In order to reduce the maintenance cost and time, simplify construction procedure, and increase the bridge life durability, the Florida Department of Transportation (FDOT) was looking for an optimized alternative of the conventional bridge deck system. The targeted self-weight is 17psf and better serviceability and durability are expected. Several alternative deck systems were previously proposed and investigated. One of these used ultra-high performance concrete (UHPC) in passively-reinforced beams without any shear reinforcement to reduce the deck self-weight. The failure mode of beams made of UHPC under bending test exhibits diagonal shear failure rather than the conventional flexural failure. Some previous work estimated the ultimate shear capacity. however, the estimation was not well predicted due to lack or inaccuracy of the input parameters to the finite element model. Hence, more experimental and analytical investigations are required to support accurate prediction of the shear strength. To better analyze the entire shear response, each of the shear contribution components need take into consideration individually. Dowel action, as one of shear contribution factors which is rarely investigated previously, becomes important under this situation. Meanwhile, several other issues related with the UHPC deck system, such as structure serviceability including fatigue, deck-girder connection type, material on-site implementation etc, were being investigated. A uni-axial fatigue test was proposed to investigate the fatigue responses of UHPC material at service level. Finally, optimization work was performed through the cooperative research group between University of Central Florida (UCF) and Florida International University (FIU) to reduce the weight of the proposed deck system from previously achieved 25psf to 17psf. Therefore, several mid-scale "T" section beams that reinforced with high strength steel (HSS) or carbon reinforced polymer (CFRP) were casted and tested. The use of carbon fiber rebar help bright down the self-weight of the deck system to a new low level. However, there are concerns on the compatibility of UHPC matrix and the rebar that will be tested. To summarize, this Ph.D research is to investigate the shear strength responses of the ultra-high performance fiber reinforced concrete, assess its fatigue behavior, as well as optimize the bridge deck system made of UHPC and CFRP bar. All of these investigation will within the scope of the light weight deck replacement project sponsored by FDOT.