Ultra-high performance concrete (UHPC) is a recently developed concrete gaining a lot of interest worldwide, and a lot of researches have been conducted to determine its material properties. UHPC is known for its very high strength and high durability. Association Francaise de Genie Civil (AFGC) has defined UHPC as a concrete exhibiting compressive strength greater than 22 ksi (150 MPa). To utilize the full high compressive strength of UHPC, complementary tension reinforcement is required. A recent research study to find light weight yet high-strength alternative deck systems for Florida movable bridges has shown that composite UHPC and high strength steel (HSS) reinforcement deck system is among the option. However, failure modes of the deck system observed during experimental test were shear failures rather than flexural failures. Interestingly, the shear failures were ductile involving large deformation and large sectional rotation.

The purpose of this research is therefore to quantify the sensitivity of mechanical response to different shear and normal stress demands of UHPC structural members as well as its underlying failure modes. Experimental investigation on small scale prisms without reinforcement, reinforced with ASTM Grade 60 steel, and with high strength steel was carried out to capture load-deflection behavior as well as modes of failure of the UHPC specimens. Numerical analysis based on Modified Compression Field Theory (MCFT) was developed to verify experimental results at sectional level, and further verification using continuum methods was performed using MCFT/DSFM (Disturbed Stress Field Method) based Finite Element Analysis software-VecTor2.

Results from the analysis could reasonably predict the load-displacement behavior as well as the failure modes of the experimental specimens where wide crack opening propagated vertically from the bottom fiber of concrete to the loading position was observed with unreinforced UHPC specimens, while UHPC - Grade 60 steel specimens failed in flexure due to yielding of reinforcement and similar wide crack opening was seen in ductile manner. On the other hand, UHPC-MMFX specimens largely failed in shear from a diagonal tension crack and crush of concrete top fiber.