DEVELOPMENT OF RAPID IN-SITU TESTING FOR CONCRETE DECK DURABILITY

Quarterly Progress Report
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1. Background and Introduction

Research has shown that the transport properties such as permeability, diffusivity, and absorption/sorption of concrete are indicators of the serviceability and durability of concrete structures as most degradation processes are dependent on the movement of fluid within the pore structure [1–8]. The currently accepted methods for assessing concrete resistance to penetration of chloride ions are the Rapid Chloride Permeability (RCP), Bulk Resistivity (BR) and the Surface Resistivity (SR) tests. The RCP test is time-consuming, laborious, has rather high variability, and is user sensitive, making it problematic for inclusion in a performance-based specification. Potential alternatives to the RCP test are the Surface Resistivity (SR) and the Bulk Resistivity (BR) Tests, methods which is dramatically easier, faster, and have less variability than the RCP test. However, the SR and BR tests have their own challenges. The moisture content, curing conditions, and temperature have can affect the results of the tests. In addition, accelerated moist-curing may not provide the same results as standard moist-curing. The proposed research aims at taking a concept that was recently developed at FIU and completing the procedure for marketing a novel approach for quickly (20 minutes) assessing the durability of existing concrete bridge decks.

2. Problem Statement

Assessing durability on-site is a challenging task. An interesting quality check test for the durability of concrete has been developed at FIU which could be modified for “in-situ” assessment of the durability concrete elements (column, beam, abutments, bridge deck, etc.) in less than 20 minutes. This which would allow for a quick quality control assessment of the concrete components used in Accelerated Bridge Construction (ABC). Following is a very brief description of this novel method. The method quickly assesses the durability of hardened concrete material against liquid ingress, at very high pressure. This proposal aims at relating this behavior to standard durability tests, such as Freeze/Thaw, Rapid Chloride Permeability, Bulk Resistivity and Surface Resistivity tests that are expensive and take a very long time. The entire test lasts 20 minutes, as described below. In the developed method, liquid at high pressure is applied to the surface of hardened concrete and time vs. pressure response is obtained. As an example, if water is used as a liquid, one foot of water, placed on a concrete surface would result in 0.433 psi pressure on concrete surface. Therefore, applying 200 psi pressure to concrete surface would be equivalent to having that concrete under 461.9 ft. of water.

3. Objectives and Research Approach

This project is aiming at establishing a relationship that might exist between routine Freeze/Thaw, Rapid Chloride Permeability (RCP), Bulk Resistivity (BR), and Surface Resistivity (SR) tests and the novel method developed. If such a relation exists, the durability assessment of concrete bridge elements can be achieved in less than 20 minutes.

4. Activities Completed

Equipment Preparation

Humidity Chamber Preparation and Calibration

Humidity chambers to maintain 75% and 95% RH (Figure 1) were prepared using saturated sodium chloride and potassium sulfate salt solutions. Portable relative humidity gages (LASCAR EL-USB-2-LCD+ probes) were used to measure the developed chamber temperature and relative humidity for a week to assess how well the environmental conditions can be maintained in the laboratory. Figure 2 shows the collected chamber temperature and relative humidity data for 1 week in the laboratory. Daily temperature fluctuations were apparent but the relative humidity was well maintained to 75% and >95%RH. The increase in temperature after 4 days was due to loss of room air conditioning. Climate control has since been restored and is not expected to cause further disruptions.

Figure 1. Example of Humidity Test Chamber.

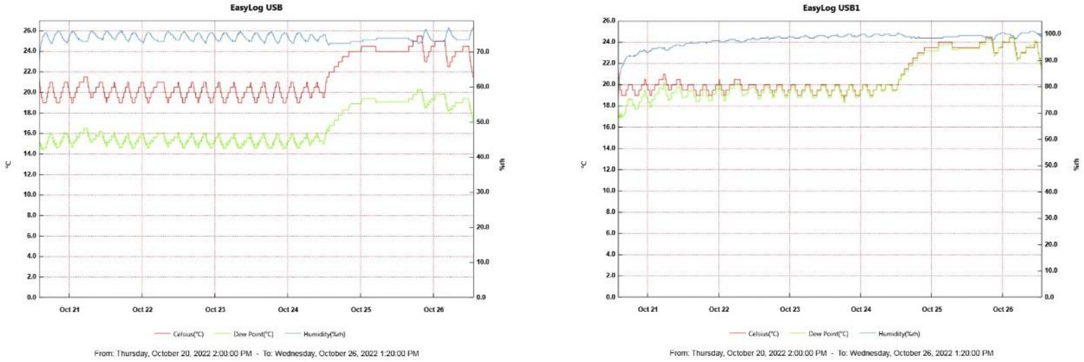


Figure 2. Controlled Relative Humidity using Saturated Sodium Chloride and Potassium Sulfate Salt Solutions.

RCPT

The necessary equipment to run rapid chloride penetration test has been procured and installed.

Freeze-Thaw

The necessary equipment to run freeze-thaw durability test is available at Rowan University to be coordinated by co-PI Mantawy. Equipment is also being procured at FIU.

Material Preparation

Limestone, River rock, and granite in graded sizes 5-7 and 8-9 each were procured. Aggregate characteristics were measured in the laboratory as shown in Table 1.

Figure 3. Coarse Aggregate

Table 1. Coarse Aggregate Characteristics

Parameters	Limestone		River Rock		Granite	
	5-7	8-9	5-7	8-9	5-7	8-9
SSD Bulk Density (lb/ft^3)	93.6	93.9	101.2	100.9	106.2	98.9
Water Absorption (%)	6.0	8.9	1.7	2.9	0.7	1.8
Gs SSD	2.39	1.97	2.6	2.45	2.62	2.61
Gs Dry	2.25	2.02	2.56	2.38	2.61	2.61
Void (%)	33.4	25.5	36.7	32.1	34.8	39.3

Fine aggregate masonry sand was procured. SSD condition was determined to be ~0.43% and the density was determined to be 91.8 lb. /ft^3.

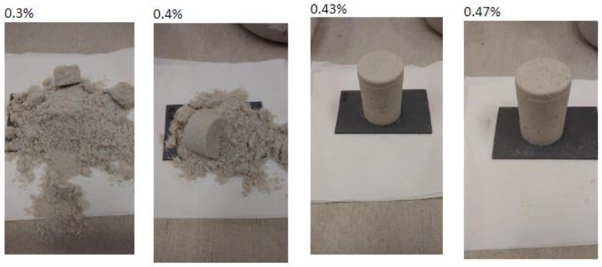


Figure 4. Fine aggregate SSD

Concrete Mix Design

The following tables shows the planned concrete mixes and mix designs.

Table 2. Concrete mixes.

Mix type based on coarse aggregate (size)	Coarse aggregate (lb.)	Sand (lb.)	Cement (lb.)	Water (lb.)
1. Limestone (5/7)	178.7	137.66	59.88	23.95 (0.4w/c)
2. Limestone (5/7)	178.7	137.66	59.88	29.94 (0.5w/c)
3. Limestone (5/7)	178.7	137.66	59.88	35.93 (0.6w/c)
1. Limestone (8/9)	179.3	137.66	59.88	23.95 (0.4w/c)
2. Limestone (8/9)	179.3	137.66	59.88	29.94 (0.5w/c)
3. Limestone (8/9)	179.3	137.66	59.88	35.93 (0.6w/c)
1.River Rock (5/7)	193.2	137.66	59.88	23.95 (0.4w/c)
2.River Rock (5/7)	193.2	137.66	59.88	29.94 (0.5w/c)
3.River Rock (5/7)	193.2	137.66	59.88	35.93 (0.6w/c)
1.River Rock (8/9)	192.7	137.66	59.88	23.95 (0.4w/c)
2.River Rock (8/9)	192.7	137.66	59.88	29.94 (0.5w/c)
3.River Rock (8/9)	192.7	137.66	59.88	35.93 (0.6w/c)
1.Granit (5/7)	202.8	137.66	59.88	23.95 (0.4w/c)
2.Granit (5/7)	202.8	137.66	59.88	29.94 (0.5w/c)
3.Granit (5/7)	202.8	137.66	59.88	35.93 (0.6w/c)
1.Granit (8/9)	188.9	137.66	59.88	23.95 (0.4w/c)
2.Granit (8/9)	188.9	137.66	59.88	29.94 (0.5w/c)
3.Granit (8/9)	188.9	137.66	59.88	35.93 (0.6w/c)

Table 3. Mix design.

	ID	w/c	Coarse aggregate type	Coarse aggregate size	Air entrainment	Internal Moisture
1	5LS57A	0.5	Limestone	5/7	Yes	Soak, >95%RH, 75%RH, Dry
2	5LS57P				No	Soak, >95%RH, 75%RH, Dry
3	5LS 89A			8/9	Yes	Soak, >95%RH, 75%RH, Dry
4	5LS89P				No	Soak, >95%RH, 75%RH, Dry
5	5RR57A		River Rock	5/7	Yes	Soak, >95%RH, 75%RH, Dry
6	5RR57P				No	Soak, >95%RH, 75%RH, Dry
7	5RR89A			8/9	Yes	Soak, >95%RH, 75%RH, Dry
8	5RR89P				No	Soak, >95%RH, 75%RH, Dry
9	5GR57A		Granite	5/7	Yes	Soak, >95%RH, 75%RH, Dry
10	5GR57P				No	Soak, >95%RH, 75%RH, Dry
11	5GR89A			8/9	Yes	Soak, >95%RH, 75%RH, Dry
12	5GR89P				No	Soak, >95%RH, 75%RH, Dry
13	4LS57A	0.4	Limestone	5/7	Yes	Soak
14	4LS57P				No	Soak
15	4LS89A			8/9	Yes	Soak
16	4LS89P				No	Soak
17	4RR57A		River Rock	5/7	Yes	Soak
18	4RR57P				No	Soak
19	4RR89A			8/9	Yes	Soak
20	4RR89P				No	Soak
21	4GR57A		Granie	5/7	Yes	Soak
22	4GR57P				No	Soak
23	4GR89A			8/9	Yes	Soak
24	4GR89P				No	Soak
25	6LS57A	0.6	Limestone	5/7	Yes	Soak
26	6LS57P				No	Soak
27	6LS89A			8/9	Yes	Soak
28	6LS89P				No	Soak
29	6RR57A		River Rock	5/7	Yes	Soak
30	6RR57P				No	Soak
31	6RR89A			8/9	Yes	Soak
32	6RR89P				No	Soak
33	6GR57A		Granite	5/7	Yes	Soak
34	6GR57P				No	Soak
35	6GR89A			8/9	Yes	Soak
36	6GR89P				No	Soak

Air entrainment admixture (MasterAir AE 90) was procured.

5. Description of Research Project Tasks

Task 1 – Literature review
A comprehensive review of existing technologies used to determine the durability of existing concrete bridge decks will be conducted. The objective of this task is to develop a database identifying all existing technologies.

The literature review is ongoing.

Task 2 – Compare Freeze-Thaw test results to FIU method test results
Conduct Freeze-Thaw tests on concrete specimens as per ASTM C 666, "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing" and AASHTO T 161, "Standard Method of Test for Resistance of Concrete to Rapid Freezing and Thawing". Compare results to the FIU method.

See section 4 for updates on material and equipment preparation.

Task 3- Compare Rapid Chloride Permeability test results to FIU method test results.
Conduct Rapid Chloride Permeability tests on concrete specimens as per AASHTO T277, "Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete" and ASTM C1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration". Compare results to the FIU method.

See section 4 for updates on material and equipment preparation.

Task 4- Compare Electrical Resistivity tests to FIU method test results.
Conduct Surface Resistivity (SR) tests on concrete specimens as per AASHTO T358 Conduct Bulk Resistivity (BR) test on concrete specimens as per AASHTO TP 119. Compare results to the FIU method.

See section 4 for updates on material and equipment preparation.

Task 5- Final reporting.
Write final report summarizing experimental results and complete system design, ABC-UTC Guide, and a video presentation will be prepared that summarize the methods used and the findings reached during the project.

No activity for Task 5 was made in this phase of work.

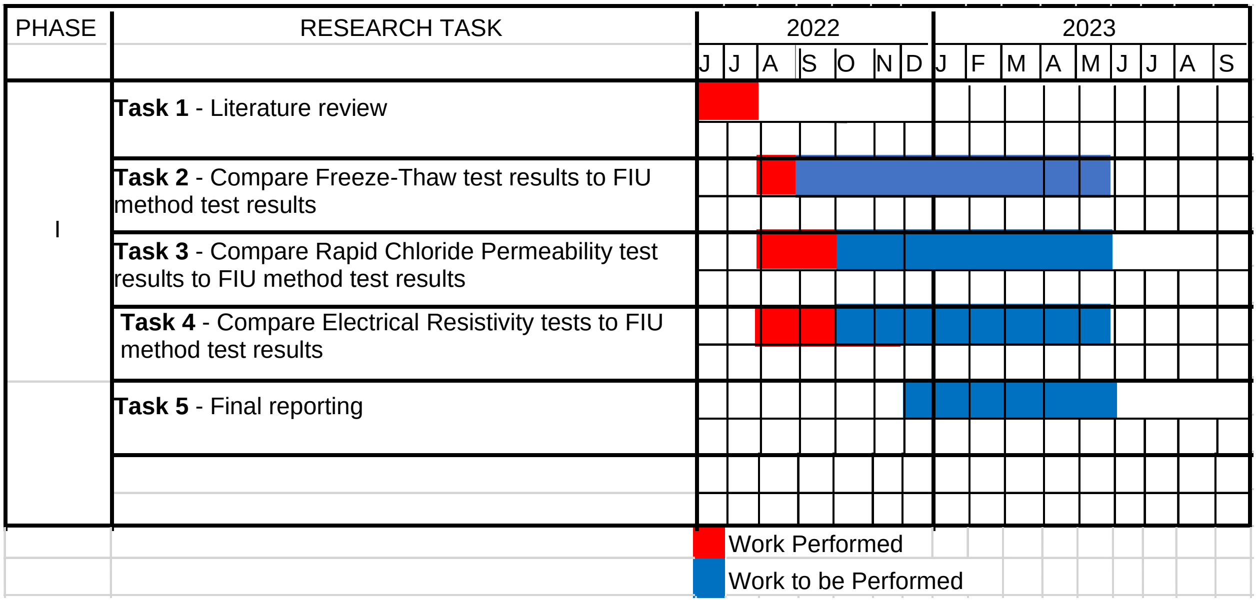
6. Expected Results and Specific Deliverables

The method, when completed, using the proposed project has the potential to make a paradigm shift in the way we assess the durability of existing concrete bridge decks and for that matter any concrete elements, such as columns, etc.

7. Schedule

Progress of tasks in this project is shown in the table below.

Item	% Completed
Literature review	75
Compare Freeze-Thaw test results to FIU method test results	10
Compare Rapid Chloride Permeability test results to FIU method test results	20
Compare Electrical Resistivity tests to FIU method test results	20
Final reporting	0



PHASE	RESEARCH TASK	2022							2023									
		J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
I	**Task 1** - Literature review	🟥	🟥														
	Task 2 - Compare Freeze-Thaw test results to FIU method test results			🟥	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Task 3 - Compare Rapid Chloride Permeability test results to FIU method test results			🟥	🟥	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Task 4 - Compare Electrical Resistivity tests to FIU method test results			🟥	🟥	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Task 5 - Final reporting							🟦	🟦	🟦	🟦	🟦	🟦				

🟥 Work Performed

🟦 Work to be Performed

8. References

[1] Relating Water Permeability to Electrical Resistivity and Chloride Penetrability of Concrete Containing Different Supplementary Cementitious Materials, Cement And Concrete Composites, Volume 107, 2020, 103491, Issn 0958-9465, https://doi.org/10.1016/j.cemconcomp.2019.103491.

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