Quarterly Progress Report:
Project Number and Title: 3.5 Prevention of Stress-Induced Failures of Prestressed Concrete Crossties of the Railroad Track Structure
Research Area: New Systems for Longevity and Constructability
PI: *Moochul Shin and Western New England University*
Co-PI(s): *ChangHoon Lee and Western New England University*
Reporting Period: *10/01/2019 and 12/31/2019*
Submission Date: *12/31/2019*

Overview: (Please answer each question individually)

During the reporting period, the WNEU research team has worked on developing Ultra-High-Performance Concrete for railroad concrete crossties and further updating the detailed 3D numerical prestressed concrete prism models. While the definition of UHPC is qualitative, the American Concrete Institute 239 committee defines UHPC as "a concrete that has a minimum specified compressive strength of 22, 000 psi (150 MPa) with specified durability, tensile ductility, and toughness requirements." The research team aims to develop a UHPC for the railroad concrete cross ties as identifying criteria shown in Table 1.

Table 1: Criteria for UHPC of Railroad Crosstie

Criteria	Conditions	Strategic Method
Cast-ability	▪ Early strength development (Manufacturing time, Sufficient strength at pre-stressing). ▪ Steam curing is generally incorporated to accelerate hydration.	▪ Use of Type III cement ▪ Chemical admixture to accelerate hydration ▪ Minimize heat damage during the steam-curing
Structural Performance	▪ Expose to consistent impact loadings, leading to fatigue failure. ▪ Damage due to friction with ballast and rail.	▪ Improve tensile toughness. ▪ Smooth finishing surface, achieved by self-compacting concrete ▪ Manipulation of the mixture to minimize the surface porosity of the concrete.
Durability	▪ Sulfate attack including delayed ettringite formation. ▪ Chloride attack, causing corrosion of pre-stressing tendons. ▪ Alkali silica reaction	▪ Improve denser microstructure to achieve lower penetration rate. ▪ Selection of aggregates to avoid chloride and sulfate.

Within the reporting period, the team was able to test concrete mixtures whose strengths reached up to 5000 psi to 7000 psi by using silica fume, fly ash, and/or granulated ground blast furnace slag (GGBFS), as shown in Figure 1(a). The aggregate used for the development was recycled aggregate (so-called "processed rock") which consists of mixed asphalt, recycled concrete, and some natural rocks. The team especially used this type of aggregate since it is easily obtained from a local quarry in the western part of Massachusetts and Connecticut. As shown in Figure 1(b), the failure occurs through the aggregates, indicating the strength of aggregate is lower than the bond strength between the aggregates and the paste matrix. In addition, the use of Type III cement combined with GGBFS showed a higher strength development rate at the early ages, as shown in Figure 1(c); T3 stands for Type III cement. The research team also investigated the influence of heat-treatment (176F (80C)), simulating a steam-curing condition. Figure 2 shows the results of the compressive strengths depending on the curing temperatures. The results indicate that the improvement of strength due to adding silica fume and fly ash can be degraded by the damage due to heat while further investigation is necessary. On the other hand, the combination of silica fume and GGBFS showed a 30% improvement in strength.

(a) Compressive strengths at 28 days *(b) Failed surface of a specimen* *(c) Strength Development with Time*

Figure 1: Results of Compressive Strength Test

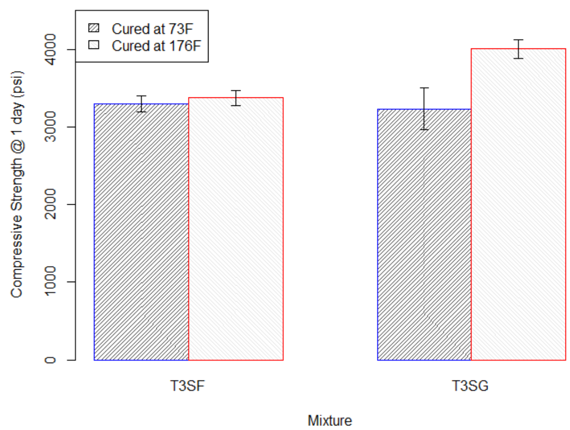

Figure 2: Compressive Strength at 1-day according to heat treatment

In this period, the research team has been finalizing the development of 3D finite element models of prestressed concrete prisms with detailed indented wires (Task1) by investigating the details of actual indentation parameters of prestressed wires including side angle, area of indentation, volume, length, and depth. At the same time, the in-house code for the large-computation using the high-performance computing power based on a parallel computing algorithm (Task2) has been updated. The in-house code is capable of carrying out both prestressed and pull-out simulations. By incorporating the high-performance computing power, the complex failure mechanism of prestressed concrete crossties can be analyzed. By introducing the engineered cementitious materials for manufacturing crossties, the structural integrity and safety of the railroad track structure can be enhanced.

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1: 3D FE Models	09/01/2018	12/30/2019	90%
Task 2: 3D FE Models on HPC	03/01/2019	09/30/2020	20%
Task 3: Crosstie Models	06/01/2020	09/30/2021	0%
Task 4: Introduction of Engineered Cementitious Materials	12/01/2018	09/30/2020	57%

Table 2: Budget Progress

Entire Project Budget	Spend Amount	Spend Percentage to Date
$385,000	$124,139	32%

The research team participated in presenting their research results and progress at the 32nd Rhode Island Transportation Forum. PI Dr. Shin gave a presentation at the Forum and discussed the issue of the railroad infrastructure. In addition, the research team submitted a research article regarding coarse aggregate's morphological effects on cement-based materials. The review was positive and the team is revising the article.

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events

Title	Event	Type	Location	Date(s)
Numerical study of the Effect of Indentation Patterns in Prestressed Concrete Prisms using High Performance Computing	The 32nd Rhode Island Transportation Forum	Presentation	Kingston, RI	10/25/2019

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status
Peer-reviewed journal	Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials	C. H. Lee, S. J. Lee, M. Shin, and S. Bhattacharya, "Interrelation of Morphological Indices and 2-D Generalized Regularity for Coarse Aggregate in Cement-Based Materials," Construction and Building Materials, 2019	12/31/2019	2nd Review

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members

Individual Name	Email Address	Department	Role in Research
Moochul Shin	moochul.shin@wne.edu	Civil & Environmental Engineering	Leading Task 1, 2, and 3
Chang Hoon Lee	changhoon.lee@wne.edu	Civil & Environmental Engineering	Leading Task 4.

Table 6: Student Participants during the reporting period

Student Name	Email Address	Class	Major	Role in research
Abdoulaye Diallo		Master	Civil Engineering	Numerical analysis
Caleb Tourtelotte		Senior	Civil Engineering	Specimen manufacture
Nicholas Pantorno		Junior	Civil Engineering	Specimen manufacture
Cameron Cox		Junior	Civil Engineering	Specimen manufacture
Andrew Masullo		Junior	Civil Engineering	Specimen manufacture

Table 7: Student Graduates

Student Name	Role in Research	Degree	Graduation Date
N/A			

The in-house code was mainly developed by Dr. Kwack (currently at Argonne National Laboratory) when he was a staff member of the Blue Waters sustained-petascale computing project, which is supported by the National Science Foundation (awards OCI-0725070 and ACI-1238993) and the State of Illinois.

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
National Center for Supercomputing Applications	Urbana, IL		V			

Changes:

N/A

Planned Activities:

1. Large-scale prestressed concrete crosstie models will be developed with multiple wires in order to investigate the overall responses using the HPC.

2. The research team will continue developing UHPC for the railroad crossties. Instead of recycled aggregates, the team will test granite (quartz-oriented) and basalt aggregates (silica-oriented).

3. We are planning to conduct a series of a pull-out test with the newly developed UHPC.