Quarterly Progress Report:
Project Number and Title: C7.2018: Alternative Cementitious Materials (ACMs) For Durable and Sustainable Transportation Infrastructures
Research Area: New Materials for Longevity and Constructability
PI: *Warda Ashraf, Ph.D., University of Maine*
Graduate Student: *Rakibul I. Khan, University of Maine*
Reporting Period: *Oct 2019 to Dec 2019*
Submission Date: *31 December 2019*

Overview

The goal of this project is to find an alternative cementitious material (ACM) to enhance the durability and longevity of concrete infrastructure. Carbonation cured binder with a high Ground granulated blast furnace slag (GGBFS) as a partial replacement of Ordinary Portland cement (OPC) was selected to produce concrete with a low carbon footprint of ordinary.

The major achievement of this project was the selection of a concrete mix proportion and curing condition for better strength. In the last semi-annual report, it was shown that 45% ~ 65% replacement of Ordinary Portland Cement (OPC) by slag with hydration-carbonation curing provided better compressive strength. It was also observed that by incorporating carbonation curing, a higher early strength of concrete is achievable compared to that obtained from traditional hydration-based curing.

The tasks of this quarter (October to December 2019) include investigations on the concrete's compressive strength variations with different binder contents, cube compressive strength of paste samples produced using carbonation/hydration curing, and rapid chloride permeability measurements of the concrete batches.

Three different binder contents (i.e., 600 kg/m^3, 475 kg/m^3, and 356 kg/m^3) with 45% OPC replacement by slag were studied here. It can be observed in Figure 1 (a) that the workability of concrete was decreased with decreasing binder content. The explanation behind the reduced workability was that the mixer had less binder to lubricate the aggregate. Figure 1 (b), (c), and (d) also show that, with decreasing binder content, compressive strength was increased.

Figure 2 demonstrates the compressive strength of the cement paste cubes at different OPC replacement level with slag for different curing conditions. Up to 65% OPC replacement by slag provided nearly the same compressive strength as the control batch. Three days of hydration followed by carbonation curing was found to be the most effective curing condition to allow a high volume of slag usage.

Rapid chloride permeability test (RCPT) as per ASTM 1202 was adopted to get the qualitative measure of concrete's resistance to chloride ingress. The RCPT test is one of the most widely used test methods to compare the durability performances of concrete. In general, a lower charge passed or a lower chloride diffusion in concrete represents a denser microstructure and more durable concrete. Figure 3 shows the RCPT test results of concrete cylinders produced using three curing conditions (i) hydration, (ii) hydration followed by carbonation, and (iii) carbonation followed by hydration. For the first two curing conditions, the increasing slag content resulted in a lower charge passed. Hydration followed by carbonation curing further resulted in a lower charge passed amount compared to pure hydration. These results are the preliminary evidence that the incorporation of high slag content with carbonation curing can improve the durability performance of concrete by producing a denser microstructure.

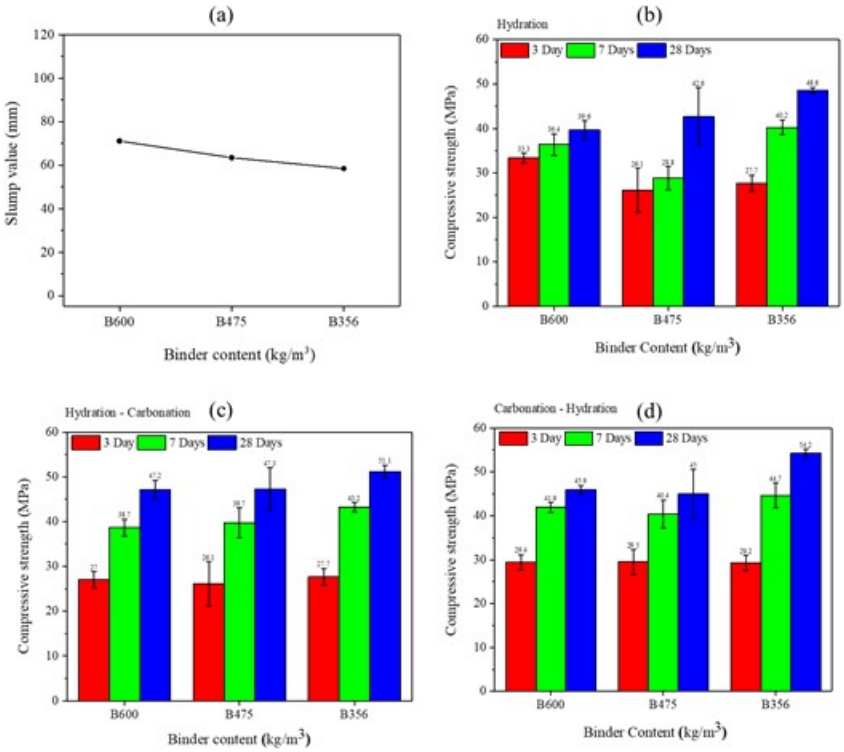

Figure 1: (a) Slump value with binder content, (b), (c), and (d) compressive strength of cylinders with different hydration, hydration-carbonation, carbonation-hydration curing condition respectively

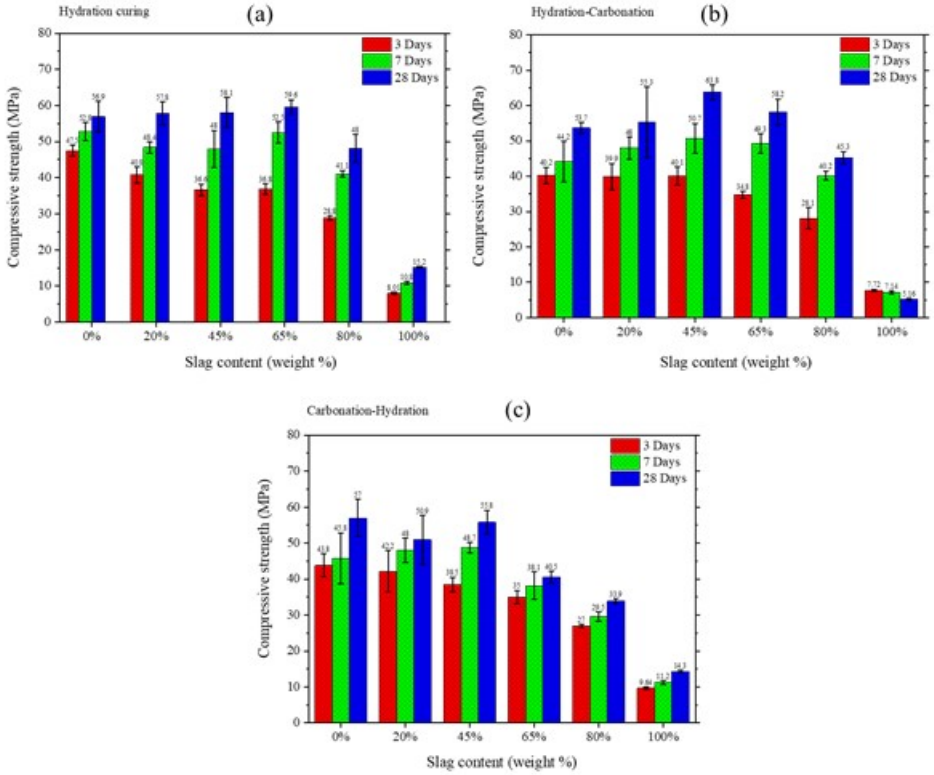

Figure 2: Cube compressive strength for different curing conditions (a) hydration, (b) hydration-carbonation, and (c) carbonation-hydration curing

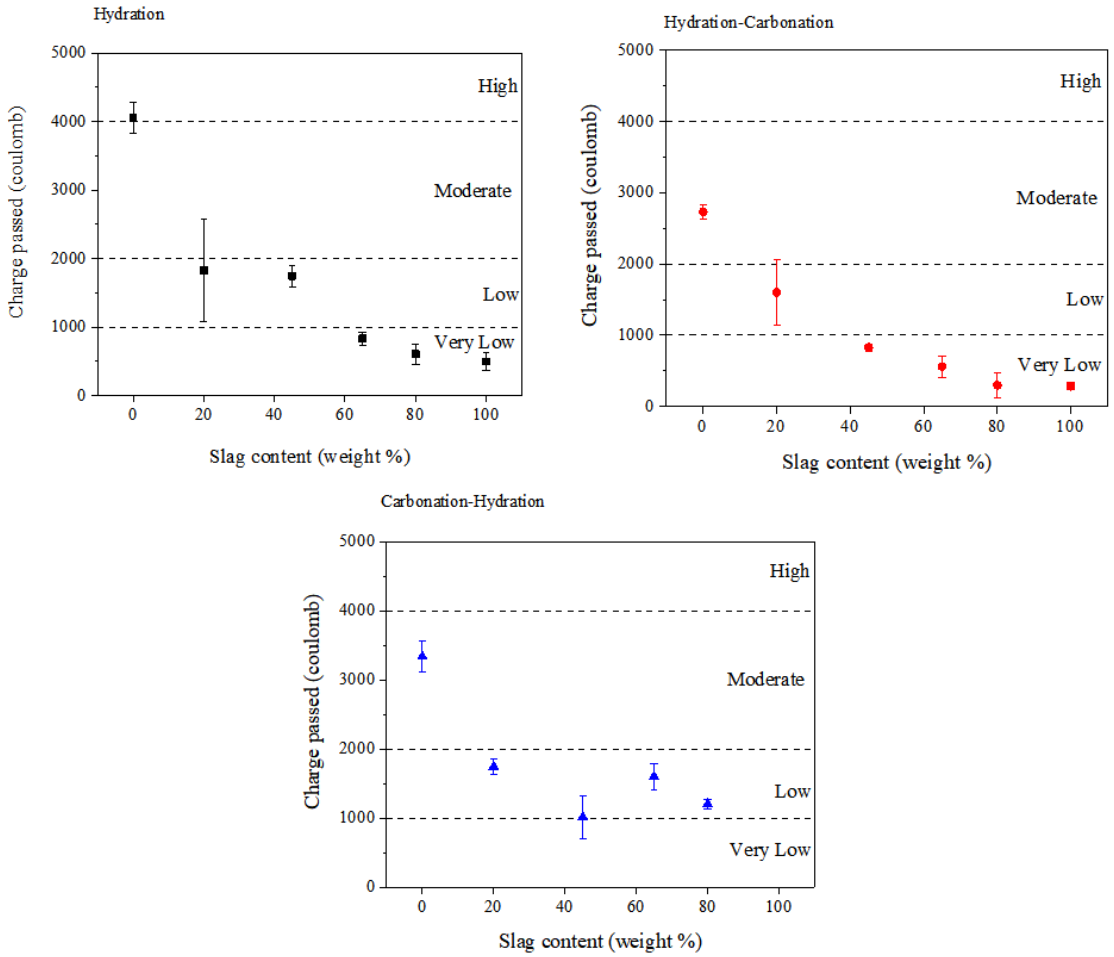

Figure 3: RCPT results of different curing conditions; (a) hydration curing, (b) hydration followed by carbonation, and (c) carbonation followed by hydration

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**Percent Complete**
Task 1: Selection of ACM with desired workability and strength	06/01/2019	12/31/2019	100%
Task 2: Shrinkage			
Task 3: Durability performance	10/01/2019	Continue	30%
Task 4: Life cycle analysis			

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$166,538	$7,596	9.1%

List all other outputs, outcomes, and impacts after the tables *(i.e. patent applications, technologies, techniques, licenses issued, and/or website addresses used to disseminate research findings).*

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
N/A				

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
N/A				

Participants and Collaborators:

Use the table below to list all individuals who have worked on the project.

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Mohammad Rakibul Islam Khan	mohammad.r.khan@maine.edu	Civil and Environmental Engineering	Perform the experiments and analysis the results
Dr. Warda Ashraf	warda.ashraf@maine.edu	Civil and Environmental Engineering	Guiding the providing expert opinion

Use the table below to list all students who have participated in the project.

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
N/A				

Use the table below to list any students who worked on this project and graduated during this reporting period.

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
Mohammad Rakibul Islam Khan	Perform the experiments and analysis the results	M.Sc.	12/21/2019

Use the table below to list organizations have been involved as partners on this project and their contribution to the project.

Table 8: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
University of Maine	Maine	X	X	X		

Changes:

The project will be handed to a new PI as Dr. Warda Ashraf moved to a different university. Dr. Ashraf will collaborate and provide suggestions and guidance as needed.

Planned Activities: