Structural Robustness of Long-span Cable-supported Bridges

Qian Chen
The City College of New York

In current bridge design practice, the bridge system is considered reliable or safe under the condition that all structural components satisfy their strength requirement under different load combinations. Some bridge types, especially long-span cable-supported bridges, are believed to exhibit sufficient levels of reserve strength or have multiple load paths to resist collapse in the event of sudden failure of some members. This ability of resisting collapse is related to structural robustness. However, ultimate bridge behavior of long-span cable-supported bridges subject to single or multiple member failure is not well understood and structural robustness is not explicitly considered during bridge design phase.

The main objective of this doctoral dissertation is to propose an integrated framework and performance-based criteria to quantify the robustness of cable-supported bridges subject to different damage initiating hazards. Two different types of cable-supported bridges, cable-stayed and suspended tied-arch, are selected as the example bridges for structural robustness analysis and progressive collapse behavior investigation. Detailed finite element models of these bridges, including explicit models developed in the LS-DYNA platform as well as implicit models developed in other software such as Midas Civil and SAP 2000. Implicit models are mainly used for linear elastic analysis to identify critical live load patterns and members, explicit models are mainly used for nonlinear dynamic analysis to investigate their ultimate bridge behavior and structural robustness.

Firstly, bridge behavior of the selected bridges under different single member loss scenarios have been investigated. Four indexes, demand capacity ratio (DCR), dynamic increase factor (DIF), static increase factor (SIF) and dynamic amplification factor (DAF), have been introduced. After that, the progressive collapse behavior of the bridges is further studied by successively removing members until system failure occurs. Secondly, bridge behavior subjected to overloading are investigated by pushdown analysis, typical limit states were identified for subsequent robustness analysis. Thirdly, by considering the shortcomings of current redundancy approach for long-span bridges suggested by NCHRP Report 406/776, a new performance-based robustness evaluation method and a robustness index for long-span bridges is proposed. Finally, robustness of the two long-span cable supported bridges are evaluated for the typical limit states identified from pushdown analysis. The result show that the effect of various scenarios of single cable loss on each bridge can be captured explicitly, demonstrating the applicability of the robustness evaluation method and robustness index proposed, especially for long-span bridges. In addition, in spite of the adverse effect of single cable loss, there was no significant reduction on the reliability and robustness in both the two long-span bridges, i.e., they are very robust against single cable loss scenarios.