TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Oklahoma Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *TPF-5(297)*	**Transportation Pooled Fund Program - Report Period:** O Quarter 1 (January 1 – March 31) O Quarter 2 (April 1 – June 30) X Quarter 3 (July 1 – September 30) O Quarter 4 (October 1 – December 31)

Project Title:
Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures

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Lead Agency Project ID: **TPF-TPF5(297)RS / JOB PIECE 30802(04)**	**Other Project ID (i.e., contract #):** AA-5-52974	**Project Start Date:** March 10, 2014
Original Project End Date: February 28, 2017	**Current Project End Date:**	**Number of Extensions:**

Project schedule status:

On schedule ☐ On revised schedule ☐ Ahead of schedule X Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$572,500	$270,000	48%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
$40,000	$40,000	58%

Project Description:

Concrete can be damaged when it is 1) sufficiently wet (has a high degree of saturation) and 2) is exposed to temperature cycles that enable freezing and thawing. The damage that occurs due to freezing and thawing can lead to premature deterioration, costly repairs, and premature replacement of concrete infrastructure elements. Current specifications for frost durability are largely based on work completed in the 1950s, and while this work included many landmark discoveries (Kleiger 1952, 1954). This work from the 1950s may not be representative of materials used in modern concrete mixtures. Results from recent studies suggest that there are several ways in which frost damage can be reduced through new tests and improve specifications that can lead to extended service life of concrete infrastructure.

The goal of the research is to produce improved specifications, and test methods; while, improving the understanding of the underlying mechanisms of frost damage. Specifically, this work will seek to develop new test procedures that may be faster and/or more reliable than the existing methods. The objectives of this project are:

- Determine the necessary properties of the air-void system to provide satisfactory frost durability in testing of laboratory and field concretes with different combinations of admixtures, cements, and mixing temperatures
- Determine the accuracy of a simple field test method that measures air void system quality with field and laboratory concrete
- Determine the critical combinations of absorption and the critical degree of saturation on the frost durability in accelerated laboratory testing
- Establish new test methods and specifications for fresh and hardened concrete to determine frost durability and field performance

In addition, a streaming lecture series on freeze-thaw durability will be generated as part of this work.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1: Literature Review and Development of the Testing Matrix (OSU and Purdue)

In this task the research teams will review the existing literature and determine a testing matrix to cover the necessary variables. Work is needed to understand how cements of different alkali content, different mixing temperatures, and types of mixing impact the air entrainment system and subsequently the frost durability of concrete. These variables can lead to changes in AEA effectiveness and their impact needs to be quantified with ASTM C 666 testing. As part of this task we will work with our project oversight committee to establish a set of materials and a testing matrix that can be used for the entire study. The decisions used in developing this test matrix will be made based on literature review, previous research by the PIs and the needs identified by the study advisory discussions.

The initial testing matrix will focus on understanding the impact of different air void systems on the freeze thaw durability of concrete. The matrix has been developed and was shared with the research oversight committee in the first conference call. Plans for future investigations were discussed in the second conference call. The team first looked at mixtures for bridge decks and then moved to mixtures for pavements. Here is an overview of the mixtures:

Limestone aggregate and natural sand from Oklahoma will be used for these mixtures. Both aggregates have been shown great freeze thaw field performance in the laboratory and the field. A mixture with 20% class C fly ash will be investigated with 6.5 sacks of total cementitious content and a w/cm of 0.45. A wood rosin AEA will be the primary admixture investigated as it is the most widely used AEA. However, select mixtures will be investigated with synthetic AEA. These AEAs will be used to produce mixtures with different spacing factors and air content. These samples will be investigated in a number of the freeze thaw tests in the project. Next, a mixture with 0.40 w/cm will be investigated with the same AEA. After that mixtures with high range water reducers will be investigated with 0.40 and 0.35 w/cm. A few mixtures with different high range water reducer dosages will be investigated.

On this project over 100 concrete mixtures have been investigated in the laboratory. Work is still ongoing to complete the hardened air void analysis and the rapid freeze thaw testing. Efforts are being made to improve the repeatability of the test method. Changes have also been made to reduce the time needed to complete the testing. Some work has been done to investigate the air void distribution with the SAM in some repair materials. The team also hopes to investigate how the SAM needs to be modified for use with light weight aggregate.

90% complete (This task will not reach 100% until the end of the project as changes are continually made to the testing matrix.)

Task 2: Sample Preparation (OSU and Purdue)

A number of the mixtures suggested in task 1 have been completed at OSU and have been shipped to Purdue for testing. Mixtures with different amounts of superplasticizers and air entraining agents have been investigated. Mixtures are also being complete to look at different dosages of superplasticizer and also some mid-range water reducers. Over 80 mixtures have been investigated. In the next quarter mixtures will be investigated that use different combinations of admixtures from materials that have proven to show interesting results from the field. In the upcoming quarter concrete mixtures before and after a concrete pump will be investigated. Also the SAM test will be modified to investigate the usage of light weight aggregate.

The research team also plans to hold a precision and bias testing at OSU in February. For this testing we will invite experienced users of the SAM to come to Oklahoma and all use their equipment to investigate a single concrete mixture. This will generate important data for the precision and bias statement of the AASHTO test method.

50% complete

Task 3: Validation of the Super Air Meter (OSU)

In this task the Super Air Meter (SAM) will be evaluated in laboratory and field mixtures. The laboratory mixtures to be investigated include: aggregate with high aggregate correction factor, light weight aggregate, hot weather concrete, cold weather concrete, and any other items that the research oversight committee feels is important. In addition a number of mixtures will be investigated in the field. This will be done by visiting local ready mix and central mix batch plants to take samples.

Over 100 laboratory mixtures have been completed and the results are being complied. The data shows that the SAM does a good job of predicting the spacing factor for the majority of the mixtures investigated. The SAM limit of 0.20 psi has shown a conservative correlation to a spacing factor of 0.008" 94% of the time. For all of these mixtures at least two different SAMs are being investigated in order to collect the precision and bias information needed for the AASHTO test method. Work will be done to look at different dosages of high range water reducer and the impact on the air content, SAM number, and spacing factor relationship. Work is continuing to be completed to investigate the variability in the test method. The current results are shown in Fig. 1.

Testing has also been done with the SAM to investigate a number of repair materials. These samples are being completed and will also be used to evaluate the tool for totally different binder systems.

In addition, the research team has evaluated over 70 different field concrete mixtures. For all of these mixtures we have used two SAMs to evaluate each mixture. These results are shown in Fig. 2.

The Turner Fairbanks Lab at FHWA has also completed a 3rd party evaluation of the SAM and they have provided their data for comparison. The results are shown in Fig. 3.

The results from the lab, field, and 3rd party evaluations are included in Figure 4. In this report. The data continues to be very consistent and show that there is about a 93% agreement between spacing factor recommendation of 0.008" and a SAM number of 0.20.

In addition commercial versions of the SAM have been provided to the following partners for their usage: Purdue, Iowa, Nebraska, Kansas, North Dakota, Illinois, Oklahoma, Pennsylvania, Minnesota, Idaho, New Jersey, and Wisconsin. The following states have either already provided or have agreed to supply field data: Iowa, Michigan, Wisconsin, Minnesota, North Dakota, Kansas, Nebraska, Colorado, Pennsylvania and Utah. In addition, the FHWA mobile concrete lab has supplied samples from Pennsylvania, Tennessee, North Dakota, and Florida. These samples are being prepared and polished for hardened air-void analysis. This data will contribute to the vast data set that is being compiled. So far there is over 70% agreement between the field data and the SAM limit of 0.20. There seems to better agreement with a SAM limit of 0.25; however, the 0.20 limit is conservative.

A student has completed his thesis at OSU over this topic. The relevant chapters have been included with the previous quarterly report.

New supplemental equipment has been developed to speed the test from 8-10 minutes to 5-6 minutes. The equipment is very close to being completed and it will be made available to the pooled fund members. This will be a goal of the upcoming quarter.

60% complete

Task 4: Creation of an AASHTO Test Method and Specification for the SAM (OSU)
A presentation was made to the AASHTO Materials subcommittee. The SAM test method has been published as AASHTO TP 118. This is a great accomplishment.

Work still needs to be done to update the provision and bias statement for the test method. Also, some text needs to be be added about the length of time between the first and second pressure step. This is an area of work for the next quarter. We hope to be able to add light weight aggregate to the document.

75% complete

Task 5: Use of X-Ray Tomography of Air Voids and Frost Damage (OSU)

Researchers at OSU have developed nondestructive techniques to examine microscopic air voids in fresh and hardened concrete by using a X-ray micro computed tomography (mCT) scanner. This is a powerful technique that allows measurements to be made not previously possible. The research team has developed techniques to image water movements and have access to a freezing stage. By combining this information about the void distribution, the moisture content and distribution, and then being able to image the damage that occurs from freezing is a powerful tool. These observations can lead to ground breaking insights into the mechanisms of frost damage and how it can be avoided.

The experimental methods are largely finished and a paper is being authored over the work. A rough draft of the paper has been developed and is being reviewed. Work has also been completed over using mCT to image samples both before and after freezing. We have successfully aligned the data sets and we can clearly show where there were existing cracks in the sample and how these cracks extend after a single freezing cycle. Some results have been included in the attached figures.

Work has also been done to investigate the mechanisms of salt scaling. Samples were imaged with the mCT scanner before and after during freezing events. These results show that damage can be observed with this method and provide quantitative mapping of the location of crack propagation. A student has completed his thesis on this topic, a journal paper is under preparation, and a poster was presented at the American Ceramics Society – Cements Division meeting. This poster was given an award for meritorious achievement. The poster was included in the last quarterly report.

Progress 40%

Task 6: ASTM C 666 (OSU)

The primary test method used to investigate the frost durability of the concrete will be the ASTM C666 test. This test is the most widely recognized test to investigate the rapid deterioration from freezing and thawing. As many mixtures will be investigated with this test as possible. As part of this task the specimen absorption and desorption of the samples will be investigated using a modified form of ASTM C1585. The impact of wetting and drying will also be investigated. While the team realizes that the ASTM C666 is a well-respected test, they feel that the three months required to complete the test is too long. The research team plans on using this information to help find a shorter test with the same rigor.

A new chamber has been purchased and a significant amount of C666 testing has been completed. A summary of the test results are shown in Fig. 5. These results show an 80% agreement with a SAM number of 0.20 and an 89% agreement if a SAM number of 0.25 is used. This difference was discussed on the conference call and a recommendation was made to stay with the 0.20 limit as it was conservative.

Progress 50%

Task 7: Absorption and Desorption (Purdue)

During this task the research team will perform desorption/sorption analysis on selected mixtures prepared in Task 2. For the sorption tests 100 mm diameter samples will be used that are 50 mm in thickness. The samples will then be placed in fluid according to a modified version of ASTM C 1585 to determine the degree of saturation over time. In addition, the complete degree of saturation will be determined using vacuum saturation.

The sampling and testing protocols have been developed (as illustrated in Fig. 6) and the samples have completed conditioning at 50% and 75% relative humidity for the sorption tests. Sorption testing on both samples conditioned to 50% and 75% RH is completed for the first half of the samples sent to Purdue. The samples in the last two series will be tested in July-Septmber 2015. Upon oven drying, the results of this test will be used to determine the nick point (S_n) (the point between initial and secondary sorption) and the slope of the secondary sorption curve, which are essential for predicting long term performance. The drying test has been completed for all samples sent to Purdue for 50 and 75% RH and the results are in the analysis stage. Additionally, dynamic vapor sorption (DVS) testing has also begun.

Progress 55%

Task 8: Degree of Saturation and Damage Development (Purdue)

Samples prepared in Task 2 will be saturated to different degrees of saturation and the freeze-thaw tests will be performed with the samples in a sealed condition. Freeze-thaw tests will be performed on samples with 50 mm thickness and 68 mm diameter using a new Longitudinal Gaurded Comparitive Calorimeter (LGCC) setup with acoustic emission sensing to detect damage. This test setup is capable of measuring temperature throughout the setup height to determine heat flow through the sample during each freeze-thaw cycle. Additionally, the setup is equipped with 2 acoustic emission sensors which can passively detect acoustic events as well as actively measure pulse velocity across the sample. The changes in pulse velocity throughout the freeze-thaw process can then be directly correlated to damage development in the concrete. Results from this test will be used to identify the critical degree of saturation with the express purpose of relating the critical degree of saturation to the quality of the entrained air system (for example the air void spacing). Information from this test will be used in conjunction with the results from Task 7 to determine if the air void system alters the time required to reach a critical degree of saturation (which is hypothesized with a higher SAM number corresponding to a lower S_{CRIT}). Additionally, a series of 3 cylinders will be used to determine the resistivity and degree of saturation over time of samples submerged in pore solution (to prevent alkali leaching). Additional resistivity tests will be performed at various ages and degrees of saturation on samples from a variety of tests in order to determine if a relationship exists to correlate resistivity and sorption.

The testing protocols have been developed (See Figure 6). DOS cylinders from all 34 total mixtures received by Purdue have been tested and the results have been used to determine the degree of saturation for cylinders in the corresponding resistivity tests. Both short and long term resistivity tests have concluded for all samples. These results are being analyzed to study the resistivity, formation factor, and degree of saturation over time. Experimental nick point values have been compared to theoretical values and have been related to both air volume and SAM numbers. There was good agreement between theoretical and measured values. This was discussed in the conference paper included in the last quarterly report. Further work is underway to investigate the relationship between formation factor at various degrees of saturation and air parameters in order to more easily assess durability.

All Freeze-Thaw samples have been cut, cored, and conditioned for testing in the LGCC (Figure 7a). This includes additional samples outside of the testing scope that will be available for future testing if necessary. The testing schedule developed in the last term which selected samples to capture samples with different air contents and varying SAM numbers from all 3 batches (Table 1) has been implemented and we remain on schedule. Two LGCC setups are being utilized for testing simultaneously and both are showing good results. To date, 8 mixtures (of 11 currently planned for testing) have undergone the full spectrum of testing in the LGCC, which includes 3 degrees of saturation for each mix (approximately 100%, 95%, and 90%). Each sample is exposed to three freeze-thaw cycles over the course of five days, with pulse velocity measurements taken hourly. Results from these tests have been analyzed; however additional mixtures are necessary to draw conclusions. An example of the acoustic emission data output is shown in Figure 8, which shows the acoustic emissions recorded by two opposing sensors on a single freeze-thaw sample. It is clear that for this fully saturated sample, cracks are emitting due to freeze-thaw damage over the course of 3 thermal cycles. Figure 9 shows an example of the information received by the acousto-ultrasonic testing in the LGCC setup. Damage in the concrete matrix (a reduction in the elastic modulus) can be correlated to the reduction in pulse velocity after each freezing cycle. It is evident that highly saturated samples show a drastic reduction in pulse velocity (large amounts of damage) while the sample closer to the critical degree of saturation shows little reduction in pulse velocity (low levels of damage). The current LGCC testing is planned to conclude in late 2015; however a new series of testing will begin. The research team is investigating an upscaling of the equipment to permit 4 inch diameter cylinder to be used directly and the device is being investigated to make this more economic.

Progress 60%

Task 9: Rate of Damage Analysis (Purdue)

This task will combine acoustic emission data and X-ray mCT to detect cracking and also image the location. This will be done in samples with different quality of air void systems and with different paste quality and saturation level.

Purdue provided 12 samples that the team at OSU scanned at several micron resolution and then sent back to Purdue so that they could investigate them in the neutron beamline at NIST. In the beamline the samples were flooded with water and then freezing cycles were used to try and create damage in the samples. The samples have been sent back to OSU and scanned again to investigate the amount of cracking. This technique can show the extensive damage in the samples with high levels of DOS. This is a great success. Some preliminary results are shown in Fig. ?. The analysis can separate the air voids, aggregates, cracks, and paste. It can clearly show where the cracks are located before and after the freezing events. This should begin to provide useful observations for the project and provide a more basic understanding of freeze thaw damage.

Progress 25%

Task 10: Technology Transfer (OSU and Purdue)

A portion of this project will be dedicated to development of a strong educational technology transfer program. The PI's propose the development of a short course that utilizes streaming video (and could be placed on a DVD for widespread dissemination). No progress has been made on this task. This will be completed late in the project so that the latest findings can be shared with the audience.

Progress 0%

Task 11: Final Report (OSU and Purdue)

This task will be completed in the final quarter of the project.

Progress 0%

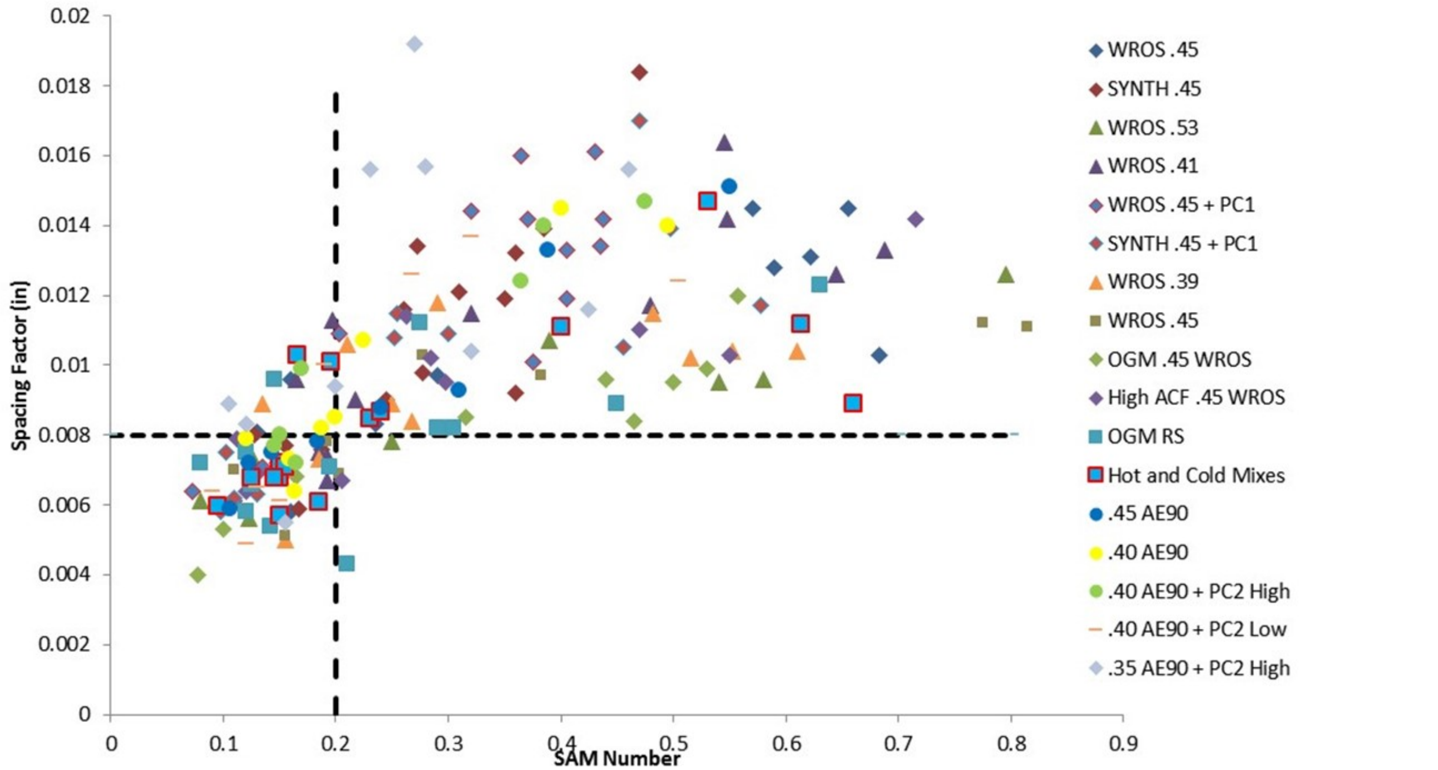

Figure 1 – Laboratory study results comparing the SAM number to the spacing factor for mixtures completed at OSU.

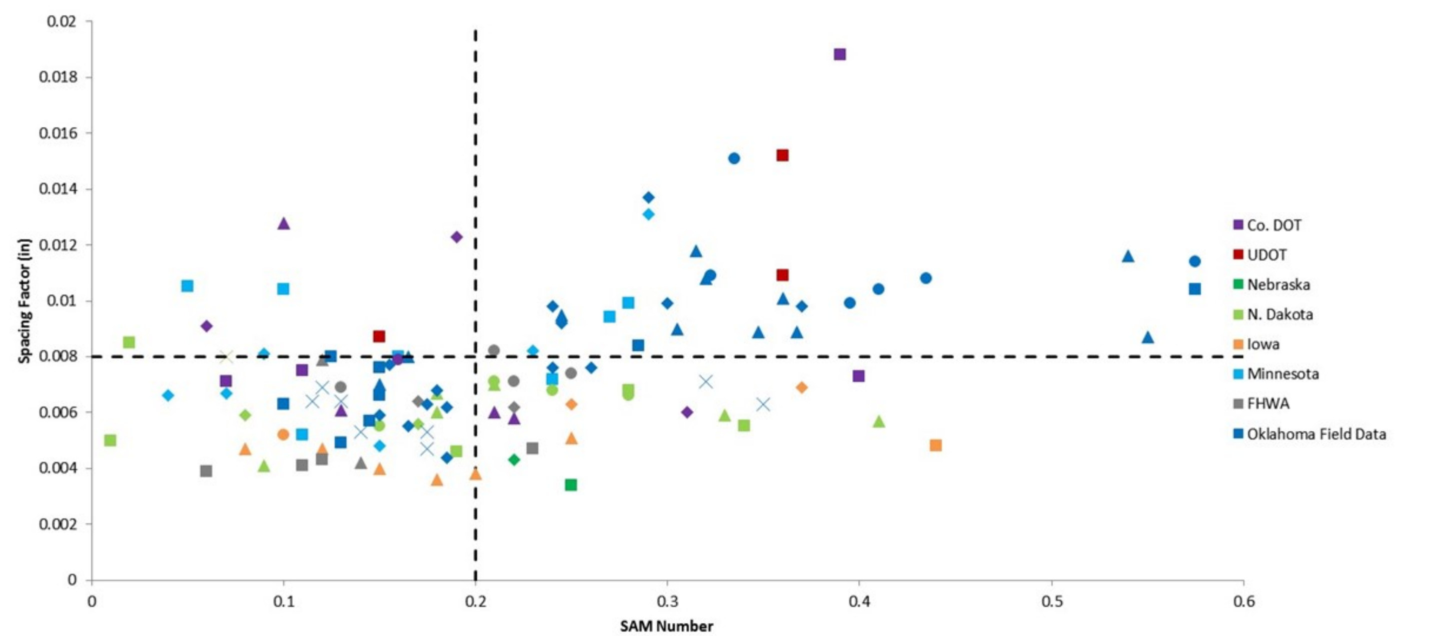

Figure 2 – Field testing data comparing the SAM number to the spacing factor for mixtures completed at OSU.

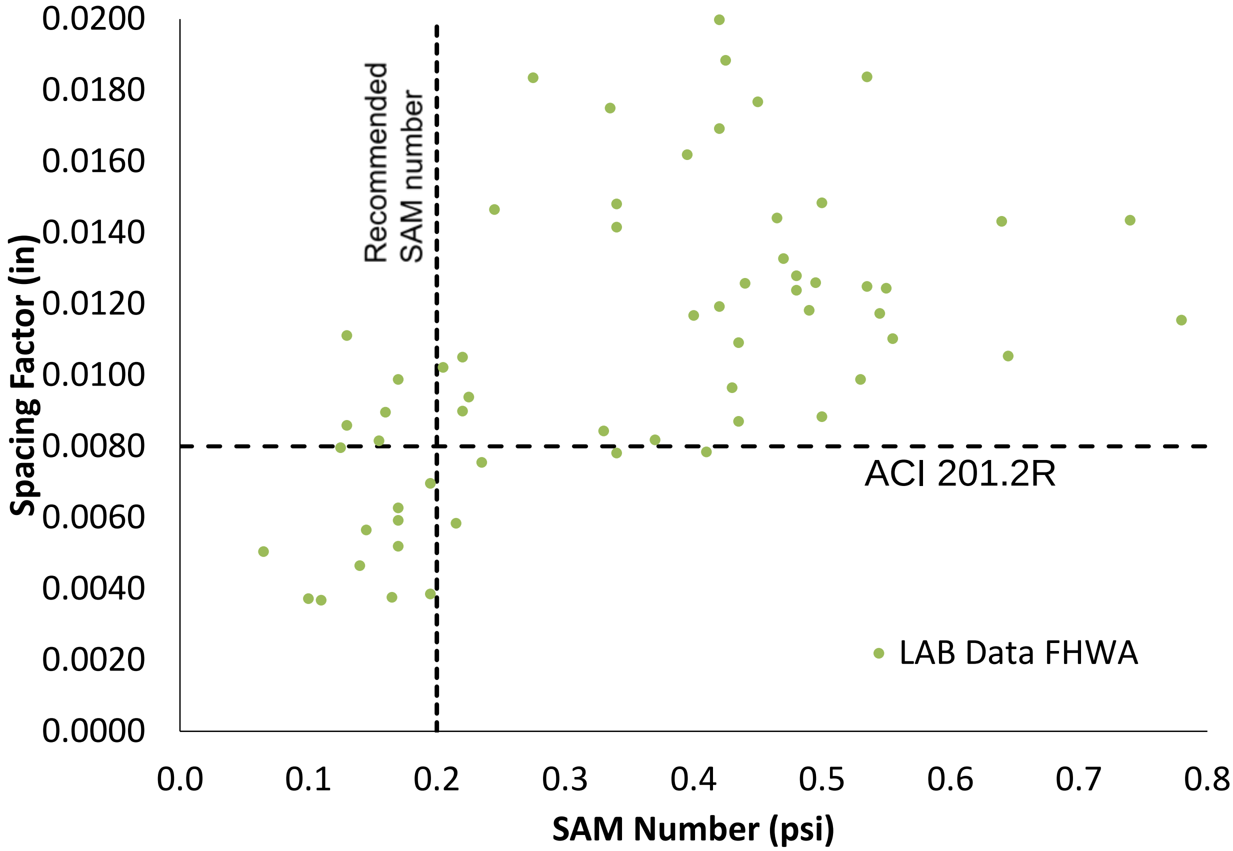

Figure 3 – Results from FHWA Turner Fairbanks Laboratory.

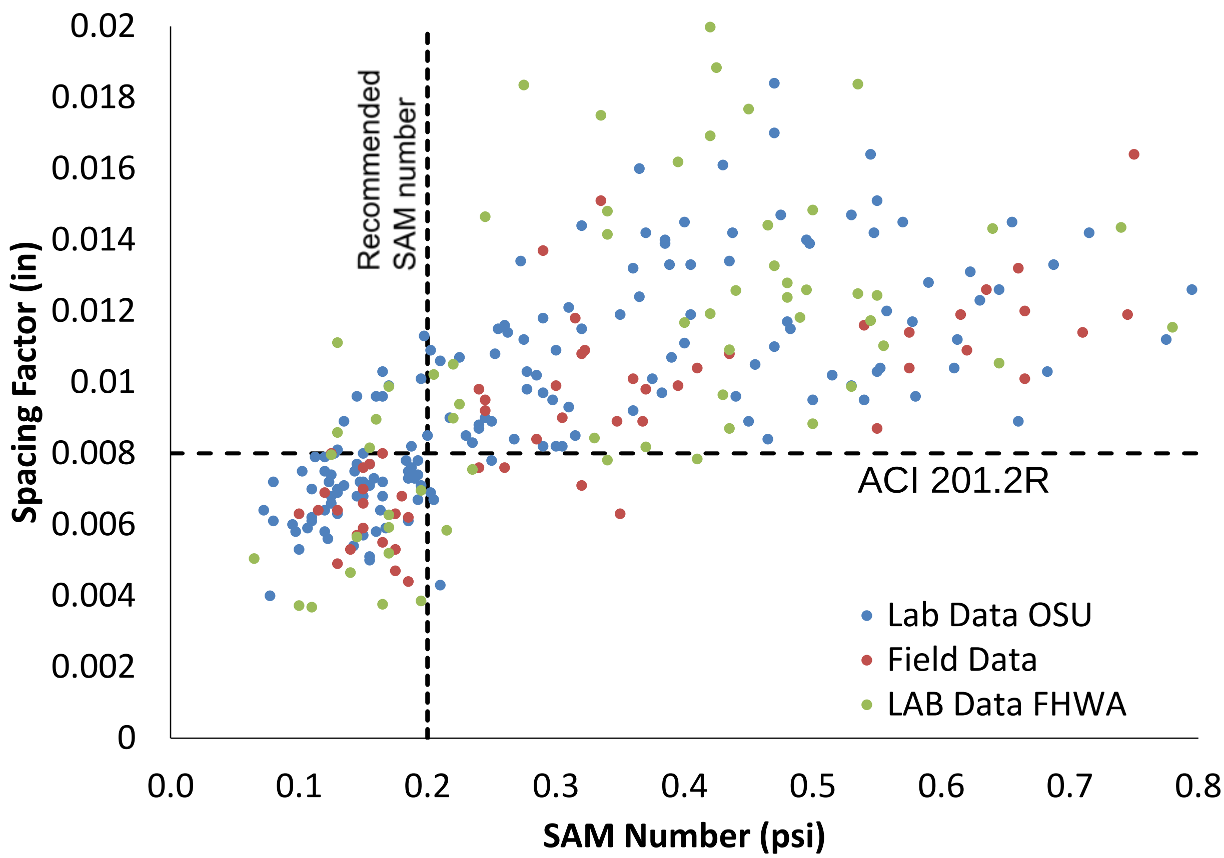

Figure 4 – A combination of the Figures 1, 2, and 3. This shows a comparison of the lab field, and 3rd party lab data.

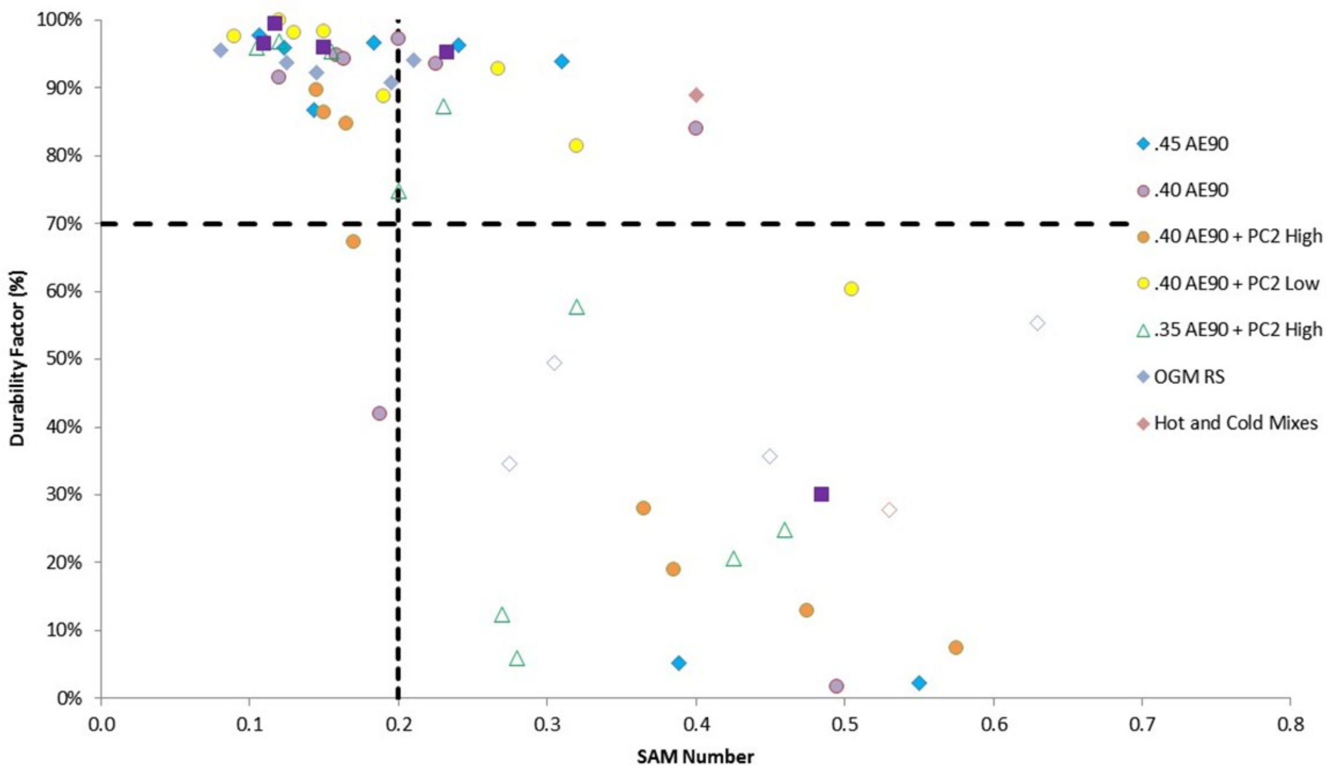

Figure 5 – The SAM number versus the Durability Factor from the C666 testing.

SORPTION (ASTM 1585)

1. CUT SAMPLES

- CUT OFF TOP 3/4" OF EACH CYLINDER

- CUT 2 SAMPLES- 2" THICK, 4" DIAMETER FROM EACH

- SAVE TOP AND BOTTOM SCRAP PIECES

- LABEL EACH SAMPLE WITH "SORP-MIXID"

2. MASS EACH SAMPLE

3. CONDITIONING

- PLACE 2 SORPTION SAMPLES AT 50%, PLACE 2 SAMPLES AT 80% RH

-MONITOR MASS EVERY 15 DAYS. REMOVE WHEN MASS CHANGES BY LESS THAN 0.02% (OR AS LONG AS TIME PERMITS)

4. TEST RESISTIVITY

4. ASTM 1585 (BEGINNING WITH PROCEDURE)

5. TEST RESISTIVITY, MASS

6. OVEN DRY, MASS

7. VACUUM SATURATE, MASS

No separate sample needed

ABSORPTION/ DESORPTION (DVS)

1. CUT SAMPLES

- DVS SAMPLES (0.8MM SLICES) WILL COME FROM SCRAP FROM DRYING TEST (MIDDLE MOST PORTION)

2. PLACE A LABEL ON IT WITH "DVS-MIXID"

3. DVS PROCEDURE

DEGREE OF SATURATION + POROSITY

1. DEMOLD

2. MASS ("SEALED MASS")

3. OVEN DRY, MASS

4. CUT

- 2 SAMPLES, 2" THICK, 4" DIAMETER

- LABEL EACH SAMPLE WITH "DOS-MIXID"

-USE REMAINING MIDDLE PIECE FOR DVS

5. MASS EACH SAMPLE

6. OVEN DRY, MASS EACH SAMPLE

7. VACUUM SATURATE EACH SAMPLE

8. MASS EACH

9. CALCULATE D.O.S.

10. CALCULATE POROSITY (ASTM 642)

- USE VACUUM SATURATION INSTEAD OF BOILING

11. UNIAXIAL RESISTIVITY

RESISTIVITY

1. LABEL EACH CYLINDER WITH "ρ-MIXID"

2. MEASURE RESISTIVITY ON SEALED CONDITION

3. ONE CYLINDER WILL BE USED TO TEST DOS AT THE CURRENT MATERIAL AGE

4. ONE CYLINDER WILL BE PLACED IN A CONDUCTIVE SOLUTION FOR 1 WEEK, OVEN DRY, MASS

5. ONE CYLINDER WILL BE PLACED IN A CONDUCTIVE SOLUTION FOR 2 MONTHS, OVEN DRY, MASS

6. RESISTIVITY AND MASS MEASUREMENTS WILL BE TAKEN PERIODICALLY FOR EACH SAMPLE.

7. MOISTURE CONTENT, DOS, MASS, AND RESISTIVITY WILL BE RECORDED WITH TIME

AE-LGCC

1. CORE EACH CYLINDER TO 2.25" DIAM (2.5" BIT)

2. CUT

- REMOVE TOP 3/4 "

-CUT 3 SAMPLES WITH 2" THICKNESS FROM EACH CYLINDER

-SAVE REMAINING ~3/4" BOTTOM PIECE AS SCRAP

3. LABELWITH "LGCC-MIXID"

4. OVEN DRY, VACUUM SATURATE TO 100% WITH LIME WATER

5. DRY EACH SAMPLE TO DESIRED LEVEL OF SATURATION

-75%, 80%, 85%, 90%, 95%, 100% (lower levels if we decide to use the leftover cylinder for this purpose)

- SEAL FOR 1-2 WEEKS

6. TEST RESISTIVITY

7. RUN IN LGCC-AE

8. TEST RESISTIVITY

DRYING

1. CUT

- FROM CYLINDER 1, REMOVE TOP INCH, CUT 1 50MM SAMPLE, CUT 1 10MM SAMPLE, CUT ANOTHER 50MM SAMPLE, SAVE BOTTOM AS SCRAP FOR DVS SAMPLE

- FROM CYLINDER 2, REMOVE TOP 2 INCHES, CUT 1 10MM SAMPLE, CUT 1 50MM SAMPLE, CUT ANOTHER 10MM SAMPLE, SAVE BOTTOM AS SCRAP

-LABEL EACH WITH "DRY-MIXID"

2. FOLLOW STADIUM TEST PROCEDURE (NOT DIFFUSION PORTION), BUT WITH VACUUM SATURATION NOT BOILING

Figure 6 - Sample cutting, conditioning, and testing plan for each series of mixtures

(a) **(b)** **(c)**

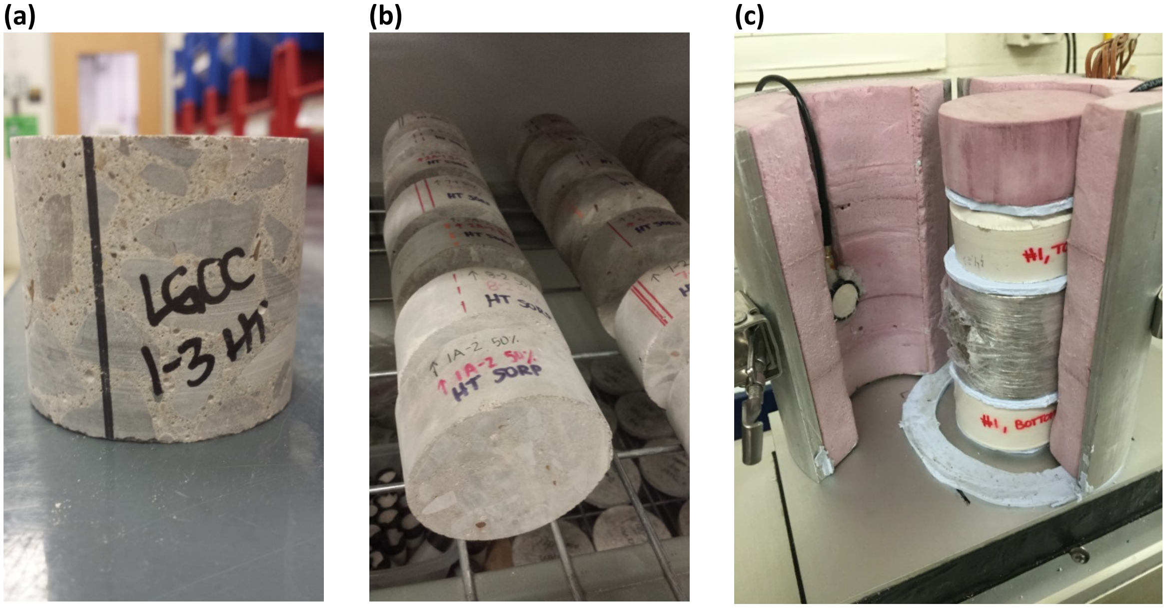

Figure 7 - Current Testing States (a) Sorption samples conditioning at 50% relative humidity (b) Sample labeling conventi

a cut and cored LGCC sample (c) LGCC Test Setup

Mix	Fresh Air %	SAM Number	Mix ID	DOS	Projected LGCC Testing
0.45 AE90 Mix 5	6.58	0.107	5-3 #1	99%	COMPLETE
			5-3 #2	95%	
			5-4 #2	88%	
0.45 AE90 Mix 7	2.59	0.55	7-3 #1	98%	COMPLETE
			7-3 #2	92%	
			7-4 #2	90%	
0.45 AE90 Mix 2	3.88	0.24	2-3 #1	100%	COMPLETE
			2-3 #2	95%	
			2-3 #3	90%	
0.40 AE90 Mix 5	1.97	0.495	5A-3 #1	100%	COMPLETE
			5A-3 #2	95%	
			5A-3 #3	90%	
0.40 AE90 Mix 7	3.65	0.2	7A-3 #1	100%	COMPLETE
			7A-3 #2	95%	
			7A-3 #3	90%	
0.40 AE90 +575 Mix 2	7.2	0.17	2B-3 #1	100%	COMPLETE
			2B-3 #2	95%	
			2B-3 #3	90%	
0.40 AE90 +575 Mix 1	4.31	0.385	1B-3 #1	100%	COMPLETE
			1B-3 #2	95%	
			1B-3 #3	90%	
0.40 AE90 +575 Mix 8	2.44	0.575	8B-3 #1	100%	COMPLETE
			8B-3 #2	95%	
			8B-3 #3	90%	
0.35 AE90 +575HIGH Mix 5	4.04	0.32	5C-3 #1	100%	IN PROGRESS
			5C-3 #2	95%	
			5C-3 #3	90%	
0.35 AE90 +575HIGH Mix 7	9.24	0.155	7C-3 #1	100%	Jul-15
			7C-3 #2	95%	
			7C-3 #3	90%	
0.35 AE90 +575HIGH Mix 11	2.42	0.46	11C-3 #1	100%	Aug-15
			11C-3 #2	95%	
			11C-3 #3	90%	

Table 1 - Updated LGCC Freeze- Thaw Testing Schedule

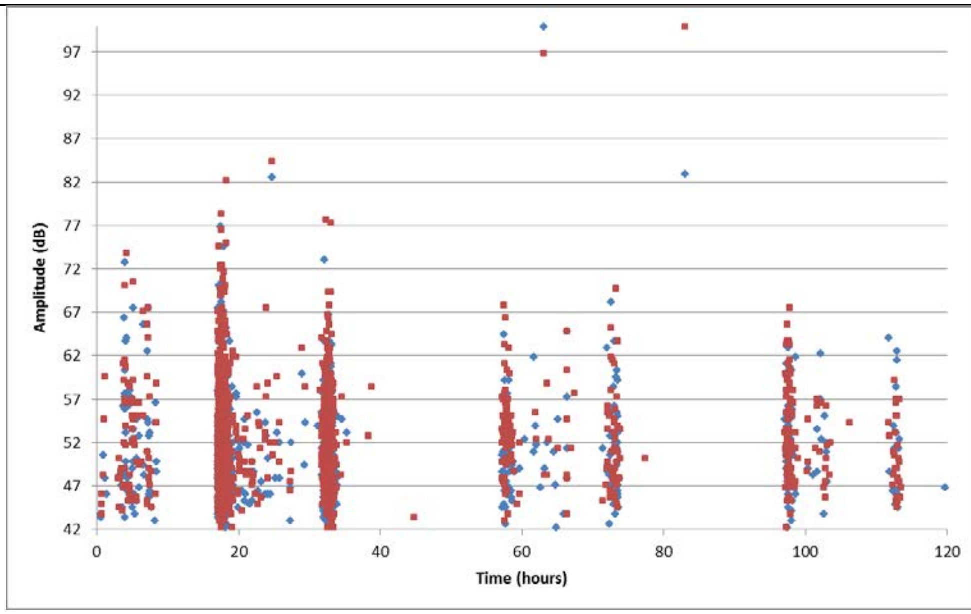

Figure 8- Example of passive acoustic emission LGCC testing data from two opposing sensors showing cracking emissions during freezing and thawing in three thermal cycles (0.40 AE 90 Mix 7, 99% Saturated).

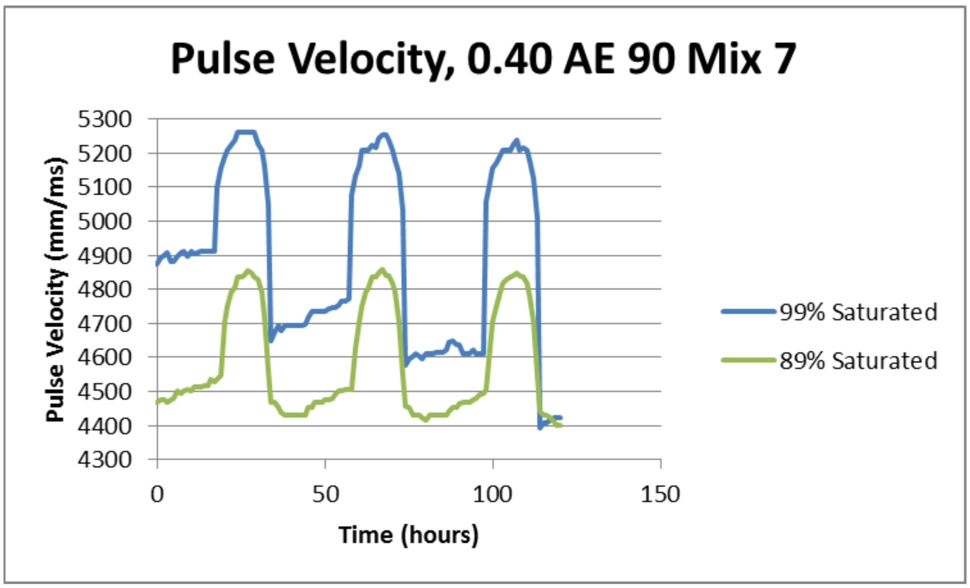

Figure 9- Example of acousto-ultrasonics LGCC testing data showing reduction in pulse velocity associated with freeze-thaw damage for highly saturated samples.

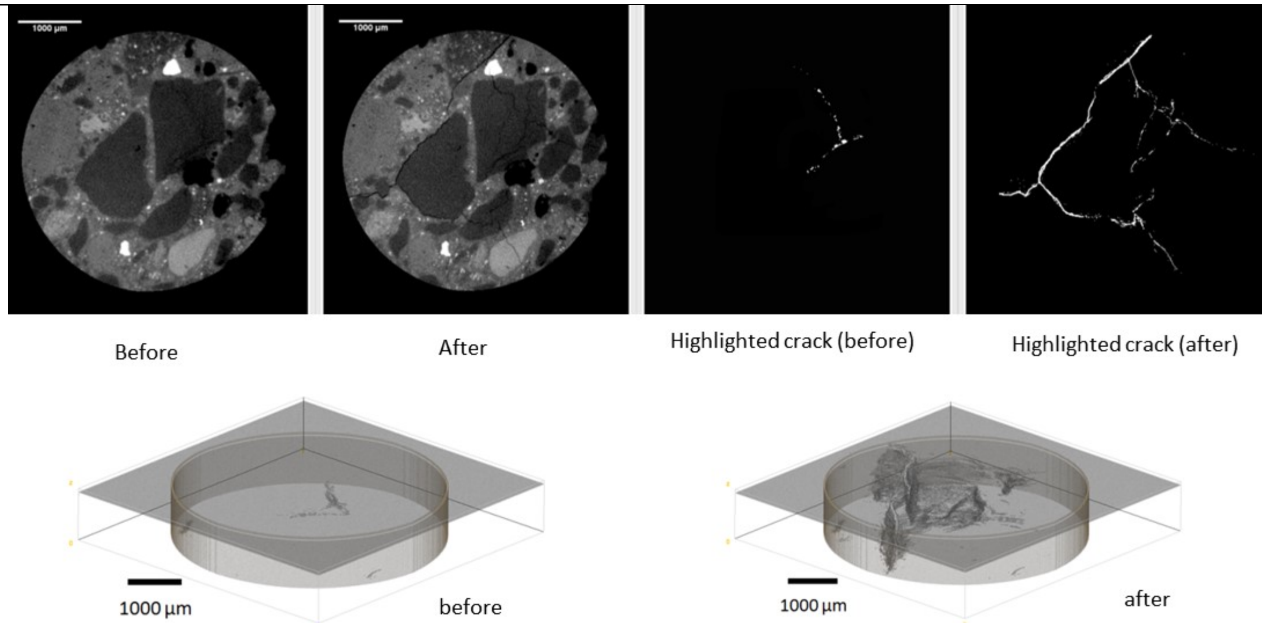

Figure 10 – An air entrained mortar sample shown both before and after a freeze thaw cycle. The highlighted cracks are shown from the cross sections. In addition, 3D data sets are shown of the crack distribution both before and after the freeze thaw cycle. The data was obtained with X-ray mCT.

Anticipated work next quarter:

The teams will continue preparing concrete mixtures to be investigated with the SAM and processing the materials produced previously. The ASTM C666 testing will continue as well as the ASTM C457 sample preparation for the samples provided by other states.

The team also plans to begin examining the rate of looking the absorption and desorption, rate of damage, and degree of saturation level on the damage with the concrete provided by OSU.

Work will continue with the mCT and neutron work.

Significant Results:

The data from over 300 different laboratory and field mixtures completed by two different labs suggest that a SAM number of 0.20 can correctly determine if the spacing factor is above or below 0.008" about 93% of the time. There is also over 80% agreement between the SAM results and the ASTM C666 results.

A presentation on the progress of the project was given at the NCC meeting in Omaha, NE and Miwaukee, WI. In addition the research team has shared information in two conference calls with the research oversight committee.

In addition, webinars and in person presentations have been given by Dr. Ley to the ACPA and their members, Missouri Science and Technology, North Dakota ACPA, Kansas KAPA, Utah ACPA, Iowa Paving conference, Colorado ACPA, Wisconsin ACPA, New Mexico Concrete School, Minnesota Concrete Association, Michigan DOT, The National ACPA Meeting, AASHTO SOM, and two National ACI conferences. The FHWA Mobile Concrete Lab visited the OSU campus for several days to discuss about our progress with the SAM and other testing methods.

The SAM is now being used in 28 states and two Canadian provinces. It has also been specified in two states.

The publication of the AASHTO TP118 test method is also significant progress.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

There was some delay getting the contracts signed. This has delayed the start of the project some but the research team doing their best to make up for this. The project is about four months behind schedule. A contract extension will likely be necessary.

Other than this issue the project is on time and on scope.

Potential Implementation:

The Provisional AASHTO test method for the Super Air Meter is in press. Changes to other test methods are also being discussed. Work will continue on the project to develop the precision and bias statement.

One paper has been submitted to a conference and several more are being authored to submit soon. Much of this work has been included as supplementary documents to previous quarterly reports.