Seismic hazard and public safety

a cura di W. Marzocchi, pubblicato su EOS Vol. 94, No. 27, 2 July 2013

The recent destructive earthquakes in Wenchuan (China), L'Aquila (Italy), Port-au-Prince (Haiti), Christchurch (New Zealand), and Tohoku (Japan) have reignited the discussion over seismic safety. Several scientists [e.g., Stein et al., 2012; Wyss et al., 2012] have questioned the reliability of some seismic hazard maps based on the probabilistic seismic hazard analysis (PSHA)—a widely used probabilistic approach that estimates the likelihood of various levels of ground shaking occurring at a given location in a given future time period—raising an intense discussion on this specific point [Hanks et al., 2012; Frankel, 2013; Stein et al., 2013].

A profound misconception about PSHA has been made by some scientists [International Seismic Safety Organization, 2012; Wyss et al., 2012; Peresan and Panza, 2012], who have claimed that the probabilistic approach is unacceptable for public safety policy and that citizens have to be protected against the maximum credible earthquake (MCE) no matter how infrequent it may be. Specifically, they propose to replace PSHA with the so-called neo-deterministic seismic hazard assessment (NDSHA), which consists of an MCE-based hazard scenario (hereafter, MCE scenario). This approach has been described in Panza et al. [2012] and references therein, and it has been proposed to the Italian government as a procedure to define the building code in Italy (http://leg16.camera.it/126?tab=2 &leg=16&idDocumento=5512&sede=&tipo=).

Despite the apparent attractiveness of this simple concept, i.e., protecting people against MCE, I argue that the use of NDSHA to define the building code seismic loading may lead to conceptual drawbacks that are an obstacle to fair decision making. Notably, the same arguments may also be used to dispute the use of the MCE scenario for planning risk mitigation strategies in other natural hazards.

The use of MCE can be criticized on physical grounds. The occurrence of several recent earthquakes (El Mayor–Cucapah in Mexico, Tohoku in Japan, and Christchurch in New Zealand) has clearly demonstrated the difficulty in defining a reliable MCE. Allen [1995, p. 364] described MCE as "the earthquake which is only a shade smaller than the minimum incredible earthquake." This tongue-in-cheek definition highlights the basic difficulty in rigorously defining the MCE concept. The concept becomes even more problematic if we consider the maxi- mum credible ground motion (which is more important for seismic safety), noting that accelerations twice that of gravity were recorded in the magnitude 6.3 Christchurch earthquake of February 2011. The very large uncertainties in defining MCE are usually neglected in setting the MCE scenario, and in general, many uncertainties are not included in the calculation.

In his paper, Allen [1995] also pointed out that the definition of MCE must implicitly assume (more or less consciously) a time window; for example, MCE is the largest earthquake expected in one region during the current tectonic regime. The existence of a time window creates a strong link between the MCE scenario and PSHA. One can interpret the MCE time window as the "return period" of PSHA [Hanks and Cornell, 1994] and thereby discover the primary practical difference between the MCE scenario and PSHA: What is the time frame of interest for risk reduction? In the MCE scenario, one implicitly defines a single very long return period (or, equivalently, a very low exceedance probability) to be used for seismic design load (building code). In PSHA, one is free to choose any return period for the building code. In PSHA practice, the choice of the critical return period is made by decision makers, not by seismologists.

In other words, the MCE scenario implicitly attributes the role of defining the acceptable risk to seismologists. There are good reasons for scientists to avoid this role [e.g., Jordan et al., 2011; Marzocchi et al., 2012; Geller et al., 2013]. The definition of any threshold for decision making, such as specifying a return period that defines the acceptable risk, requires competences not typically held by scientists, including careful analysis of costs and benefits, of political consequences, and of feasibility. This difference in roles is of pivotal importance, but it is still often neglected in practice. Scientists frequently advise decision makers, but the role and responsibility of scientists in the decision making process is often unclear. We need to clarify these roles and responsibilities; the recent conviction of seven scientists and decision makers after the L'Aquila earthquake emphasizes the importance of this need [Marzocchi, 2012].

It is our duty as scientists to estimate hazard with pure intentions remaining focused only on describing the natural process; we must not allow the implied risk to affect our hazard estimates. Decision makers (engineers, public officials, etc.) have to make choices taking into account the scientific output and carefully weighing costs and benefits of each mitigation action (such as the definition of an appropriate building code), as well as considering the political and practical needs. Of course, despite this strict separation in their roles, scientists and decision makers have to work together to prepare transparent and coherent decision-making protocols; these protocols should establish the right balance between the decision makers' needs and what scientists may (and may not) offer.

It is also noteworthy that, besides attributing the role of decision makers to seismologists, the use of the MCE scenario may lead to unethical and/or irrational decision making. Some seismologists have claimed that the use of the MCE scenario is desirable because it encompasses the precautionary principle, which states that action should be taken if there is a possible risk of harm, independent of its likelihood. While this principle is often adopted by decision makers in many real situations, it cannot be straightforwardly applied in cases where the likelihood of false alarm and the cost of mitigation actions are large [e.g., Marzocchi et al., 2012], and it may lead to untenable decision making.

The problem comes from the fact that in most real cases, there is a finite budget for reducing risks, so any money spent to reduce earthquake risk would take away from funding available to reduce other risks. Using an MCE scenario, citizens living in areas where the return period of seismic events is long could be aggrieved if a lot of money is spent to mitigate a small risk (the seismic one) and few resources are left for mitigating a greater risk. For example, a magnitude 6 earthquake with an epicenter under London is possible, with an extremely long return period, but there are no seismic code requirements in London. Any earthquake protection expenditure would unnecessarily diminish funding for upgrading flood protection, which is by far the greatest natural hazard threat to London, especially with climate change. To summarize, rational decision making must consider the return period of threatening events, and it must find a balanced strategy to spend the available funds for reducing risks, taking into account all hazards that threaten the area under study.

Furthermore, the implementation of MCE would convey a misleading message to citizens, i.e., that they can be fully protected against earthquakes. However, surprises always remain possible. Moreover, the vulnerability of edifices can be defined only in probabilistic terms because it is impossible to predict with certainty the behavior of a structure when significant loads are applied. In this respect, a probabilistic approach for hazard and risk is more honest because it recognizes that full protection is not always possible.

A final consideration derives from Italian experience. Some criticisms of PSHA are often based on the fallacy that earthquakes caused casualties because the seismic building code was wrong. This is not necessarily true. In Italy, to my knowledge, the last two earthquakes (L'Aquila, 2009, and Emilia, 2012) did not cause any casualties among people living in structures constructed according to the present building code. On the contrary, all casualties were caused by the collapse of edifices that did not respect the actual building code or that were built badly. Sooner or later, the building code will be revised; how- ever, from these experiences, engineers and decision makers should ask themselves if, as the first priority, it is wiser to make the code provisions for new buildings more stringent or to enforce the actual building code and to spend money to retrofit buildings.

References

Allen, C. R. (1995), Earthquake hazard assessment: Has our approach been modified in the light of recent earthquakes?, Earthquake Spectra, 11, 357–366.

Frankel, A. (2013), Comment on "Why earthquake hazard maps often fail and what to do about it" by S. Stein, R. Geller, and M. Liu, Tectonophysics, 592, 200–206, doi:10.1016/j.tecto.2012.11.032.

Geller, R., W. Epstein, and J. Noeggerath (2013), Fukushima—Two years later, Seismol. Res. Lett., 84, 1–3.

Hanks, T. C., and C. A. Cornell (1994), Probabilis- tic seismic hazard analysis: A beginner's guide, in Proceedings of the Fifth Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping, pp. I/1-1–I/1-17, N. C. State Univ., Raleigh. Hanks, T. C., G. C. Beroza, and S. Toda (2012), Have recent earthquakes exposed flaws in or misunderstandings of probabilistic seismic hazard analysis?, Seismol. Res. Lett., 83, 759–764.

International Seismic Safety Organization (2012), Position statement on earthquake hazard assessment and design load for public safety, Arista, Italy. [Available at http://www.assisi - antiseismicsystems.org/Territorial/GLIS/ Glisnews/PositionStatementFirstEdition-ISSO_6Aug2012.pdf.]

Jordan, T. H., Y.-T. Chen, P. Gasparini, R. Madar- iaga, I. Main, W. Marzocchi, G. Papadopoulos, G. Sobolev, K. Yamaoka, and J. Zschau (2011), Operational earthquake forecasting: State of knowledge and guidelines for utilization, Ann. Geophys., 54, 315–391.

Marzocchi, W. (2012), Putting science on trial, Phys. World, December, 17–18.

Marzocchi, W., C. G. Newhall, and G. Woo (2012), The scientific management of volcanic crises, J. Volcanol. Geotherm. Res., 247–248, 181–189.

Panza, G. F., C. La Mura, A. Peresan, F. Romanelli, and F. Vaccari (2012), Seismic hazard scenarios as preventive tools for a disaster resilient society, Adv. Geophys., 53, 93–165.

Peresan, A., and G. F. Panza (2012), Improving earthquake hazard assessment in Italy: An alternative to "Texas sharpshooting," Eos Trans. AGU, 93(51), 538–539, doi:10.1029/2012EO510009.

Stein, S., R. Geller, and M. Liu (2012), Why earth- quake hazard maps often fail and what to do about it, Tectonophysics, 562–563, 1–25.

Stein, S., R. Geller, and M. Liu (2013), Reply to comment by Arthur Frankel on "Why earthquake hazard maps often fail and what to do about it", Tectonophysics, 592, 207–209, doi:10.1016/ j.tecto.2013.01.024.

Wyss, M., A. Nekrasova, and V. Kossobokov (2012), Errors in expected human losses due to incorrect seismic hazard estimates, Nat. Hazards, 62, 927–935.