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Seismic hazard assessment – a holistic micro zonation approach

Syed Salman Haider Rizvi, Jaya Srivastava

12/10, Ashirwaad enclave, Vasant Vihar, Dehradun-248006

Presenting author, E-mail: *slmnhdr@gmail.com*

Abstract

In this paper, attempts have been made on the probable mitigation and management issues of seismic hazard necessitate seismic micro zonation for hazard and risk assessment at the local level. Such studies are preceded with those at a regional level. A comprehensive framework, therefore, encompasses several phases from information compilations and data recording to analyses and interpretations. The state-of-the-art methodologies involve multi-disciplinary approaches namely geological, seismological, and geotechnical methods delivering multiple perspectives on the prevailing hazard in terms of geology and geomorphology, strong ground motion, site amplification, site classifications, soil liquefaction potential, landslide susceptibility, and predominant frequency. The composite hazard is assessed accounting for all the potential hazard attributing features with relative rankings in a logic tree, fuzzy set or hierarchical concept.

Introduction

Socio-economic and environmental impacts are implicit in the scientific and technological aspects towards the mitigation and management of seismic hazards outlining well defined objectives: (i) evaluation of earthquake and related hazards, (ii) standardization of a global implementation scheme to facilitate uniform action plans towards adapting urbanization regulations and codes for design and constructions practices, and (iii) seismic vulnerability assessment, and risk prognosis to enable preventive measures against the hazard. The seismic hazard defines the potentially damaging ground shaking in terms of peak ground acceleration (PGA), peak ground velocity (PGV), and/or peak ground displacement (PGD). The quantitative assessment can be achieved either through a deterministic or probabilistic approach, the former delivers absolute values, while the latter estimates the same in terms of probability of non-exceedance corresponding to a certain determined level at a site of interest. A quasi-deterministic or quasi-probabilistic approach employs a hybrid seismological, geological, geomorphological, and geo-technically guided framework wherein all the potential hazard attributing features are considered with relative rankings in a logic tree, fuzzy set, or hierarchical concept. Regional hazard zonation do not incorporate local and secondary effects induced by the earthquakes leading to its infeasibility in land use development and planning, hazard mitigation and management, and structural engineering applications at site-specific terms. It is necessary to overcome these limitations, especially in the highly populated urban centers with unplanned urbanization practices in vogue. Seismic micro zonation is, therefore, envisaged to subdivide a region into sub-regions in which different safeguards must be applied to reduce, and/or prevent damages, loss of life and societal disruptions; in case a large devastating earthquake strikes the region. It involves prediction of the hazard at much intrinsic scale with enhanced resolution and greater precision (say, from 1:50 000 to 1:25 000, 1:10 000, or 1:5 000 scales).

A micro zonation project extends from elementary to exhaustive data analyses involving innumerous technical aspects underlying the knowledge base with methodological diversity, but culminating ultimately into recommendations defining constraints on the national/global regulations with local ones.

Experimental Details

1) Micro zonation framework
   A seismic micro zonation process is initiated with rudimentary assessments based on existing regional level hazard estimation, seism tectonic and macro-seismic studies. Several local specific hazard factors are, thereafter, evaluated and mapped on a Geographical Information System (GIS) platform with a uniform and consistent georeferencing scheme.
2) Regional Assessment
   The regional level analysis encompasses the seismicity, seismic sources, and earthquake potential based on available historical and instrumental data covering hundreds of years,
   Micro- and macro-seismicity, regional tectonics and neotectonics (faults/lineaments network), seism tectonics, geology, geo-hydrology, crustal structure, landslides incidents,
   Observed soil liquefactions, etc.
3) Local Specific Assessment
   - The geology and geomorphology serves as a significant attribute towards seismic ground motion depiction at a site of interest.
   - The shear wave velocity profile of soil column is used for site response modeling as well as site classification adhering to National Earthquake Hazard Reduction Program (NEHRP, Building Seismic Safety Council 2001) and Uniform Building Code (UBC, ICBO 1994) terminology.
   - The site amplification of ground motion is primarily attributed to either the geomorphological features that produce scattering, focusing, or defocusing of incident energy (topographic effect) or thick alluvium-filled terrain that causes reverberations due to trapped energy (basin effect).
   - The predominant frequency corresponds to the maximum amplitudes of the ground motion in frequency domain. The proximity of predominant frequency of the soil layers and natural frequency of the buildings indicate higher vulnerability of the built-environment owing to resonance effects.
   - The quantitative assessment of seismic hazard necessitates measurement of peak ground motion parameter (e.g. PGA) from earthquake records.
   - The rapid estimations of the ground motion parameters at a site of interest are often achieved by using a ground motion prediction relationship that relates a specific strong ground motion parameter of ground shaking to one or more attributes of an earthquake.
   - Probabilistic Seismic Hazard Assessment (PSHA) incorporates uncertainty and the probability of earthquake. Four steps of probabilistic seismic hazard analysis

currences delivering the hazard in probability of nonexceedance (or exceedance) for a specified return period.

4) Induced hazard assessments
    - The secondary phenomena associated with ground shaking include ground spreading, slumping, soil liquefaction, landslide, rock falls, etc., that contributes to the overall seismic risk.
    - Soil liquefaction is triggered when loose or soft saturated unconsolidated soil transforms from a solid state to a viscous state due to the increase in pore water pressure and consequent decrease of effective stress.
    - Earthquakes can activate slope failures in the undulating terrains leading to landslides with catastrophic effects. These depend on several factors inherent to the soil conditions such as geology, hydro-geology, topography, and slope stability.
    - Site class specifications are employed to characterize generic subsurface conditions towards seismic response of the soil.
5) Composite hazard evaluation
    The composite hazard assessment incorporates multiple attributes through multi-criteria evaluation technique for the spatial delineation.

Conclusion

Soil liquefaction is one of the determinant geotechnical hazard especially in the regions previously of natural water and swampy tracts because it is connected to loose soil and geohydrological conditions. On the other hand overburden thickness of soil is one the specific hazard influenced by the geotechnical and geological conditions. The seismic micro zonation has emerged as an important issue in high risk urban centers across the globe. The compilation of data pertaining to geological, geophysical, geotechnical and seismological aspects comprises a major part of the venture, which necessitates a consortium of several public and private organizations engaged in diversified but related domains. The effort towards enhancing our understanding of the seismic hazard and related effects is an on-going process, and therefore, the framework and tools for the seismic micro zonation studies presented here needs to be continuously updated in the light of ongoing advancements as well as experiences gained during earthquakes. It is expected that seismic micro zonation will enable updating building codes as well as formulate actions for hazard mitigation at sub-regional and local levels. Active programs related to infrastructural improvements and response planning can led to reduction of seismic risk.