Towards Displacement-Based Design in Seismic Design Codes

Seismic design philosophy has undergone many changes in the approximately 100 years since earthquakes were first considered as quantifiable design actions. Initially, a lateral force, typically of 10% of the structural weight was uniformly distributed up the height (for buildings) or along the length at deck level (for bridges). As the importance of elastic dynamic response and acceleration spectra became better understood, lateral force levels became period-dependent, and were approximately distributed in proportion to the fundamental mode shape of structural response. Distribution of lateral force through the structure was based on elastic material response. Later developments included multimodal considerations, the use of uniform-risk spectra to represent seismic hazard, and the concept of ductility to reduce the level of seismic design force, in recognition that structures were observed to survive levels of seismic intensity that clearly exceeded their elastic capacity. Capacity design was utilized to ensure that inelastic action only occurred at intended plastic hinges. Essentially, this brings us to the current state of seismic design philosophy, as embodied in codes. Elastic structural analysis and elastic acceleration spectra are still the basis for determining the distribution and magnitude of required member strength, despite the clear contradiction of such an approach with the actualities of the expected ductile, inelastic response.

The philosophical problems associated with the use of elastic characterization of the seismic hazard, and elastic structural analysis are well known and include, amongst others, gross errors in structural period determination, errors in estimating displacement response, poor distribution of seismic resistance between different lateral force resisting elements, and the invalid requirement that all structures of a similar basic structural form (e.g. all concrete frames) and detailing level should be designed for the same ductility (or behavior, or force-reduction) factor.

Recently, efforts have been made to eliminate the philosophical problems noted above by development of seismic design philosophy where displacement levels based on strain or drift limits (which can be directly related to damage potential) are the basis for determining the magnitude and distribution of seismic forces. Inelastic action is directly, rather than implicitly considered. Several papers in this issue examine aspects of displacement-based seismic design. Although the methodology has been used for design in many countries, with code compliance verified by non-linear time history analysis, further implementation has been hampered by the lack of codified design provisions. Although the design approach is simple and logical, implementation in design codes has in the past been slow, with exceptions being the development of displacement-based seismic design for marginal wharves in Los Angeles, for bridges in Australia and New Zealand (in draft form) and for buildings in Ecuador. It is time that efforts be accelerated to implement displacement-based design in major seismic design codes across the globe.

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