The research presented in this dissertation focuses on the material characterization of ultra-high performance fiber reinforced concrete (UHP-FRC) at both the microscopic and macroscopic scales. The macroscopic mechanical properties of this material are highly related to the orientation of the steel fibers distributed within the matrix. However, the fiber orientation distribution has been confirmed to be anisotropic based on the flow-casting process. The orientation factor and probability density function (PDF) of the crossing fiber orientation was obtained based on theoretical derivations and numerical simulations with respect to different levels of anisotropy and cut planes oriented arbitrarily in space. The level of anisotropy can be calibrated based on the image analysis on the cut section from the harden UHP-FRC prisms. Simplified equations provide a framework to predict the mechanical properties based on a single fiber-matrix interaction rule selected from existing theoretical models. Along with the investigation of the impacts from different curing methods and available post-cracking models, a versatile parameterized uniaxial stress-strain constitutive model was developed and calibrated.

The constitutive model was implemented in a finite element analysis software program, and the program was utilized in the preliminary design of moveable bridge deck panels made of passively reinforced UHP-FRC. This deck system was among the several alternatives to replace the problematic steel grid decks currently in use. Based on experimental investigation of the deck panels, failure occurred largely in shear rather than flexure during bending tests. However, this shear failure is not abrupt and usually involves large deformation, large sectional rotation, and wide shear cracks before losing the load carrying capacity. This special shear failure mode observed was further investigated numerically and experimentally. Three-dimensional FEM models with the ability to reflect the interaction between rebar and concrete were created in the commercial FEM software to investigate the load transfer mechanism before and after the bond failure. Small scale passively reinforced prisms were tested to verify the conclusion drew from simulation results. As an effort to improve the original design, several shear strengthened deck panels were tested and their effectiveness is discussed. Finally, the methods and equations to predict the ultimate shear capacity were calibrated. A two-dimensional frame element based complete moveable bridge finite element model was built for observation of bridge system performance. The model contained the option to substitute any available deck system based on a subset of pre-calibrated parameters specific to each deck type. These alternative deck systems including the aluminum bridge deck system and the glass fiber reinforced plastic (GFRP) deck system. All three alternatives and the original steel grid deck system were evaluated based on the global responses of the moveable bridge, and the advantages and disadvantages on adopting the UHP-FRC deck system were discussed.

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The public is welcome to attend.