TRANSRE CATASTROPHE RESEARCH

Shaking Things Up (Part III): Global Seismic Outlook

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Executive Summary

Earthquakes have caused on average $46 billion in economic losses and $6 billion in insured losses per year since the turn of the century. Over the same period, earthquakes have been by far the deadliest natural peril causing nearly 700,000 fatalities.[1] Given this persistent threat to both life and property, better understanding the risk posed by earthquakes to communities across the world is a critical concern.

Part III in this series of articles gives a global seismic outlook. Topics covered include:

- **Seismic Hotspots** –The proximity of many urban centers to active seismic zones exposes around one in three people globally to earthquakes. Several regions of high exposure stand out as critical seismic hotpots.
- **Construction Practices** – Differences in construction across the globe can have a significant impact on the destructiveness of earthquakes and need to be understood when underwriting seismic risk.
- **Sub-Perils** – Earthquakes pose several sub-perils in addition to shake that can be large contributors to overall losses.

Part I in this series reviewed the impact of the recent February 6, 2023 Turkey earthquake. Part II investigates California exposure to a major earthquake.

Seismic Hotspots

A region's seismicity is influenced by a variety of factors including the proximity of faults, the frequency at which accumulated strain is released, and local soil conditions amongst others. These variables can be quantified to estimate the likelihood of exceeding a certain seismic intensity over a period of interest. Figure 1 shows such a Global Seismic Hazard Map developed by the Global Earthquake Model (GEM).[2]

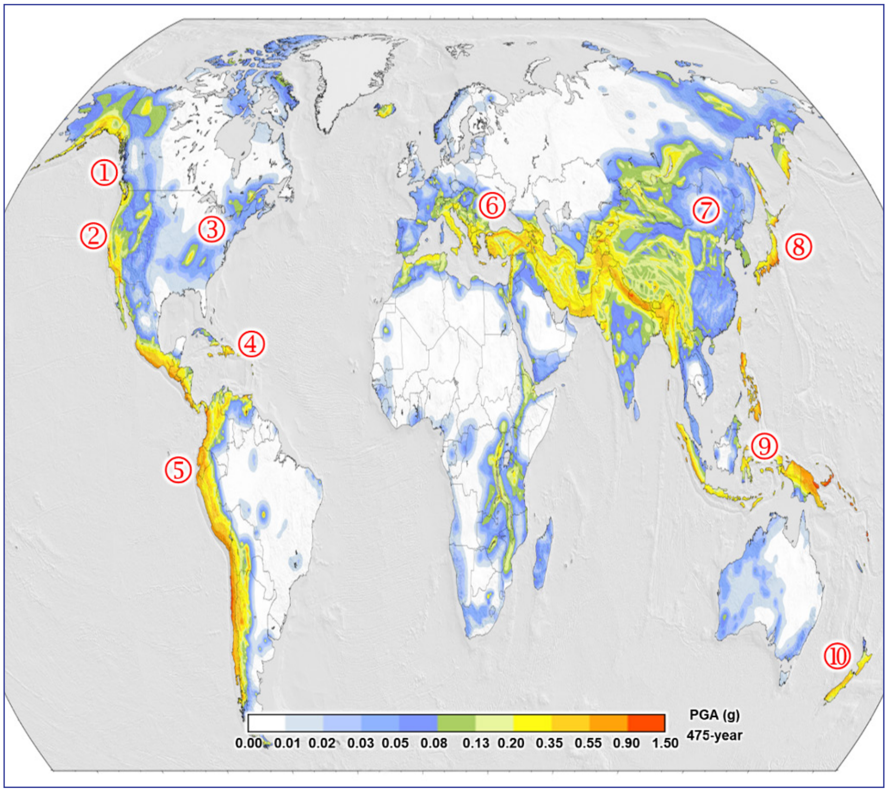

Figure 1 – Global Seismic Hazard Map (475-yr PGA) by GEM. Peak Ground Acceleration (PGA) is a measure of ground motion representing the maximum ground acceleration at a location.

1 Aon (2023). Weather, Climate and Catastrophe Insight.

2 Global Earthquake Model (2018). Global Seismic Hazard Map.

Many concentrations of wealth and population around the world are located near active seismic zones. In total, around 2.7 billion people globally are exposed to earthquakes, a figure that has nearly doubled over the last 40 years. More than 50 million people live in areas exposed to violent shaking where even specially designed structures could be damaged or could collapse.[3] Table 1 highlights ten regions of interest (marked on Figure 1) with high seismic risk.

Table 1 - Ten high seismic risk areas.

Location	Name	Description
1	Cascadia	Site of at least seven large earthquakes in the last 3,500 years with an average return interval of 400-600 years.[4] The 1700 Cascadia Earthquake (M9) generated a tsunami which inundated areas as far away as Japan.
2	California	The hypothetical magnitude 7.8 “Big One” on the San Andreas fault in southern California would cause over $350 billion in economic losses and 1,800 deaths.[5]
3	New Madrid	Site of three major earthquakes with magnitudes greater than 7 between 1811 and 1812. The probability of a similar earthquake in the next 50 years is about 10% with a potential economic loss of $590 billion.[6]
4	Caribbean	Most of the Caribbean’s 100 million inhabitants are within 50 km of at least one active fault.[7] In 2019-2020, over two dozen of earthquakes with magnitude 4.5 or greater caused $3.1 billion in economic losses.[8]
5	Latin America	The active Pacific subduction zone stretches 10,000 km from Mexico to Chile. Mexico City is built on soft soil from an ancient lakebed that can significantly amplify ground motion.[9] The 1960 Great Chilean Earthquake (M9.6) is the most powerful earthquake ever recorded.
6	Southern Europe	Istanbul, Turkey lies on the Marmara section of North Anatolian Fault which last ruptured with the 1766 Istanbul Earthquake (M7.1) and has an estimated return period of 200-250 years.[10]
7	China	The 1976 Tangshan Earthquake (M7.6) near Beijing is the deadliest earthquake on record with up to 655,000 fatalities. The 2008 Sichuan Earthquake (M8) caused over 69,000 deaths.
8	Japan	The 2011 Tohoku Earthquake (M9.1) is the costliest natural disaster in history. The last major earthquake to hit Tokyo was the 1923 Great Kanto Earthquake (M8.2). There is a 70% change of a magnitude 7.3 earthquake hitting Tokyo before 2050.[11]
9	Southeast Asia	The 2004 Indian Ocean Earthquake (M9.3) off the Indonesian coast generated a 30 m tsunami. The region is at the junction of four major tectonic plates.
10	New Zealand	New Zealand straddles the active collision of two tectonic plates. The 2010 and 2011 Canterbury earthquakes caused a combined $23 billion industry loss.[12]

3 Ehrlich et al. (2018). Remote sensing derived built-up area and population density to quantify global exposure to five natural hazards over time.
4 Pacific Northwest Seismic Network. Cascadia Subduction Zone.
5 USGS (2008). The ShakeOut Scenario.
6 Missouri Department of Natural Resources. Facts about the New Madrid Seismic Zone.
7 Styron et al. (2020). CCAF-DB: The Caribbean and Central American active fault database.
8 Center for Disaster Philanthropy (2020). Puerto Rico Earthquakes.
9 Associated Press (2017). Soft soil makes Mexico City shake like it was built on jelly.
10 Bohnoff et al (2017). Repeating Marmara Sea earthquakes: indication for fault creep.
11 ABC News (2022). Japan is due for a mega earthquake, with experts warning many people are unprepared.
12 Insurance Business (2021). New Zealand’s costliest natural disasters in the past decade.

Construction Practices

Differences in construction across the globe can have a significant impact on the destructiveness of earthquakes. Understanding local construction practices therefore is essential for properly assessing the exposure at risk and making informed underwriting decisions. Important considerations include:

- **Construction Type:** The lateral force on a structure during an earthquake is proportional to its weight. Therefore, lighter and more flexible structures (e.g. wood and steel) generally perform better than heavier and more stiff structures (e.g. masonry and concrete). A country's predominant construction type can depend on the availability of materials, ease of construction and climate.
- **Lateral Resistance:** Structures need a lateral load path to successfully transfer earthquake loads to the ground without damage. Unreinforced masonry structures lack such a load path and have repeatedly been observed to perform poorly during earthquakes. While their use in earthquake prone areas has steadily decreased, such as their immediate ban in California following the 1933 Long Beach (M6.4) earthquake, they remain common in many developing countries. Amongst many examples, the widespread failure of unreinforced masonry structures was a leading cause of death from the 2010 Haiti (M7.0) earthquake (Figure 2).[13]
- **Design Code Enforcement:** Lessons from past earthquakes have tremendously improved seismic design practices over recent decades. The enforcement of design codes, however, is not uniform across the globe. Poor enforcement can result in improper design, subpar materials, and inadequate workmanship. These factors can result in earthquakes with unexpectedly large losses. A recent example is the 2023 Turkey (M7.8) earthquake where buildings granted amnesties from critical design requirements performed poorly.[14]

Sub-Perils

In addition to shake damage, earthquakes also pose several sub-perils that can contribute significantly to overall losses. These sub-perils can damage structures otherwise unaffected by ground shaking or magnify damage to structures already weakened by shaking. Examples of earthquake sub-perils include:

Figure 2 – Unreinforced masonry building damaged in 2010 Haiti earthquake.

- **Tsunami:** Offshore earthquakes can displace large volumes of water and generate large waves called tsunamis. The 2004 Indian Ocean (M9.3) triggered a 30-meter tsunami resulting in more than 200,000 casualties.[15]
- **Fire-following:** Shake damage to gas lines and electrical equipment can ignite rapidly spreading fires. The 1995 Kobe (M6.8) earthquake triggered 148 separate files that destroyed over 6,000 buildings.[16]
- **Liquefaction:** Liquefaction can occur when soil saturated with water losses its strength in response to ground shaking. This transformation can undermine a building's foundation and cause collapse. Widespread liquefaction was observed following the 2011 Christchurch (M6.2) earthquake in New Zealand (Figure 3).[17]

13 Earthquake Engineering Research Institute (2010). The 12 January 2010 Haiti Earthquake.
14 BBC (2023). Turkey earthquake. Why did so many buildings collapse?
15 USGS (2014). Indian Ocean tsunami remembered: Scientists reflect on the 2004 Indian Ocean that killed thousands.
16 National Fire Protection Association (2015). Fire history: Kobe earthquake and fire.
17 Temblor (2016). Living with liquefaction.

- **Landslide:** Ground shaking can trigger the movement of earth down a slope in a landslide. The Las Colinas landside from the 2001 El Salvador (M7.6) earthquake led to 585 fatalities.[18]

Figure 3 – Effect of soil liquefaction from 2011 Christchurch earthquake.

Losses from earthquake sub-perils tend to have distinct features. First, sub-perils can have high spatial variability due to rapid changes in certain parameters (e.g. ground slope for landslide, elevation for tsunami, and soil strength for liquefaction). As a result, detailed data is needed to spatially resolve sub-peril risk. Second, losses from sub-perils can have high uncertainty due to the impact of many factors apart from shake intensity. In the case of fire-following, for example, losses are sensitive to the availability of fire engines, supply of water, and strength of prevailing winds amongst other. Since such variables are difficult to predict precisely, modeled losses for sub-perils can have a high degree of uncertainty.[19]

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18 Evans & Bent (2004). The Las Colinas landslide, Santa Tecla: A highly destructive flowslide triggered by the January 13, 2001 El Salvador earthquake.

19 Shome et al. (2018). Quantifying model uncertainty and risk.