Hazard Assessment Methods for Large and Critical Infrastructure

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This presentation introduces the concept of hazard assessment and highlights key remaining technical issues and challenges for the design of critical infrastructure. The presentation is focused on seismic ground motion hazard assessment, which is used to introduce many important features common to assessment of different hazards such as landslides, storms, fault ruptures or tsunamis.

Seismic ground motions often control the design of critical facilities in many parts of the world and their assessment and quantification is essential to adequate design practices. The first element of ground motion assessment is a characterization of the fault rupture hazard in a given area, which is commonly based on geologic, geodetic or geophysics studies and the knowledge of past earthquake activity. The fault rupture hazard is compiled into a source model that includes the location, geometry, slip rate (displacement along a fault averaged over many years) and rate of occurrence of earthquakes of different magnitude on active faults. The second part of the ground motion assessment process requires ground motion models typically derived from past earthquake data, providing information such as the type of earthquake source, the effect of magnitude on ground motions, the attenuation and damping of seismic waves with distance and site effects due to the near-surface geological deposits. These models are usually referred to as ground-motion prediction equations (GMPEs) and are more easily developed for seismically active regions where there is enough data to constrain the variability. The source model and the GMPEs are used together to quantify the ground motions that can be expected at a site through a seismic hazard analysis (SHA) process.

The seismic ground motion hazard assessment at a site is primarily done in one of two ways. In the deterministic approach (DSHA), the hazard analyst selects a large plausible earthquake scenario near the site and ground motions are assessed using GMPEs. The "level" of ground motion (a certain percentile of the GMPE distribution) is often specified by a jurisdictional entity or a building-code type of requirement. The second approach is probabilistic (PSHA) and is based on the total probability theorem. PSHA combines the rates of earthquakes and GMPE distributions conditioned on a certain earthquake event occurring and sums all the rates for all the events in a region. PSHA results are summarized by hazard curves that relate the intensity of ground shaking to its mean rate of exceedance. Seismic design has typically been prescribed for the ground motion intensity corresponding to a certain probability of exceedance. This practice is changing through the advent of performance and risk-based approaches.

The presentation summarizes the two types of SHA and highlights current limitations and research needs. For both types of analyses, a main issue is often the lack of earthquake data, especially in regions with relatively low seismic activity rates. This is the case, for example, for the Central and Eastern North America (CENA) region where, although large earthquakes are relatively rare, they are to be expected and considered in the design of critical structures, such as nuclear power plants. The lack of data affects both the source model and the GMPE development. Because the quantified variability is translated into distributions, it affects both DSHA and PSHA results. For PSHA, it is especially important to better constrain the shape of the distributions. Insight into the problem and solutions considered for CENA are presented as an example.

The SHA approach is then generalized for other types of hazard, highlighting similarities in the assessment process.