Ensuring Safety Against Catastrophic Failures

ARUNPRAKASH M. SHIROLÉ

The catastrophic collapse of the Silver Bridge in 1967 served as a rude awakening for bridge engineers in the United States. Since then, systematic bridge inventory and inspection programs have been initiated by agencies to evaluate the condition of bridge components. These programs have resulted in repair and rehabilitation activities that have eliminated or reduced condition-related deficiencies that can cause bridges to fail.

Catastrophic bridge failures, however, are not always due to deficiencies in condition. Most structures were not designed in anticipation of today's significantly different design loads and better knowledge of natural events. Design requirements and material characteristics once accepted as the state of the art have been demonstrated with time and further study to be undesirable. Therefore, bridges can be vulnerable to failure modes, such as hydraulic or seismic, unaccounted for in their design.

Current efforts under way in the United States have been addressing the comprehensive safety assurance needed to eliminate or reduce bridge vulnerabilities to catastrophic failure. A nationwide bridge failure survey conducted by the New York State Department of Transportation has identified six failure modes—hydraulic, collision, overloads, steel details, concrete details, and seismic—as most significant.

There are approximately 600,000 highway bridges in the United States, 20,000 in New York State alone, and not all of them are vulnerable to all failure modes. Clearly, for example, bridges not crossing water are not vulnerable to scour failure (hydraulic) or water vessel collision. Therefore, a multilevel vulnerability assessment is used in New York State to screen out from further investigation bridges meeting relevant criteria, and to classify the remaining bridges on the basis of their relative vulnerability (high, medium, or low) to particular failure modes. This process is applied for all failure modes, and provides a uniform measure of the likelihood of failure and its consequences for each structure. The likelihood of failure denotes the probability of external load conditions exceeding structural capacity, whereas the consequences of failure denote the impact in terms of loss of life, injury, traffic disruption, or economic loss. These vulnerability ratings will assist in determining the types of corrective action needed and their urgency. NYSDOT has rated most of its bridges for vulnerability to the hydraulic and steel details failure modes, and has included safety assurance as a component of its bridge management system.

The bridge vulnerability ratings will be used together with condition ratings in determining priorities and making programmatic decisions designed to ensure bridge safety against catastrophic bridge failures.

The author is executive director, National Steel Bridge Alliance.

the University of California, San Diego (UCSD) in the mid-1980s that resulted in the now widely used technology of strengthening bridge columns with external jackets.

The timeliness of this research was reemphasized by the Loma Prieta and Northridge earthquakes, which again revealed hinge confinement problems, column shear failure, and bond failures. The 1989 Loma Prieta earthquake resulted in an accelerated retrofit application program in which, as Phase II of the Caltrans bridge retrofit, primarily single-column bents were retrofitted with the UCSD-developed steel jacket technology. Retrofitting of the columns for increased ductility or strength also required that adjacent bridge members be strengthened based on capacity design principles to transfer the increased seismic column forces. For example, spread or pile footings originally built with only a bottom mat of reinforcement require additional piles and top reinforcement to develop the full moment capacity of the column. The success of the Phase II retrofit program became obvious during the 1994 Northridge earthquake. No significant damage to any of the Phase II retrofitted bridges was reported, even though 115 of these bridges were in areas where the ground motions exceeded 0.25 g, and 36 were in areas with ground motion estimates in excess of 0.5 g.

The retrofit technology development and implementation program continued at a rapid pace after the Loma Prieta and Northridge earthquakes. New column jacket technologies utilizing advanced composite (glass and carbon) jacketing systems were developed at UCSD. Numerous tests were con-