African Seismological Commission (AfSC) - Asian Seismological Commission (ASC)

Preparatory Joint Working Group on Neo-Deterministic Seismic Hazard Assessment (pJWG NDSHA)

Newsletters

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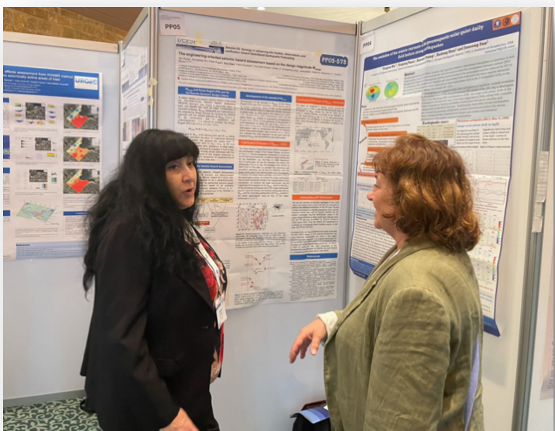
More reliable physics in seismic hazard assessment (SHA) for disaster risk reduction (DRR)

(More reliable physics in SHA for DRR)

This issue

JWG members took part in the 39th General Assembly (GA) of the European Seismological Commission (ESC)

On September 22~27, 2024, the 39th General Assembly (GA) of the European Seismological Commission (ESC) was held in Corfu, Greece. Some JWG members took part in the GA on site, and gave oral/poster presentation. Prof. Antonella Peresan is one of the conveners of Session 13, “New data and methods for earthquake risk assessment: Statistical models and machine learning tools applied to ground and satellite data (Part 2)”, and Session 02, “Sinergy in advancing the models, observations, and verification toward Operational Earthquake Forecasting (Part 2)”. She also gave the presentation titled as “An approach to rockfall hazard scenarios based on earthquake ground motion modelling”, and the presentation of the paper "Ground Motion Forecasting for the 2023 Al Haouz and 2004 Al Hoceima Earthquakes in Morocco: insights from Maximum Considered Earthquake concept and Mdesign definition" by Hassan et al. With the help of engineering seismologist Prof. Kun Chen, the poster from Dr. Yan Zhang and his colleagues was also shown in the conference.



Prof. Antonella Peresan while illustrating the poster related to JWG

Prof. Antonella Peresan and Prof. Kun Chen

ESC2024 22-27 September 2024 www.escgreece2024.eu

Session 02: Synergy in advancing the models, observations, and verification toward Operational Earthquake Forecasting

PP05-573

The engineering oriented seismic hazard assessment based on the design magnitude M_{design}

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M_{design} and Panza-Rugarli (PR) Law for Earthquake Resistant Design Criteria

$$M_{design}=M_{max}+\gamma_{EM}\sigma_M$$

To obtain reliable and realistic seismic hazard in key areas, the Neo-deterministic Seismic Hazard Assessment (NDSHA) approach considers the Maximum Credible Magnitude (M_{design}) of all potential earthquake sources that may impact a populated region or even one specific site: such as major infrastructure or important buildings. M_{design} safeguards are implemented in the engineering-design process by combining the NDSHA (M_{max}) approach (Figure 1) with codified definition of M_{design}, where: γ_{EM}=Magnitude Safety Factor, and σ_M= the global standard deviation of magnitude estimate (σ_M=1/4). To be conservative and in agreement with uniformitarianism, it is natural to consider the Panza-Rugarli (PR) Law (Wang and Wen, 2024). In such a way, M_{design} = M_{max}+0.7, is formally strictly connected with the upper magnitude bound of the largest observed or estimated (e.g., pattern recognition or morphostructural zonation) magnitude in any study area.

Neo-deterministic Seismic Hazard Assessment

The Neo-deterministic Seismic Hazard Assessment (NDSHA) utilizes physics-based computations to generate scenario earthquakes over a gridded pattern of node sites. By utilizing all available geophysical-geological-tectonic datasets, this physics-based multi-disciplinary approach is more comprehensive and reliable in the evaluation of seismic hazard (Panza et al., 2022). Figure 1 shows the procedures of the NDSHA in which the role of M_{design} is highlighted.

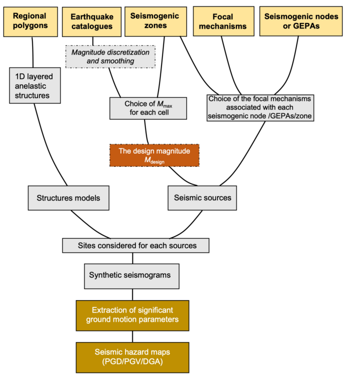

Figure 1 Schematic diagram of Neo-deterministic Seismic Hazard Assessment (NDSHA) based on regional polygons with structural models, earthquake catalogues, seismogenic zones, focal mechanisms and seismogenic nodes/GEPAs with magnitude defined by the design magnitude M_{design}.

NDSHA

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Development of the concept of M_{design}

Development of the concept of M_{design}, or the Panza-Rugarli (PR) Law (Wen and Wang, 2024), can be outlined by several milestones, which include: (a) the systematic use of the central value of magnitude standard deviation at global scale, σ_M, that varies in the range 0.2-0.3 (Båth, 1973; Borman et al. 2007; Kossobokov, 2007); (b) the safety factor γ_{EM} rooted in engineering considerations (Rugarli et al., 2019); (c) the application of the principle of uniformitarianism to clarify the role of M_{max} (Panza and Bela, 2020; Panza et al., 2022); (d) the introduction of the seismogenic node to compensate the lack of historical and/or paleo-seismological data (Gorshkov et al., 2003), and, probably the most important; (e) the point that the proposed M_{design} can be falsified by real earthquakes.

Falsification/Verification of M_{design}: CSES

The China Seismic Experimental Site (CSES) region is located in the southeastern margin of the Tibetan Plateau, as shown in Figure 2. Pseudo-prospective falsification is conducted by the following procedures: (a) select a target earthquake for the falsification, e.g., the May 12, 2008 Wenchuan M_W7.8 earthquake; (b) use the catalogue just before the earthquake (Figure 2), say, the catalogue from 26 BC to 2007/12/31 in this case; (c) compare the seismicity and smoothed seismicity (as an input to NDSHA) with the target earthquake in the following three plus one aspects: (1) whether the target earthquake have occurred in one of the seismogenic zones; (2) whether the target earthquake has an focal mechanism similar to the representative focal mechanism; (3) whether the target earthquake has its magnitude M enveloped by the M_{design}, which is the M_{max} of the controlling earthquake near to the target earthquake plus 0.7; and (4) whether the historical earthquake with its M_{max}, and the controlling earthquakes with M_{max}, located in the same seismogenic zone as that of the target earthquake (Figure 3).

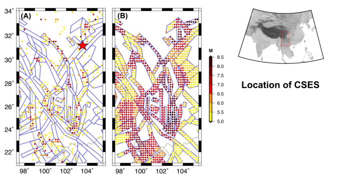

Figure 2. Pseudo-prospective falsification for the Wenchuan earthquake. (A) Seismicity from 26 BC to 2007/12/31, and seismogenic zones; (B) Smoothed seismicity, with a centered smoothing window that radius equal to 3 cells to account for errors in the location of the source and its extension in space. More details can be found in Panza and Bela (2020). The red star indicates the epicenter of the 2008 Wenchuan earthquake.

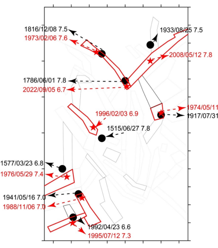

Figure 3. Pseudo-prospective falsification of M_{design}: The China Seismic Experimental Site (CSES). The seismogenic zones in which target earthquakes (red star) occurred are shown in red polygons. The black dots is the historical earthquake whose magnitude is taken as M_{max}.

Falsification/Verification of M_{design}: Worldwide

We select all recent M≥7.0 shallow events around the world (Figure 4, Table 1), and find that all events could be enveloped by M_{design}, except the July 6th, 2023, M_W7.2 event in Alaska (however, according to the definition of σ_M, the result that M_{design}-M_W is -0.1 is still geophysically acceptable). For more details, in the figure, the January 1st, 2024, Noto Peninsula M_W7.5 earthquake is plotted in the subplot.

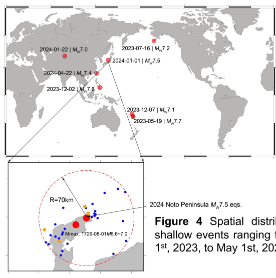

Figure 4 Spatial distribution of shallow events ranging from May 1st, 2023, to May 1st, 2024

Table 1 Falsification/Verification of M_{design} by recent major earthquakes worldwide

Recent Earthquake				Historical earthquake				Envelop	
Time	Location	Depth [km]	M_W	Time	Location	Distance from the target event [km]	M_{max}	M_{design}	M_{design}-M_W
2023/05/19	170.7°E, -23.2°N	18	7.7	2022/03/31	170.4°E, -22.6°N	78	7.0	7.7	+ 0.0
2023/07/16	-160.8°E, 54.4°N	25	7.2	1917/07/25	-161.1°E, 54.5°N	23	6.4	7.1	- 0.1
2023/12/02	126.4°E, 8.5°N	40	7.6	1991/02/18	126.5°E, 8.9°N	39	7.0	7.7	+ 0.1
2023/12/07	169.3°E, -20.6°N	48	7.1	1976/08/02	169.3°E, -20.6°N	4	6.9	7.6	+ 0.5
2024/01/01	137.3°E, 37.5°N	10	7.5	1751/05/21	138.2°E, 37.1°N*	91	7.4	8.1	+ 0.6
2024/01/22	78.7°E, 41.3°N	13	7.0	1915/12/17	79.1°E, 41.7°N	64	6.5	7.2	+ 0.2
2024/04/22	121.6°E, 23.8°N	40	7.4	1986/11/14	121.6°E, 23.9°N	8	7.4	8.1	+ 0.7

*Deduced location

Conclusions and discussion

We use the historical earthquake catalogue in the CSES region and recent events since mid-2023 as examples to perform the validation/falsification of the PR Law. The test is firstly conducted in a pseudo-prospective form, and the historical events are used to inspect whether the PR relation envelopes the real earthquake cases in the region where NDSHA has been performed. Results show that the PR law can be verified by M_W≥7.0 events in CSES since 1970. Then, we extend the falsification to worldwide by investigating recent shallow events. In that case, the PR law still holds.

At present time, we have considered two types of the test. For the CSES region it is the pseudo-prospective test using historical earthquakes, but since in this region NDSHA has been conducted, it is a *senso stricto* test; For the worldwide recent earthquakes, it is a prospective test, but since the NDSHA has not been performed, the test is a kind of *senso lato* test. With progresses in the development and application of NDSHA, we look forward to a prospective *senso stricto* test in near future.

References

Båth, M.,1973. Introduction to Seismology, Birkhäuser Verlag, Basel.

Bormann, P. Liu, R. F., Ren, X., Gutdeutsch, R., Kaiser, D., Castellaro, S., 2007. Chinese National Network magnitudes, their relation to NEIC magnitudes, and recommendations for new IASPEI magnitude standards. Bulletin of the Seismological Society of America, 97, 114–127.

Kossobokov, V., 2007. What do we know about earthquakes and their sequences? *Ninth Workshop on Non-linear Dynamics and Earthquake Predictions*. The Abdus Salam International Centre for Theoretical Physics. https://indico.ictp.it/event/a06219/session/10/contribution/4/material/0/0.pdf.

Gorshkov, A., Kossobokov, V., Soloviev, A., 2003. Recognition of earthquake-prone areas. In: Keilis-Borok, V. I., Soloviev, A. A. (eds.), *Nonlinear Dynamics of the Lithosphere and Earthquake Prediction*, 239-310. Berlin: Springer, 239-310.

Panza, G. F., Bela, J., 2020. NDSHA: A new paradigm for reliable seismic hazard assessment. Engineering Geology, 275, 105403.

Panza, G. F., Kossobokov, V. G., Laor, E., De Vivo, B. eds., 2022. Earthquakes and Sustainable Infrastructure: Neodeterministic (NDSHA) approach guarantees prevention rather than cure. Amsterdam: Elsevier.

Rugarli, P., Vaccari, F., Panza, G.F., 2019. Seismogenic nodes as a viable alternative seismogenic zones and observed seismicity for the definition of seismic hazard at regional scale. Vietnam Journal of Earth Sciences, 41, 289–304.

Wen, Z. P., Wang, G. X., 2024. Book review, Earthquakes and Sustainable Infrastructure - Neodeterministic (NDSHA) Approach Guarantees Prevention Rather Than Cure, Edited by Giuliano F. Panza, Vladimir G. Kossobokov, Efraim Laor and Benedetto De Vivo, 2022 Elsevier, ISBN: 978-0-12-823503-4. Earthquake Science, 37, 1-5.

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