# SEISMIC DESIGN OF BRIDGES

During the past century, many countries around the globe have suffered from the devastating effects of massive and destructive earthquakes causing huge damages to property and more importantly, the loss of many precious lives. About 30 per cent area of India lies in high seismic zone and Himalayan region, Indo-Gangetic plain, Western India, Kutch and Kathiawar regions are geologically most unstable parts of the country, where some devastating earthquakes of the world have occurred. A large part of peninsular India has also been devastated by strong earthquakes in the past, in which a large number of structures, especially bridges have either suffered damages or have collapsed.

The bridges are a vital part of our road network to maintain connectivity and their damage and collapse results in loss of communication, life, property and also badly affect the relief and rehabilitation activities. It is, therefore, desirable that suitable seismic protection strategies in structural design of bridges be evolved, so that they can withstand the effects of strongest possible earthquakes without collapse or suffering excessive damages.

Nationally and internationally, current seismic design philosophy is based on the concept that bridges may suffer damage and may need to be replaced, but they should have low probabilities of collapse due to earthquake motions, so as to minimize the serious injuries and loss of life and property. The most significant aspect in design philosophy for bridges is a shift from a force-based assessment of seismic demand to a displacement-based assessment of demand and capacity. The former force approach was based on generating design level earthquake demands by reducing ultimate elastic response spectra forces by a reduction factor. The reduction factor was selected based on structure geometry, anticipated ductility, and acceptable risk. The newly adopted displacement approach is based on comparing the elastic displacement demand to the inelastic displacement capacity of the primary structural components while insuring a minimum level of inelastic capacity at all potential plastic hinge locations.

There is a marked difference in seismic design aspects of bridges and other civil engineering structures. The reduced degree of indeterminacy in bridges leads to reduced potential of dissipating energy and load redistribution. In bridges, the superstructure (piers, abutments and deck arrangement) is the main structural element which must be capable to provide resistance to seismic forces. This essentially means that the formation of plastic hinges or flexural yielding is allowed to occur in these elements during severe shaking to bring down the lateral design forces to acceptable levels. Since yielding would lead to damage, plastic hinging is localized by design at points accessible for inspection and repair, i.e. those parts of the substructure from foundation upwards. No plastic hinges are, of course, allowed to occur in the foundation or in the bridge deck. As we know that the abutment is an important component for dissipating the seismic energy, it has to be designed in longitudinal direction to resist forces elastically, utilizing the passive pressure of the backfill.

The seismic design criteria adopts a performance-based approach specifying minimum levels of structural system performance, component performance, analysis, and design practices for ordinary standard bridges. Bridges with non-standard features or operational requirements above and beyond the ordinary standard bridge may require a greater degree of attention. Generally, it is observed that seismic performance of structures is typically better for regular configurations and for evenly distributed stiffness and strength over the entire structure. It is also observed that typical geometric configurations such as skewness, unequal pier heights, and horizontally curved bridges conflict to some extent, with the standard seismic design goals. In foundation design, updated provisions incorporating both current practices and recent research results have to be used. The concept of capacity provisions has to be considered while designing as it specifically addresses to the issues of uplifting and yielding of the foundation.

Seismic isolation and energy dissipation systems are innovative strategies for the seismic design of bridges. Special devices are used to reduce the seismic forces in the bridge structures, like decoupling the structure from seismic ground motions, so as to reduce the earthquake-induced stresses in its members. This can be done by increasing natural period of the structure by base isolation and increasing damping of the system by energy dissipating devices. Active damping uses powered devices to apply forces to the structure to counteract vibrations. Passive damping relies on harnessing the movements of the structure to absorb energy.

Liquefaction has been one of the most significant causes of damage to bridge structures during past earthquakes. When liquefaction occurs during an earthquake, it causes vibrations and permanent ground movements simultaneously. Thus, in order to sustain this effect, special detailing requirements for steel components, which are expected to yield and dissipate energy in a stable and ductile manner during earthquakes, have to be developed. These may include provisions for ductile moment-resisting frame substructures, concentrically braced frame substructures, and end-diaphragms for steel girder and truss superstructures. The design approach should be based on use of deep foundations, such as piles or drilled shafts, as spread footing foundations will not typically be used when soil conditions lead to the possibility of liquefaction and associated lateral spreading or settlement.

With the occurrence of every major earthquake, there has been a world-wide tendency to increase the capacity demand of the structure to counteract such events. The current international practice has shifted towards a performance-based engineering design. It is, therefore, imperative that the Indian Seismic Codes should also reflect the current understanding on seismic protection of bridges.

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