  http://www.crrel.usace.army.mil/concrete/NH_Field_Demonstration.htm
- *Second field project, Wisconsin, March 2002:*
- *http://www.crrel.usace.army.mil/concrete/Wisconsin_Demo/Wisconsin_Field_Demo.htm*

So far, both Wisconsin and New Hampshire have indicated an interest to work with us again. Is anyone else interested?

Based on what we learned from the two field tests, this year's field-testing should concentrate on the process of pre-qualifying mixes, on quality control of the concrete, and on coordinating a project in cold weather. We'd like to do the pre-qualifying but then step back a bit to follow how the work is coordinated and checked for quality by the agency responsible for the repair work. We'd like a project large enough to require at least two deliveries of concrete to the work site. This will expose any weakness in multiple batches without getting over extended. As with last year, each truck may be limited to half capacity, as some of our mixes tended to lose slump quite rapidly. We'll better be able to determine that need as our testing progresses between now and this fall.

What we need from you: We'd like several states to volunteer to coordinate the efforts for our demonstration project this coming winter, 2002-03. We'll choose the site that offers the most benefit to all of us. The project should not be on a critical path or be a critical element in your project, as the weather is unpredictable—we may not get the work done on schedule if warm weather sets in for a time. Another reason for not selecting a critical project is that we are still conducting an experiment. We have had positive responses from both NH and WI thus far. These would be excellent places to build on what was learned last winter. However, there may be other possibilities to consider. Please let us know if you have a demonstration site for us to consider. We'd like to hear from you in October 2002, if possible.

***Heads Up -- Phase II*:** We'd like to bring to your attention some interesting possibilities for future studies that are directly related to our current work. During the testing we have done so far, it has become apparent that more could be done to expand on what we are now accomplishing with off-the-shelf

antifreeze admixtures. We plan to send out a separate proposal to all cold regions states at a later date, but thought that we'd share some of our ideas with you at this time to get your input.

The pooled fund study "Extending the Season for Concrete Construction and Repair" has essentially demonstrated the practicality of antifreeze admixtures for concrete. Phase I, ***Establishing the Technology***, is on track toward delivering the tools to design, mix, place, and cure concrete in below-freezing weather. Now we are looking at a possible Phase II, ***Defining Engineering Parameters***. Below are a few thoughts on four possible studies that should be considered:

- Longer Lasting Concrete: Preliminary study shows that the freeze-thaw durability of concrete, and perhaps its salt scaling resistance as well, could be greatly enhanced with judicious use of certain admixtures. Data at this time points to a possible doubling of the service life of concrete in cold regions. FHWA studies show huge potential savings in our nation's infrastructure maintenance dollars if concrete service life could be improved by as little as 1%. Imagine what a longer service life could mean to bridge decks alone.
- Quality Assurance Tools: During the current Phase I testing it became apparent that there was no reliable means for assuring that the concrete delivered to the job site had the correct freezing point depression or that it developed the needed strength before it was placed into service. We can measure the freezing point of fresh concrete in the laboratory within 15 minutes but now we need to develop a portable method that the job-site inspector can use in the field. For measuring strength gain, it is common to use the maturity method. However, this method has never been tested at below freezing temperature, partly because there has never been a need to do so. A study should be done to develop a maturity algorithm for low temperatures and antifreeze concrete along with the proper protocol for easy field use.
- Define Thermal Safety: The concrete coming out of Phase I will be able to be cooled to –5°C and still perform well. How cold can the weather be? This is a logical question and one not easily determined. A computer model would provide the most direct solution. However, to be reliable, the model would necessarily have to consider the heat evolved from the cement as a function of admixture and temperature. Data on this is non-existent. CRREL recently fabricated a calorimeter that measures heat output from cement paste as a function of temperature. Numerous computer programs exist that predict thermal profiles in concrete but none are used on a routine basis in the field; probably because they are quite involved. There is a need to develop an easy-to-use program run from a laptop computer to predict concrete temperatures (and thusly concrete strengths) over time. We envision something as simple as using a 5-day weather forecast along with a few facts about the concrete to generate the results. The key is the calorimetric data, and, as said, we have a good start on that.
- Other Cements: Phase I concentrated on only Portland cement concrete, but much of today's concrete uses blended cement. There is a need to determine what effect using fly ash, blast furnace slag, or silica fume as additives or as partial replacements of Portland cement has on the low-temperature performance of concrete. Some mineral additives react with calcium hydroxide in a secondary cementing action that delays attainment of ultimate strength. Others are more cementitious in nature, though still slower reacting than plain cement. It would be nice to find admixtures that would make these materials more useful in the cold. We think it is possible.

We plan to circulate a more detailed proposal for follow-on work to all participants in Phase I and to other states later this fall. We'd like to hear from you before then to get your input on the information presented above. We feel that all of the above studies merit some consideration—perhaps you can think of others—but the one that jumps out at us is the potential that admixtures have for creating longer service life. There should be a huge payback on this one. Let us know what you think.