WindSTAR
Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center

Mechanical Properties, Micro-structure Property Relationship and Manufacturing/Construction Methods for Ultra-High Performance Fiber Reinforced Concrete for Wind Towers

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Ultra-High Performance Fiber Reinforced Concrete (UHPC) is a relatively new construction material that is mainly composed of high-performance concrete and fiber materials. The combination of higher binder and fiber dosage with low water to binder ratio provides UHPC with exceptionally mechanical properties such as high strength, outstanding ductility and durability, and energy absorption capability. Motivated by its remarkable material properties, a combined experimental/modeling approach has been established in this project to investigate the application of UHPC as a material solution for wind tower. The experimental studies were focused on identifying key mechanical properties such as stiffness, flexural, tensile and compressive strengths, and resistance to crack imitation and propagation. In addition, microstructures of UHPC were characterized by micro-CT. The experimental results have been incorporated into a multiscale model to capture the critical link between the microstructural constituents of UHPC and the macroscopic mechanical properties. In this multiscale model, a micromechanical modeling approach employing representative volume element (RVE) was first established. This approach accounts for the key effects such as size, shape, distribution and orientation of the constituents that were obtained from the experiments. Based on the RVE studies, a macroscopic constitutive model featuring coupled plasticity and damage effects was developed and implemented in the finite element method (FEM). Extensive design analysis employing a commercial FEM code were performed on UHPC wind towers of three different heights of 100 m, 150 m and 200 m. Key design parameters were obtained by performing both static and dynamic analysis to ensure that the requirements on stress and deflection were met. Topological optimizations were further performed on the initial designs to reduce material consumption. Based on the optimized UHPC wind tower design, levelized cost of energy (LCOE) analysis were carried out and compared to the cases of all-concrete and all-steel towers. The comparison demonstrated significant advantage of UHPC solution for tall wind towers. Such an advantage can be further enhanced by the outstanding durability and longer service life of UHPC, which requires more study.

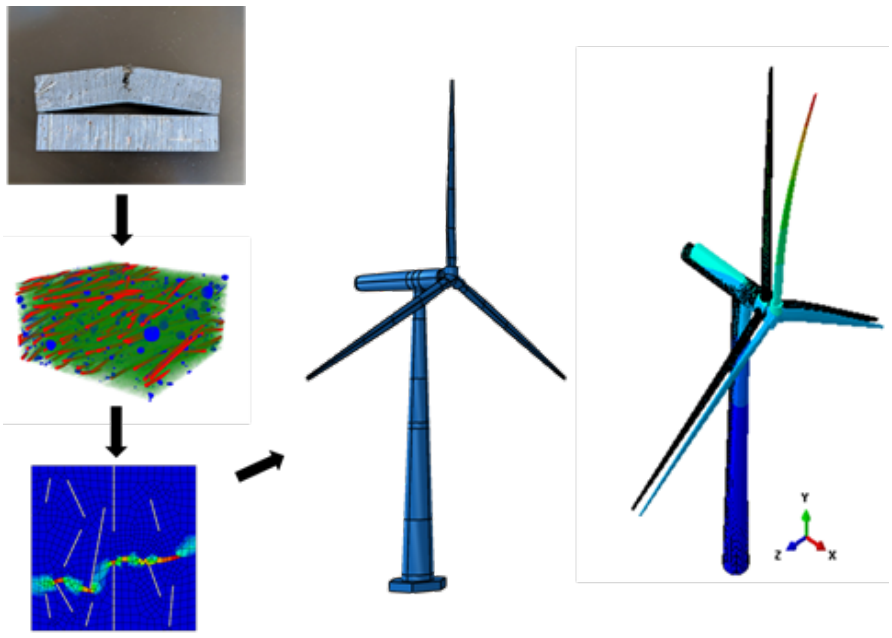

Figure 1: A combined experimental/model approach to the design of wind tower based on Ultra-High Performance Fiber Reinforced Concrete (UHPC).