Semi-Annual 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
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Co-PI(s): ***ChangHoon Lee and Western New England University***
Reporting Period: ***04/01/2019 and 9/30/2019***
Date: ***9/30/2019***

Overview:

In this period, the WNE research team has been further developing finite element models of concrete prisms with detailed indented wires (Tasks 1 and 2), and conducting a pull-out test to characterize the bonding characteristics at the interface of concrete and prestressing wires (Task 4). In practice, there are many types of prestressing wires with various indentation geometrical characteristics in use, which result in a wide range of structural performance and bonding mechanisms. 10 different types of prestressing wires with different indentation shape, depth, and diameter were collected and donated by prestressed concrete crosstie manufactures and a prestressed concrete crosstie research lab. Figure 1 shows a picture of the various prestressing wires.

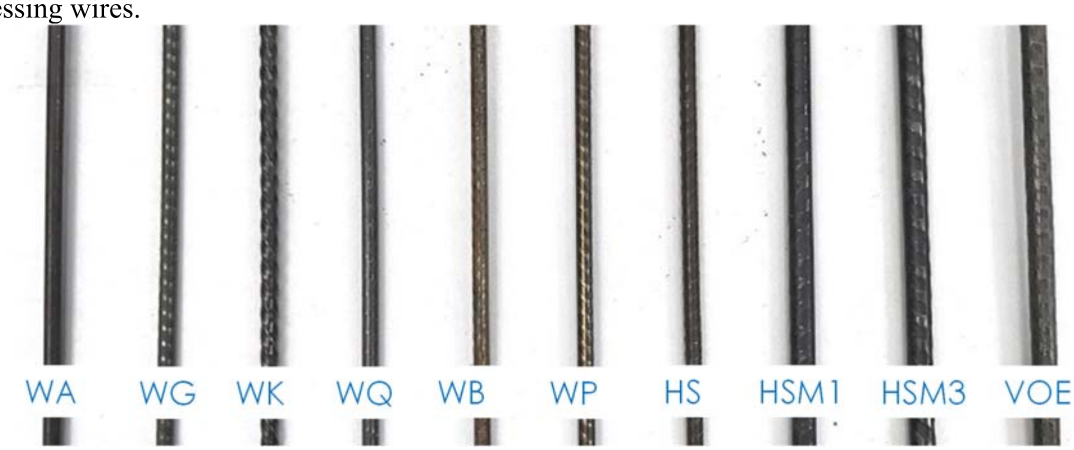

Figure 1. Various prestressing wires with different shape, depth, and diameter.

In the meantime, the WNEU research team prepared a 3 in x 6 in concrete cylinder with a 5.32 mm chevron pattern-shallow depth indented wire (WG) and conducted a pull-out test. Figure 2 shows a picture of the sample and the pull-out force vs. displacement graph. The shallower the indentation depth is, the weaker the bond strength would be expected. However, too strong mechanical bond can be associated with an earlier splitting/bursting failure after de-tensioning the wire. The average strength of the concrete used for the pull-out test was found to be 5,500 psi at 28 days, approximately 37.5% of enhancement only with 7% of silica fume replacement as compared to the base mixture (only with Portland cement).

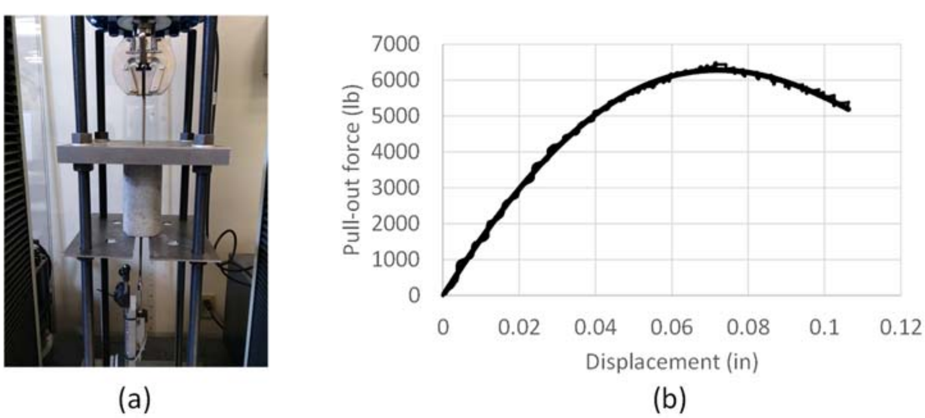

Figure 2. Pull-out test sample with WG wire (a) and the pull-out force and displacement curve (b)

Semi-Annual Progress Report

A numerical framework has been established for conducting a complex geometry-model simulation using the high-performance computer available on the XSEDE Stampede2 at the Texas Advanced Computing Center at the University of Texas at Austin. Using the high-performance computer the elastic models of prestressed concrete prisms were analyzed based on four geometric parameters (i.e. indentation shape, side angle, depth, and average area). The parallel computation requires the following four steps: 1) generating a detailed mesh and input file, 2) converting the input file to a format compatible with the parallel computing solver, 3) partitioning the model, and 4) analyzing the model and visualizing the results. 1”x1”x4” prestressed concrete prism models with various indented wires were analyzed. Two numerical tests were conducted: 1) Pull-out test and 2)Prestress releasing test. The sensitivity analysis was conducted to figure out a suitable mesh resolution on a local workstation using a commercial finite element analysis software, ABAQUS CAE. The numerical model was divided into five different zones: 1) coarse concrete, 2) intermediate concrete, 3) fine concrete, 4) fine steel, and 5) coarse steel. Finer meshes are assigned to the zones at the interface. Figure 3 shows the cross-section of the model with the five zones, and mesh, and the sensitivity analysis result. In terms of the initial stiffness of the prestressed concrete prism when the prim was pulled-out, the model with the number of the elements of about 20 million showed only 0.1% difference as compared to the model with 40 million elements.

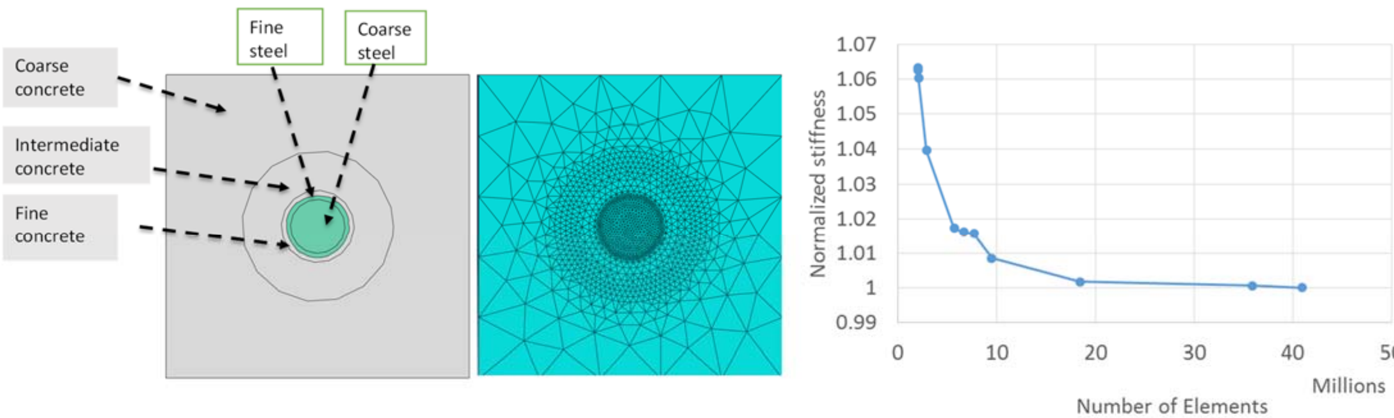

Figure 3. Meshing schemes and the sensitive analysis with respect to the size of a problem.

In order to perform a numerical analysis using a parallel computing algorithm, an in-house program has been developed using *MPI library, PETSc Library, and METIS library.* Prestressed release simulations were performed using a commercial FEA software program (ABQAUS) and the in-house program to validate the parallel computing simulations. A 1” x 1” x 4” prestressed concrete block was prepared with WG wire. The prestressing wire is subjected to the prestress of 203 ksi. The DOFs of the model with WG was 18 million. Figure 4 shows the comparison of the displacement and strain contours obtained from ABAQUS (Fig.4.a) and the in-house code (Fig.4.c). In addition, the strain contours of the wire were presented (Fig.4. b and d). They showed the same results.

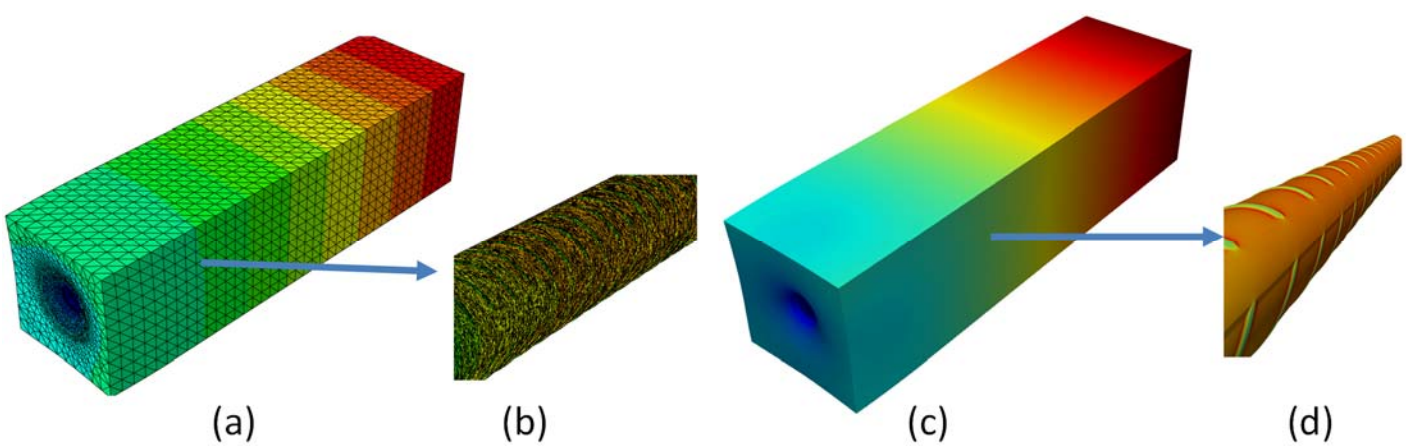

Figure 4. Prestress release simulation results: (a) Displacement contour from ABAQUS, (b) strain contour of the wire from ABAQUS, (c) Displacement contour from the in-house code, and (d) strain contour of the wire from the in-house code.

Semi-Annual Progress Report

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Participants and Collaborators:

XSEDE: University of Texas at Austin – Providing an access to their High performance computer, Stampede2 in TACC
Dr. JaeHyuk Kwack at the Argonne National Laboratory as a collaborator
Abdoulaye Diallo, Master's student in Civil Engineering, building numerical models and conducting numerical simulations as a graduate research assistant
Caleb J. Tourtelotte, Senior Civil Engineering, preparing testing samples and setting-up tests as an undergraduate research assistant

Changes:

Caleb J. Tourtelotte has recently joined in the research team since 2019 Fall.

Planned Activities:

1. We are planning to conduct a series of a pull-out test with different indentation in order to characterize the different bond-mechanisms between prestressing wires and surrounding concrete block.
2. We will come up with an optimized concrete mix design with the utility of the ternary cement-based matrix to mitigate splitting failure
3. We will keep developing detailed prestressed concrete prism models with different parameters that would affect the bonding mechanism.