State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2003

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Effects of Ground Granulated Blast Furnace Slag in Portland Cement Concrete	**Project ID:** 0092-02-14a
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Error! Bookmark not defined.	**Approved Starting Date:** Nov 7, 2001
Approved by COR/Steering Committee: $194,251.00	**Approved Ending Date:** Dec 31, 2003
Project Investigator (agency & contact): Steve Cramer: UW-Madison	

Description: Federal transportation directives encourage the use of by-product materials and mandate open and unrestricted competition for alternative cementitious materials. In 1995, the EPA listed ground granulated blast furnace slag (GGBFS) as a recyclable material in the Federal Register. GGBFS is a cementitious materials that replaces a portion of the portland cement in a concrete mix and is being used with increasing frequency for pavement in concrete in Wisconsin.

The production and use of GGBFS is more than 100 years old, yet significant levels of use in Wisconsin are quite recent. GGBFS is manufactured across the world but recently has been offered in Wisconins by only one manufacturer.

Relevant questions associated with GGBFS use for Wisconsin include: 1) what replacement level of cement is most appropriate and what are the performance tradeoffs with different levels?
2) How do the fineness and activation characteristics vary from shipment to shipment of GGBFS among shipments of the current primary supplier and those of other new suppliers planning product introduction in 2001?
3) How does the GGBFS effect performance, change with different cement chemical compositions?
4) Are there undesirable interactions with admixtures or other additives?

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date	Percent Complete
$194,251.00	**$64,750.33**	$12,086.69	Error! Bookmark not defined.	**53 (%)**

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Progress This Quarter:
(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)
Progress this quarter has consisted of the following: 1) Preparation of concrete mixtures and specimens at 40°F, 2) Compression tests from the 40°F mixes, 3) Completion of deicer scaling tests for igneous aggregates and one brand of cement 4) sampling of GGBFS shipments from a regional ready-mix supplier, 5) recruitment and hiring of a new graduate student to continue work on the project.

The current use of GGBFS is restricted to temperatures above 40°F. We conducted tests as part of the study plan to determine the impact of mixing and curing at 40°F. Six mixtures involving one brand of Type I cement, cement replacement levels of 0%, 30%, and 50% with GGBFS and two types of aggregate were prepared. Prior to mixing the materials were conditioned to 40°F for 24 hours. The mixture was prepared in 40°F temperatures followed by specimen curing in a temperature controlled room. Mixture temperatures were monitored throughout the process. Strength gain, shrinkage and development of the air void system will be assessed from these specimens. Early examination suggests a strength loss of approximately 1000 psi at 14 days as a result of the lower temperature.

A sample of GGBFS has been obtained each month from a regional ready-mix supplier for monitoring the variability of GGBFS materials being delivered into the state. The chemical analysis and particle distribution results for samples from August to October 2002 showed low variability; therefore, these tests were suspended during the winter months. Now that the construction season is starting and the GGBFS turn over is faster, these tests will be continued. However, Blaine fineness and activation will be spot checked on these samples to determine their conformance with samples previously evaluated..

Scaling tests for 6 mixes using one brand of cement, 3 cement replacement levels and igneous aggregates were completed this quarter after 100 cycles of freeze-thaw testing (1 cycle per day). These tests revealed trends similar to those mixes that used limestone aggregates. From visual inspection, limestone aggregates remained intact under the freeze-thaw deicer cycles, but the igneous aggregates break apart and

dislodge from the concrete. Another difference is that the curing compounds seemed to be less beneficial for igneous mixes compared to those that using limestone aggregates.

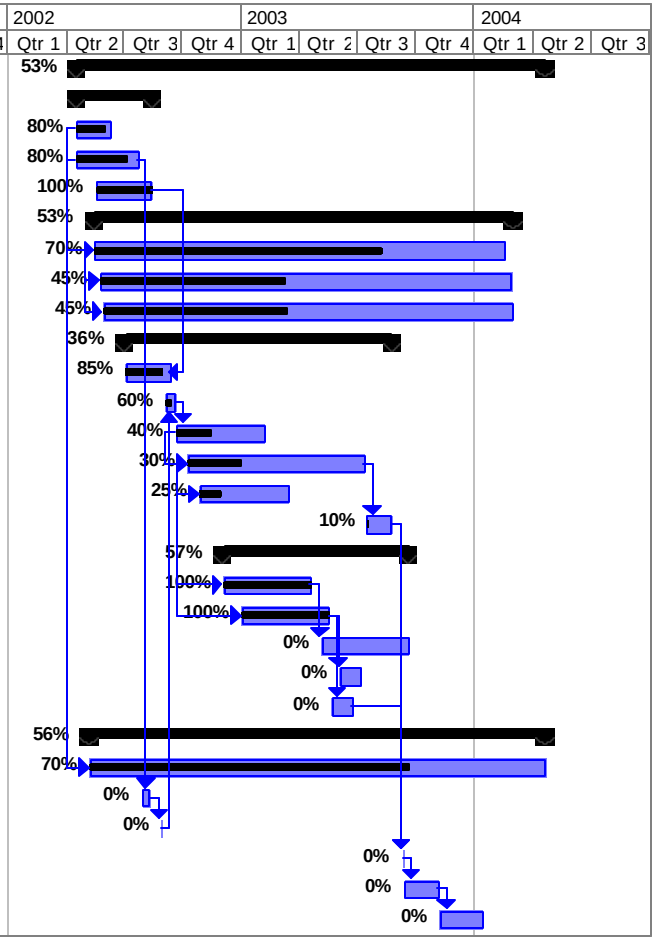
The original study plan was based on a team of two graduate students working with the principal investigator. Both resolution of technical issues with the WisDOT and the lack of a second graduate student put the project off to a slow start. In early June, a new graduate student joined the project team. He has been trained and oriented with regards to the project and is now contributing participant.

Work Next Quarter:
The goal for next quarter is to substantially complete preparation of concrete mixtures for evaluating the influence of different cement brands on the strength gain and shrinkage characteristics of concrete with cement replacements with GGBFS.

Circumstances affecting progress/budget:
Despite substantial progress this quarter, this project is behind schedule (for reasons stated) and will need to be extended to complete the study plan. We will be requesting a no-cost extension once we establish the minimum amount of extra time needed to complete the project.

Gantt Chart:

ID	Task Name	Duration	Start	Finish
1	**Project Status**	**525 days**	**Tue 1/15/02**	**Mon 1/19/04**
2	**Task I**	**85 days**	**Tue 1/15/02**	**Mon 5/13/02**
3	Update literature study	40 days	Tue 1/15/02	Mon 3/11/02
4	Survey and document regional experiences	70 days	Tue 1/15/02	Mon 4/22/02
5	Re-examine & finalize study plan	62 days	Fri 2/15/02	Mon 5/13/02
6	**Task 2: Monitor GGBFS Variability**	**470 days**	**Tue 2/12/02**	**Mon 12/1/03**
7	Obtain GGBFS samples	460 days	Tue 2/12/02	Mon 11/17/03
8	Send out for fineness and chemical tests	460 days	Thu 2/21/02	Wed 11/26/03
9	Conduct activation tests	460 days	Tue 2/26/02	Mon 12/1/03
10	**Task 3: Strength & Air Void Development**	**299 days**	**Tue 4/2/02**	**Fri 5/23/03**
11	Obtain materials	50 days	Tue 4/2/02	Mon 6/10/02
12	Prepare and check mix designs	10 days	Wed 6/5/02	Tue 6/18/02
13	Prepare specimens	100 days	Thu 6/20/02	Wed 11/6/02
14	Curing and testing	200 days	Mon 7/8/02	Fri 4/11/03
15	Air void tests	100 days	Fri 7/26/02	Thu 12/12/02
16	Analyze results	30 days	Mon 4/14/03	Fri 5/23/03
17	**Task 4: Deicer scaling tests**	**210 days**	**Mon 9/2/02**	**Fri 6/20/03**
18	Scaling tests - series 1	100 days	Mon 9/2/02	Fri 1/17/03
19	Scaling tests - series 2	100 days	Mon 9/30/02	Fri 2/14/03
20	Scaling tests - series 3	100 days	Mon 2/3/03	Fri 6/20/03
21	Scaling tests - series 4	26 days	Mon 3/3/03	Mon 4/7/03
22	Analyze results	26 days	Mon 2/17/03	Mon 3/24/03
23	**Reporting**	**510 days**	**Tue 2/5/02**	**Mon 1/19/04**
24	Interim Quarterly Reports	510 days	Tue 2/5/02	Mon 1/19/04
25	Prepare interim report & TOC meeting	10 days	Mon 4/29/02	Fri 5/10/02
26	TOC Meeting #1	2 days	Mon 5/27/02	Tue 5/28/02
27	TOC Meeting #2	2 days	Mon 6/9/03	Tue 6/10/03
28	Prepare draft final report	40 days	Wed 6/11/03	Tue 8/5/03
29	Review/Revise/Submit final report	50 days	Wed 8/6/03	Tue 10/14/03



Note: Gantt chart shown in State Fiscal Year Quarters

State of Wisconsin/Department of Transportation

RESEARCH PROGRESS REPORT FOR THE QUARTER ENDING: Jun 30, 2003

Program: SPR-0010(36) FFY99	**Part: II Research and Development**
Project Title: Evaluation of Methods for Characterizing Air-Void Systems in Wisconsin Paving Concrete	**Project ID:** 0092-03-16
Administrative Contact: Nina McLawhorn	**Sponsor:**
WisDOT Technical Contact: Dave Larson	**Approved Starting Date:** Jan 1, 2003
Approved by COR/Steering Committee: $199,965.00	**Approved Ending Date:** Jun 1, 2005
Project Investigator (agency & contact): Lawrence Sutter. **Error! Bookmark not defined.**	

Description: The study will be conducted over 30 months, and be completed in 7 phases:

1. Literature review
2. Interim report summarizing the Literature Review findings
3. Preparation of Concrete Mixtures
4. Testing of Fresh Concrete
5. Testing of Hardened Concrete
6. Data Analysis
7. Final Report

Total Study Budget	Current FFY Budget	Expenditures for Current Quarter	Total Expenditures to Date	Percent Complete
$199,965.00	**$66,655.00**	$6,576.00	**$0.00**	**3.3 (%)**

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Progress This Quarter:

(Includes project committee mtgs, work plan status, contract status, significant progress, etc.)

Progress will be discussed on a phase-by-phase basis. Note that the official start date for this project is February 20, 2003, which is a delay of almost eight months from the anticipated start date of July 2002. This unfortunate delay has resulted in one problem for the research team. As some of our workforce is composed of students, summer is always the most productive time to the year. It was anticipated in the original schedule that the summer of 2002 would fall in the middle of Phase 3 of this study, providing the extensive amount of time needed to prepare concrete mixtures and test them. With the change in the start date, the research team's ability to complete Phases 3, 4, and 5 in a timely manner becomes significantly compromised unless the proposed schedule is changed slightly. For this reason, work on Phases 1 and 2 has been slightly delayed and work on Phase 3 and 4 greatly accelerated over that proposed in the original work plan.

Phase 1: Literature Review (Anticipated Duration: 4 months)

The literature review is progressing well. To this point it has focused on the technical literature regarding the functionality of air entraining admixtures and methodologies used to assess the air-void system parameters in fresh and hardened concrete. Preliminary work has been initiated to better understand WisDOT concrete mixture design and construction practices with respect to achieving desirable air-void system parameters.

Phase 2: Interim Report (Anticipated Duration: 5 months)

Work on the Interim Report has begun. It is estimated that the delivery of the report will be delayed by approximately two months as the project team has focused the research effort on Phases 3 and 4, which must be initiated during the summer months when materials and personnel are most readily available. It is expected that an Interim Report will be sent to the WisDOT by the end of September, 2003.

Phase 3: Preparation of Concrete Mixtures (Anticipated Duration: 11 months)

Preparation of concrete mixtures has been initiated. This task has been begun early to avoid serious problems with scheduling workers and obtaining materials that might occur if the productive summer months were not fully utilized. To help accelerate this task, the research team has been able to capitalize on some contacts with a concrete ready-mix producer in Wisconsin who has offered to assist in obtaining materials from WisDOT approved sources and provide mix design expertise. In designing the mixes to be used in this study, research was initiated by obtaining WisDOT specifications (found at www.dot.wisconsin.gov) on concrete (section 501 of the standard specifications manual). Section 501.3.2.2, and its accompanying table, presented the master limits of components for WisDOT's grades of concrete. Since this study is focused on grades A and A-FA, those values were used. The research proposal called for a constant water-to-cement ratio (*w/c*) of 0.42. For Grade A Concrete with a cement content of 565 pounds per cubic yard (6 bag mix), this equates to 237.1 pounds of water. The aggregate content is specified to have a maximum total weight of 3120 pounds per cubic yard. The percent fine aggregate of total aggregate has a range of 30 to 40 percent. The selected mixture design contains a percent fine aggregate content ranging from 40 to 45 percent. This was determined after discussing the concrete mix design with Jerry Carlson, owner of Lakehead Concrete Works in Superior, Wisconsin. Jerry has 35+ years experience in the industry and has used the source pit of the aggregates for his entire career. To determine the exact weights of coarse and fine aggregate to be used, the volumes of the cement, water and target air content were calculated using each components specific gravity. The coarse and fine aggregate contents were then calculated to ensure the yield of the mix design was exactly 1 cubic yard. Jerry Carlson, along with Bob Cushman, was consulted to help determine the proper dosage of air entrainment to use in each mix design. Bob is the batch plant operator at Lakehead Concrete Works in Superior, WI and has worked with WisDOT on numerous paving projects in the northern portion of the state. Factors considered in determining the air dosage were target air content, fly ash content and target slump. The mix designs for the A-FA grade concrete was done in a similar manner except the cementitious material consisted of 395 pounds of cement and 170 pounds of class C ash. These mix designs were then scaled down to the necessary batch sizes to complete the tests and produce the specimens necessary for this project.

After mixing three trial batches, the following observations have been made. The workability of these mixes has been very poor, with the slump values averaging about 0.5 in. Although the air content has been in the target range, concern exists regarding the quality of the test specimens produced since the low slump mixtures were very difficult to consolidate. To improve the workability of the mixes while holding the *w/c* at a constant 0.42, two options were attempted. One option was to increase the paste content of the mixture, increasing the cement content of the mix from a 6.0 sacks to 6.5 sacks per cubic yard of concrete. The second option was to use the 6.0 sack mixture, but add a water reducer to increase the workability. Both trial mixtures achieved a desirable 1.5 in slump while retaining the target air content values. All the mixture design information is attached in Appendix A.

At this juncture, the research team is inclined to use the 6.5 sack mixture for this study as it has the mix design and fresh concrete properties needed to meet the project requirements. It is felt that the use of the water reducer could provide unaccounted for interactions with the other mixture constituents potentially affecting the air-void system characteristics in the concrete. If WisDOT routinely uses water reducers in their paving concrete, the expansion of the experimental matrix to include water reducers as an additional variable might want to be considered for an additional phase of this study.

Phase 4: Testing of Fresh Concrete (Anticipated Duration: 8 months)
As Phase 3 progresses, a number of tests have been conducted on the fresh concrete. In addition to slump and unit weight, both ASTM C-231 *Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method* and ASTM C-173 *Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method*, have been conducted.

Phase 5: Testing of Hardened Concrete (Anticipated Duration: 15 months)
No work has been completed on this task during the previous quarter.

Phase 6: Data Analysis (Anticipated Duration: 10 months)
No work has been completed on this task during the previous quarter.

Phase 7: Final Report (Anticipated Duration: 7 months)
No work has been completed on this task during the previous quarter.

Work Next Quarter:
Work to be conducted next quarter will be discussed on a phase-by-phase basis.

Phase 1: Literature Review (Anticipated Duration: 4 months)

The literature review will be completed and submitted as part of the Interim Report.

Phase 2: Interim Report (Anticipated Duration: 5 months)

The Interim Report will be completed and submitted to WisDOT for review. It will include the literature review, the mixture design information as determined by the Phase 3 and 4 work conducted, and the revised experimental work plan. It is expected that an Interim Report will be sent to the WisDOT by the end of September, 2003.

Phase 3: Preparation of Concrete Mixtures (Anticipated Duration: 11 months)
Preparation of concrete mixtures will continue with all the mixture designs finalized and the production of underway if approved by WisDOT.

Phase 4: Testing of Fresh Concrete (Anticipated Duration: 8 months)
As Phase 3 progresses, so will the testing of fresh concrete.

Task 5: Testing of Hardened Concrete (Anticipated Duration: 15 months)
As Phase 3 progresses, so will the testing of hardened concrete.

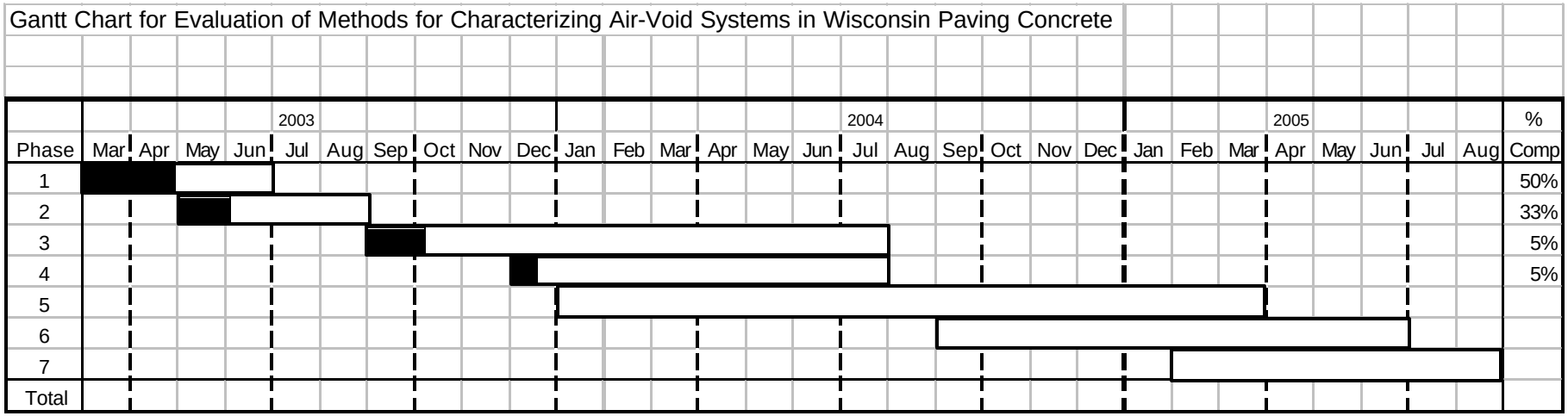
Task 6: Data Analysis (Anticipated Duration: 10 months)
No work has been completed on this task during the previous quarter.

Task 7: Final Report (Anticipated Duration: 7 months)
No work has been completed on this task during the previous quarter.

Circumstances affecting progress/budget:

As discussed in the section, "Progress This Quarter," the delay in the project start date necessitated a slight change in the proposed project schedule to fully utilize the summer months for mixture production. The project is ahead of schedule, but Phases I and II will be slightly delayed as the work has focused on completing laboratory work during this critical time period.

Gantt Chart:



Note: Gantt chart shown in State Fiscal Year Quarters