Ductile Fracture Assessment and Representation in Large-Scale Structures

Xudong Qian

Department of Civil and Environmental Engineering, National University of Singapore

Ductile crack extension followed by unstable fracture failure poses critical threats to the safety of large-scale engineering structures, including bridges, steel buildings and offshore platforms, under an environmentally or artificially induced overloading event. The fracture assessment of large-scale structures faces critical barriers in the scalability of the material level fracture resistance to the fracture representation in the structural-component level.

The understanding on the ductile fracture in metallic materials has inspired the development of innovative approaches at multiple scales, from the micromechanical Gurson-Tvergaard-Needleman approach, widely known as the GTN model to describe the growth, nucleation and coalescence of voids in the metallic materials, to the cohesive zone model for simulation of the material separation in thin-walled structures with a known crack path. These approaches encounter different challenges in predicting the ductile fracture response for large-scale structures or structural components with a complex topology and loading conditions.

This lecture revisits the fundamental experimental approach to measure the material fracture resistance, characterized by the *J-R* curve, and extends the *J-R* curve measurement to non-conventional fracture specimens including the mixed-mode specimens, surface-cracked specimens and pipes with a circumferential surface crack. Based on the η-approach originally proposed for standard fracture specimens, this lecture presents a method to couple the material *J-R* curve with the load-deformation responses for structural components, exemplified by the welded tubular joints frequently used in large-scale steel structures. Such load-deformation responses thus reflect the effect of ductile tearing on the load resistance of the structural component, as well as the effect of final unstable fracture on the ductility of the structural component. The validation of the proposed coupling method covers both the experimental investigation on the tubular joint level and large-scale tests on tubular frames, which experience ductile tearing prior to the unstable fracture failure.

Dr. Xudong Qian is currently an Associate Professor in the Department of Civil and Environmental Engineering at the National University of Singapore (NUS), and the Director for Centre for Advanced Materials and Structures in NUS. His research interest covers ductile and brittle fracture, fatigue and impact for steel/offshore structures, welded connections, steel-concrete-steel composite structures, as well as non-destructive crack detection and sizing, through experimental, numerical and hybrid approaches. Prof Qian has been serving as members in different Technical Committees for the International Ship and Offshore Structures Congress. He is currently also a member of the ASTM E-08 committee on fatigue and fracture.