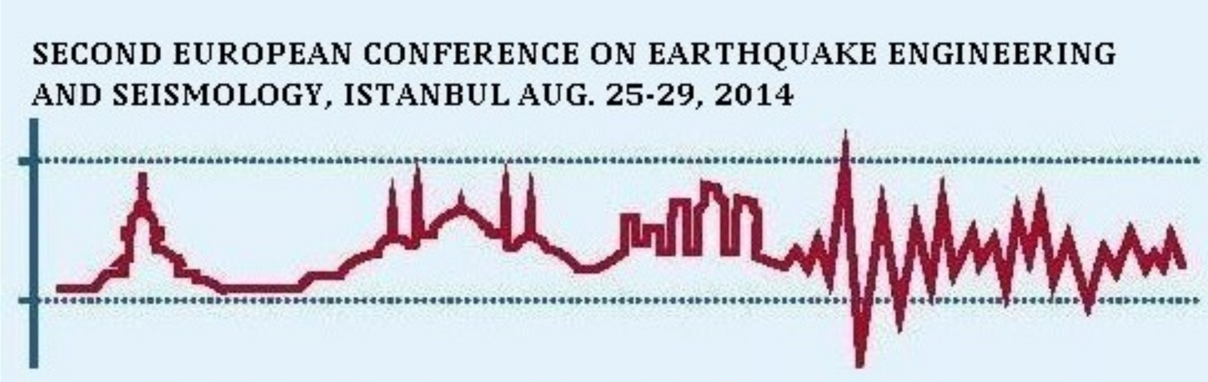

UNDERSTANDING SEISMIC HAZARD NEEDS FOR INFRASTRUCTURE RISK ANALYSIS: LESSONS FROM SYNER-G

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The potential impact that infrastructural failures may have on both the social and economic losses from earthquakes, as well as in post-disaster response and recovery, have been clearly seen in recent damaging earthquakes such as Haiti (2010) (e.g. DesRoches et al., 2011) or Christchurch (2011) (e.g. Giovinazzi et al., 2011). A comprehensive understanding of the potential losses that may be faced from future earthquakes in a region cannot be gained without consideration of the seismic risk to different infrastructures or utility systems and their potential interactions. Whilst analysis of seismic hazard and risk for site-specific structures is a somewhat well established methodology, the application in an infrastructural risk context presents several new challenges. An investigation of the methods to address them is one of the outcomes of the SYNER-G project, and related implications may be relevant for seismic risk analysis of spatially distributed systems, including critical infrastructures.

Analysis of seismic risk to spatially distributed, and inter-connected, systems generates a new set of requirements from the hazard analysis. To undertake a probabilistic seismic risk analysis for an infrastructure system, seismic hazard analysis must take into account the following:

i) aleatory uncertainty in the characteristics of the seismic source, the attenuation of ground motion and amplification due to local geological conditions;
ii) spatial correlation in the ground motion, or, more specifically, the spatial variability of intra-event residuals of ground motion intensities (IMs) across a spatially distributed set of locations;
iii) spatial cross-correlation amongst different IMs, for the purposes of adopting different IMs in the modelling of seismic fragility of different elements of the systems;
iv) potential for, and extent of, geotechnical failure (i.e., permanent ground deformation) due to one or more phenomena, including liquefaction, slope displacement or co-seismic fault rupture.
v) the means of characterising both transient ground motion hazard and permanent ground deformation occurring within the same event.

To fulfil these requirements in a probabilistic context, in the SYNER-G project the aleatory uncertainty was modelled using Monte Carlo simulation. From the input seismic hazard model a synthetic set of earthquakes is simulated, and for each of these earthquakes a realisation of ground motion fields (corresponding to each IM required for the risk analysis) is generated. In this process the

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spatial correlation (within each field) and spatial cross-correlation (between fields of different IMs) is taken into account. Models of spatial correlation and cross-correlation derived from European and Italian strong motion records (Esposito and Iervolino, 2011; 2012) were adopted to describe the spatial correlation structure of the transient ground shaking hazard.

The incorporation of geotechnical hazard in the context of seismic risk to a spatially distributed infrastructure requires that detail in the level of geotechnical characterisation be counter-balanced by the feasibility of implementation over an urban, and possibly regional, scale. In the SYNER-G approach, the slope displacement and liquefaction susceptibility classifications of HAZUS (NIBS, 2004) were adopted and subsequently modified with updated empirical displacement models, where available. The SYNER-G approach differs from previous application, however, as the respective probabilities of ground deformation are then sampled in order to generate random realisations of permanent displacement for each event. For co-seismic fault rupture, a Monte Carlo based probabilistic fault displacement hazard method was adopted, ensuring that co-seismic displacement on any given event refers to the same rupture used to generate the ground motion field.

These hazard calculators, both in terms of the ground shaking and the geotechnical hazard, may form the initial step toward understanding, and modelling, the hazard requirements for infrastructure risk. Nevertheless, they still are simplifications of the earthquake process, and critical issues such as uncertainty and spatial correlations in permanent ground deformation, or the potential impact of near-source effects, or the modelling of seismic sequences, require further research in order to incorporate them into the modelling process. As understanding infrastructure risk assumes a greater role in effective seismic risk mitigation, the need to improve such modelling process in a manner that is practical on a larger spatial scale, is paramount. Future studies of seismic risk will require that the hazard input model address some of the issues raised in this work, and further research will be needed to better constrain empirical and/or physical models of ground shaking and permanent displacement that underpin this effort.

REFERENCES

DesRoches R, Comerio M, Eberhard M, Mooney W, Rix GJ (2011) "Overview of the 2010 Haiti Earthquake," *Earthquake Spectra*, 27(S1): S1 – S21

Esposito S and Iervolino I (2011) "PGA and PGV spatial correlation models based on European multievent datasets," *Bulletin of the Seismological Society of America*, 101(5): 2532 – 2541

Esposito S and Iervolino I (2012) "Spatial correlation of spectral acceleration in European data," *Bulletin of the Seismological Society of America* 102(6): 2781 – 2788

Giovinazzi S, Wilson T, Davis C, Bristow D, Gallagher M, Schofield A, Villemure M, Eidinger J, Tang A (2011) "Lifelines Performance and Management Following the 22 February 2011 Christchurch Earthquake, New Zealand: Highlights of Resilience," *Bulletin of the New Zealand Society for Earthquake Engineering,* 44(4): 402 – 417

National Institute for Building Sciences (NIBS) (2004) HAZUS-MH Technical Manual, Technical Report, Federal Emergency Management Agency (FEMA), Washington D.C., United States