POSITION STATEMENT ON EARTHQUAKE HAZARD ASSESSMENT AND DESIGN LOAD FOR PUBLIC SAFETY

by

International Seismic Safety Organization (ISSO)

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Summary

In view of the devastation produced by large earthquakes and associated phenomena exemplified by the 2004 Sumatra earthquake and tsunamis, the 2008 Wenchuan earthquake in China, the 2010 Haiti earthquake, and the 2011 Tohoku earthquake and tsunamis in Japan, it is imperative that structures should be designed and constructed to withstand the largest or Maximum Credible Earthquake (MCE) events that include or exceed such historic events; and the public should be advised to be prepared and ready for such possible events beforehand. These are the most dangerous and destructive events that can happen at any time regardless of their low frequencies or long recurrence intervals. Therefore, earthquake hazard assessment to determine seismic design loads should consider the MCE events. Emergency management policy should consider scenarios for possible MCE events.

The traditional Deterministic Seismic Hazard Analysis (DSHA) using MCE has been successfully used for determining seismic design loads in California with confidence since the early 1970's to the present time and its enhanced variation, neo-DSHA (NDSHA), published in 2001 for Italy, has proved reliable when its estimates were compared with actual data for the most recent Northern Italy May 2012 earthquakes. Therefore, DSHA or NDSHA should be used for public safety policy and determining design loads.

The current Probabilistic Seismic Hazard Analysis (PSHA) approach is unacceptable for public safety policy and determining design loads for the following reasons:

(1) Many recent destructive earthquakes have exceeded the levels of ground motion estimates based on PSHA and shown on the current global seismic hazard map. Seismic hazards have been underestimated here.

(2) In contrast, ground motion estimates based on the highest level of PSHA application for nuclear facilities (e.g., the Yucca Mountain site in USA and sites in Europe for the PEGASOS project) are unrealistically high as is well known. Seismic hazards have been overestimated here.

(3) Several recent publications have identified the fundamental flaws (i.e., incorrect mathematics and invalid assumptions) in PSHA, and have shown that the result is just a numerical creation with no physical reality. That is, seismic hazards have been incorrectly estimated.

The above points are inherent problems with PSHA indicating that the result is not reliable, not consistent, and not meaningful physically. The DSHA produces realistic, consistent and meaningful results established by its long practice and therefore, it is essential that DSHA and its enhanced NDSHA should be adopted for public safety policy and for determining design loads.

Seismic sources that most impact the site should be used for designing strategic and public buildings as well as critical structures. Seismic sources that most impact a region should be used for emergency management for that region. Such considerations would reduce the risk of large devastation and loss of human life in future earthquakes, and should be used for all critical cases to secure public safety.

Critical cases would include situations where the consequences of failure (i.e., risks) are too costly and intolerable as illustrated below by some recent examples.

Assessment and communicating of hazard and risk

The “level” of risk is directly related to the “severity” of the hazardous event when all other factors are fixed. That hazardous event when based on a realistic earthquake scenario such as MCE magnitude, automatically considers all potential cascading hazards, and its application ensures public safety and structural integrity.

The determination of MCE magnitude is time-independent or time-invariant, and magnitude estimates are both robust and reliable, as demonstrated during its continuous use in California from the early 1970’s to the present. This is advantageous over PSHA for determining seismic design load because it will not depend on recurrence intervals and return periods; it will be applicable for any design, economic, or useful life of structures.

Note that when an earthquake with a certain magnitude occurs, it causes a specific ground shaking hazard that does not take into account whether the event is rare or not. Therefore, ground motion hazard parameters for risk mitigation should not be scaled by the occurrence frequency or sporadicity (irregularity, aperiodicity, etc) of earthquakes but by using realistic scenario earthquake such as MCE based on the analysis of earthquake history, earthquake prone areas and seismogenic faults identified through morphostructural analysis.

Site hazards generated by earthquakes from seismic sources are discrete and can be “compared” to determine the governing sources. Therefore, comparison (and not addition) of seismic hazards from sources must be used to find the governing sources for applications.

Seismic hazard analysis should be transparent and physically tractable, and not overly complex. This is important not only for the analyst but also to effectively communicate hazard information to the users and stake-holders. The result must be used with professional judgment.

When a scientific understanding is inconclusive for example, determining ongoing events as foreshocks to main earthquake or otherwise, the assessed hazard must “always” be on the conservative side as a precaution for public safety - a must and non-negotiable policy from anthropocentric and benefit-cost perspectives.

It would be far costlier the consequences of many deaths than being warned and preparing for the "main" event, even when it may not occur. This has been the case of the April 2009 L'Aquila earthquake, when the public could be advised and prepared for an earthquake that was not possible to exclude, whereby many died in that moderate earthquake.

Therefore, it should be the operative rule for advising the public, without alarming, and to be alert and prepared for the possibility of the largest potential earthquake. Using a long recurrence interval or low frequency argument as a basis for "improbable" earthquake leads to a false and unjustified sense of security. As demonstrated by the L'Aquila and Tohoku earthquakes, the low probability associated with their occurrence did not preclude those events with disastrous consequences.

It would be much more prudent for society to pay a modest increased cost or suffer inconveniences in preparing for the consequences of MCE events than suffer irreparable loss by ignoring or under-estimating potentially catastrophic hazardous events. This concept is rational and reasonable for civilized society when the consequences of failure (i.e., risks) are too costly and intolerable.

Communicating hazard and risk assessment information to the public must be clear and meaningful for appropriate actions. This can be done well with seismic hazard based on DSHA or NDSHA as they are easily understandable, transparent and physically tractable. That is a problem with that based on PSHA because it is abstract and simply a numerical creation that cannot be related to physical reality.

Emergency warning failures are unavoidable and can be improved with experience and new technologies.

<u>Some recent examples demonstrating advantages in using the DSHA or NDSHA approach</u>

1. L'Aquila earthquake, Italy: 2009 April 6 (M6.3)

The indictment of the Italian Major Risks Commission (Commissione Grandi Rischi or CGR) on resulting death and great destruction caused by only a moderate, magnitude (6.3) L'Aquila earthquake was not because of "failure to predict the earthquake" as circulated widely by certain leading organizations but for miscommunicating the associated risk and underestimating the anticipated earthquake hazard. Although seismic hazards and the risk in L'Aquila were already known to be very high, the CGR came to conclude that a larger earthquake was "improbable", overlooking and even in direct contradiction and scientific betrayal of their knowledge.

Repetitions of such situation are unacceptable. Regardless of how long is the recurrence interval of a large earthquake, the consequences from a possible seismic event should always be considered; specifically (a) the largest earthquake that can be expected, (b) the strongest one that can scientifically be assessed, or (c) at the very least, the size of the strongest one that has happened in the past. The risk due to such events must be communicated to the public for appropriate consideration.

Had the existing (since 2000) hazard computation based on NDSHA using the MCE magnitude for the L'Aquila earthquake source (in light of our understanding of regional geology, historic seismicity, and morphostructural analysis) been used, it could have helped to reduce the humanitarian disaster considerably.

2. Tohoku earthquake, Japan: 2011 March 11 (M9)
The Fukushima nuclear power plant suffered spectacular damage resulting from the 14 meter high tsunami triggered by the subduction zone megathrust earthquake. The facility was designed for a 5.2-meter tsunami, based on a probable earthquake event of magnitude 8-1/2, and was subsequently damaged. The tsunamis with run-up height up to 40-meter from this earthquake and other historic cases were a matter of record along the eastern coasts of the Japanese islands. Therefore, probability or frequency of event as currently used do not adequately assessed the size of such hazardous source and thus under-estimate the risk. The use of the strongest case that can be scientifically assessed must have been applied for the design of the nuclear power plant to avoid or reduce potential catastrophic disasters as was actually experienced.

Had the MCE magnitude of M9+ and the associated tsunamis been used beforehand for the design of the above nuclear power plant, it would definitely have helped to reduce considerably the damage caused by this mega earthquake. It makes sense for securing public and economic safety to use a realistic and prudent seismic hazard assessment based on DSHA or NDSHA for such critical structures.

3. Emilia earthquake, Italy: 2012 May 20 (M5.9)
The PSHA map, at bedrock, on which the Italian building code is based, indicates that the epicentral area is designated in the third category with a peak ground acceleration (PGA) <0.175g. In contrast, the NDSHA map, at bedrock, published for the first time in 2001, indicates design PGA values in the range [0.15g-0.30g] which brackets and is in good agreement with actual recorded values of 0.25g. The NDSHA map, as superior and realistic, may become a better basis for developing building code in Italy and other seismic regions of the world.

Note that a series of magnitude 5 or more earthquakes that followed on May 29th in the same area were even more deadly than the shock on May 20, possibly a result of the weakened condition of damaged buildings, other destabilized construction, hour of a day that the aftershocks occurred and their different hypocentral positions.

Conclusions

To ensure public safety and designing structures to withstand future earthquakes, earthquake hazard generated by MCE that exceeds all other events based on DSHA and NDSHA should be used for emergency management policy and determining design loads. The DSHA is transparent, robust, and has a relatively long record of reliable performance.

There are compelling reasons to justify that earthquake hazard assessment based on PSHA is unacceptable for both establishing public safety policy and determining seismic design loads.

PSHA produced inconsistent results and it is just a numerical creation without physical reality. DSHA and NDSHA produced consistent and realistic results.

The DSHA and NDSHA are transparent and can be communicated to the public in clear and understandable ways, whereas PSHA is complex, abstract, not transparent and difficult to communicate to the public.

The NDSHA demonstrates its reliability and superiority over PSHA in the most recent Northern Italy May 2012 earthquakes, and may become a better basis for developing building code in Italy and other seismic regions of the world.

Emergency warning failures are unavoidable and can be improved with experience and new technologies.

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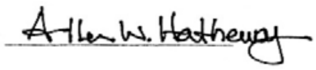

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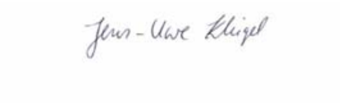

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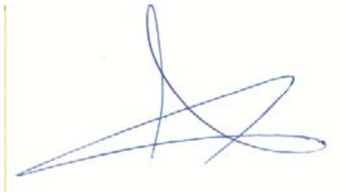

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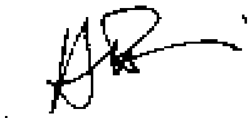

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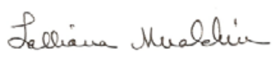

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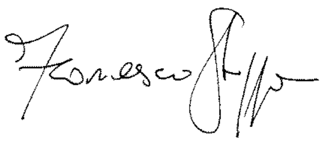

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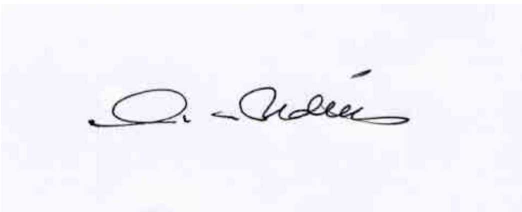

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