Proposal: SP&R Pooled-Fund Study TPF-5(XXX)

Start (est.): Oct 2005
End (est.): Apr 2007

Phase III **[Continuation of TPF-5(003) & TPF-5(075)]**

Extending the Season for Concrete Construction and Repair

Guidance for Optimizing Admixture Dosage Rates

Phase III goal: The right dosage for strength, durability, and economy.

Phase I: West Lebanon bridge repair after two winters. Top = control concrete noticeably spalled. Bottom = antifreeze concrete in good condition. Phase II testing corroborates this result by suggesting that antifreeze concrete can be more durable than ordinary concrete.

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EXECUTIVE SUMMARY

Background

Phase I, FHWA pooled-fund project TPF-5(003), demonstrated the practicality of using commercially available admixtures as antifreeze admixtures for concrete. Eight admixture formulations, developed under laboratory conditions, were successfully demonstrated in the field. The concrete made with these admixtures fully cured at internal temperatures of –5°C, was as durable as normal concrete, and was less expensive than conventional concrete because no additional heat was required to keep the antifreeze concrete warm. The project report, released in February 2004, provided the first-ever tools in north America to design, mix, place, and cure concrete in below-freezing weather.

Phase II, TPF-5(075), is investigating the potential that admixtures may enhance the freeze-thaw durability of concrete. Preliminary test results demonstrate that the Phase I admixtures increase the freeze-thaw durability of concrete, at least at moderate dosages, possibly by actively depressing the freezing point of pore water in hardened concrete. In support of this finding, a recent condition survey of the West Lebanon bridge repairs made two seasons ago during Phase I showed that the antifreeze concrete repairs were performing better than were the conventional concrete repairs (see photos on proposal cover). Phase II, originally scheduled to end in October 2005, is expected to lead to guidance for enhanced service life of concrete in northern climates.

Phase III (proposed) will develop design guidance for specifying admixture dosage rates to match given job site weather conditions. Current guidance provides for one capability: –5°C concrete. Experience has shown that this capability is often more than necessary. What is needed is a guide for tailoring admixture dosages to a given situation, based on mix design, weather conditions, and element size.

Objective

Develop admixture dosage guidance. It is envisioned that this guidance will be in the form of a series of tables based on max/min expected air temperatures, boundary conditions, mixture proportions and temperature, and concrete mass. This guidance will complete the field guide drafted in Phase I.

Benefits Obtained from this Study

Participants in this study will receive design guidance to the field production and use of off-the-shelf concrete admixtures as antifreeze admixtures. Included will be guidelines for adjusting admixture dosage rate to specific job conditions.

How to Participate in this Study

A consortium of stakeholders will fund this study, where each stakeholder contributes between $20K and $50K per year. State DOTs are encouraged to direct their 100% SP&R funds toward participation in this project. States that want to commit funds to Phase III may do so on the Transportation Pooled Fund web site [www.pooledfund.org].

TPF-5(XXX)

[Continuation of TPF-5(003) and 5(075)]

Phase III

Extending the Season for Concrete Construction and Repair

Guidance for Optimizing Admixture Dosage Rates

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INTRODUCTION

Phase I, *Establishing the Technology,* **Extending the Season for Concrete Construction and Repair,** pooled-fund study [TPF-5(003)], performed by the U.S. Army Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (CRREL), ended in October 2003. Phase I, supported by ten northern State Departments of Transportation, demonstrated the practicality of antifreeze admixtures for concrete and delivered the tools to design, mix, place, and cure concrete in below-freezing weather.

Phase II, being conducted under TPF-5(075) and supported by nine state DOTs, was scheduled to end in October 2005. The focus of this project is to define the effect of the Phase I antifreeze formulations on the freeze-thaw durability of concrete. Preliminary results show that freeze-thaw durability increases with admixture dosage, except at higher doses, where durability declines (Fig. 1). Does this finding suggest that there is a limit to the maximum amount of admixture that may be added into concrete? Or is there a limit to the lowest temperature to which concrete can be exposed? We hope to answer these and other questions in this study as they will have interesting implications as to how cold weather concrete may be designed in the future—for strength and durability.

Currently, concrete made according to the Phase I recommendations is capable of resisting freezing to at least –5°C. However, experience has shown that this much protection is not always necessary. In effect, a –5°C concrete can be over-designed for many applications and thus may be more expensive than is necessary. This proposal intends to develop guidance for designing various levels of admixture dosages to fit a wide range of job conditions.

Guidance for Optimizing Admixture Dosage Rates

Based on the success of Phase I, which established the practicality of using antifreeze admixtures in concrete, and the preliminary results from Phase II, which are showing that antifreeze admixtures can enhance the freeze-thaw durability of concrete, it is time to complete this cold-weather concreting program by producing design criteria for the field production of antifreeze concrete.

Background: Phase I developed a concrete that can gain strength while its internal temperature is –5°C. Currently, we can't adjust the admixture dosage to coincide with the varying levels of protection that might be necessary for a given weather situation. We have a one-size-fits-all situation because we can't forecast an internal temperature as a function of changes in outdoor temperature. Users of this technology need the capability to predict how a concrete mixture will perform in a particular environment, making it possible to optimize mixture design, economize material costs, and assure a desired outcome.

Past experience: The five winter field trials conducted in Phase I illustrated the difficulty of determining how the concrete would perform when subjected to the unstable outdoor conditions. In all cases, the air temperatures varied from the freezing mark down to 0°F or lower during the first few days of curing. These temperatures were low enough to freeze normal concrete but, in each instance, the antifreeze concrete was barely challenged. Easily, the work could have been conducted in more severe weather or the amount of admixture used could have been lessened. As early results from Phase II are beginning to reveal, using less admixture can be advantageous when it comes to the freeze-thaw durability of concrete (Fig. 1). Thus, for durability, strength, and economy, there is a need to understand how to design antifreeze admixture dosage rates for concrete.

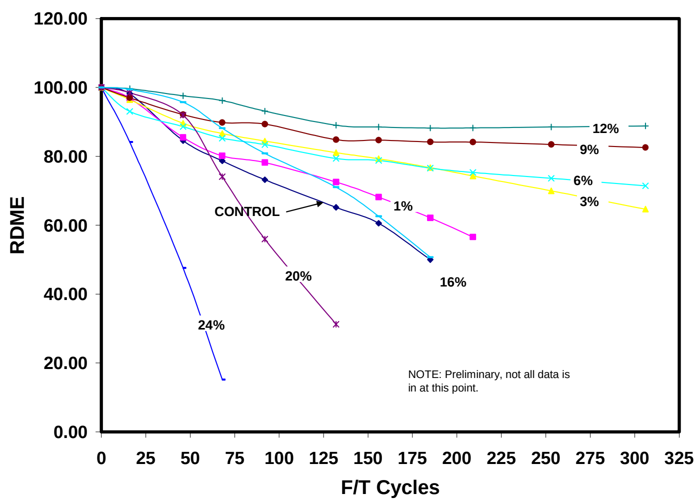

Figure 1. Phase II preliminary results. Note that antifreeze admixtures enhanced the freeze-thaw durability of non-air-entrained concrete at dosages up to at least 12% (wgt of dry admix by wgt of water). At much higher dosages the durability declines. Phase I uses dosages of around 16%.

This project will develop a user-guide that will allow admixture dosages to be adjusted for a specific protection level. The guide will set dosage rates for general sets of conditions to provide a conservative protection of the concrete while it cures. The dosage rates will account for the environmental conditions and for several different types of concrete elements—slabs on grade, elevated slabs, and beams—of varying thickness.

The guide will allow technicians to design the correct mix and protective measures based on weather predictions for the first few days following concrete placement. The plan is to develop a series of design tables.

Deliverables: The user will simply use the forecasted high and low temperatures for the period of interest, the cement factor, the type and thickness of element and then look up the required dosage of admixture to maintain the temperature of the concrete above its critical freezing point. Coupled with this the user will be able to consult the report generated in Phase I of this study to determine how soon the structure will be ready for use.

PROJECT GOVERNANCE

The project leader, Charles Korhonen, will maintain contact with all project sponsors by updating our project web site at [http://www.crrel.usace.army.mil/concrete/Durability_pooled_fund_study.htm]. Periodic progress reports will be e-mailed to each sponsor and be placed on the web site.

PROJECT SCOPE

The broad outlines of the project are described above. As issues arise during the course of experimentation, the project leader will propose and communicate any necessary amendments. As with Phases I and II, a web site will be maintained to facilitate dissemination of project information as it is developed.

PROJECT COSTS

This project is targeting $325K for 18-months. As with Phases I and II, the amount each state contributes will be left up to the discretion of each state. We will continue to accept states until the funding target is met.

PROJECT DURATION

1½ years.

QUALIFICATIONS

Dr. Korhonen has led a team of engineers to handle Phases I and II. The same approach will be used with Phase III, where individuals with the particular skills will be called on as needed. Following is a summary of his qualifications.

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Korhonen joined CRREL in 1975. He is engaged in research on the maintenance and rehabilitation of structures in the cold regions. He has evaluated radar facilities situated on the Greenland ice cap, developed methodology for non-destructive evaluation of roofing systems, conducted field and laboratory studies of external coatings for buildings, and promoted improved methods for extending construction practices into the winter. His research has led to the adoption of infrared roof warranty surveys by the Corps of Engineers to identify leaks before they become the problem of the building owner, the commercialization of a miniature vent to economically repair blistered roofs, and the patenting of an antifreeze admixture that allows concrete to be cured at below freezing temperatures.

Areas of Specialization:

- Cold weather concrete.
- Masonry construction.

Current Projects:

- Expedient cold-weather concrete admixtures for the Army.
- Off-season repairs for the transportation industry.
- Enhanced durability of portland cement concrete.

Notable Contributions or Highlights from Past Projects:

- Infrared roof warranty surveys.
- Commercial roof blister vent.
- Antifreeze admixture patent.

Education:

- B.S. Civil Engineering, 1973, Michigan Technological University.
- M.S. Arctic Engineering, 1981, University of Alaska.
- Ph.D. Civil Engineering, 2003, Purdue University.

Other Professional Information:

- Memberships/Professional Organizations:
  - Member ASCE.
  - Member ACI.
  - Member ASTM
- International Experience:
  - Cooperative research with the Technical Research Center, Finland.
- Additional:
  - Professional Engineer, NH.
  - Serves on various technical committees.
  - Published over 80 papers.

Cold Regions Research and Engineering Laboratory

CRREL is a testing and research establishment of the U.S. Army Corps of Engineers whose mission is to investigate engineering and scientific issues that pertain to regions affected by freezing and thawing. The CRREL facilities that will be used during the course of the current project are located in Hanover, New Hampshire, and include:

Facilities and Equipment Description

- Cold laboratories, which contain a 26-unit cold-room complex, where temperatures can be lowered to –35°F.
- Soils laboratory, which consists of a main soil analysis laboratory, thermal conductivity measurement area, sample preparation room, humidity storage room, controlled humidity room, and bituminous concrete testing room.

- Concrete laboratory, which contains equipment to mix concrete in laboratory batches and to test a wide range of properties and performance behaviors, including strength and durability, as affected by freeze–thaw.
- Construction materials laboratory, which includes a light microscope integrated with digital image processing and image analysis systems, a mercury intrusion porosimeter, and petrographic specimen preparation equipment.
- Resilient modulus testing system, which analyzes the resilient characteristics of concrete under simulated loading.
- In-house and field test sites, which include full-scale test sections that are constructed on-site at CRREL as well as in remote locations.
- NDT equipment:
  - Ground Penetrating Radar System.
  - Falling Weight Deflectometer (Dynatest Model 8000).