Earthquake Architecture

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Design history research essay written in 2024, reformatted in 2026

Introduction

Natural disasters, such as earthquakes, are defined as natural phenomena that create destruction and disruptions to the environment including infrastructure as well as human life (Metych, 2023; Ross, 2023). These events occur most frequently at tectonic plate boundaries, especially in convergent boundaries such as the Pacific Ring of Fire (Figure 1) (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.; Metych, 2023). The ring of fire encompasses boundaries that surround the Pacific and Nazca plates, resulting in natural disaster- prone areas such as New Zealand, Taiwan, Japan, and South America (Figure 2) (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.; Metych, 2023). To combat devastation, those countries have created earthquake resistant infrastructure to mitigate damage when an earthquake occurs. The natural process of climate change has been enhanced because of industrialisation and human intervention, therefore significantly increasing global temperatures and icecap melting. This gradual rise in global sea levels has resulted in a rise of earthquakes both in intensity and frequency (Hart. et al, 2020; Ross, 2023). This leads to intraplate earthquakes becoming more common (Geoscience Australia, 2022) and may create a need to implement earthquake architecture all around the world.

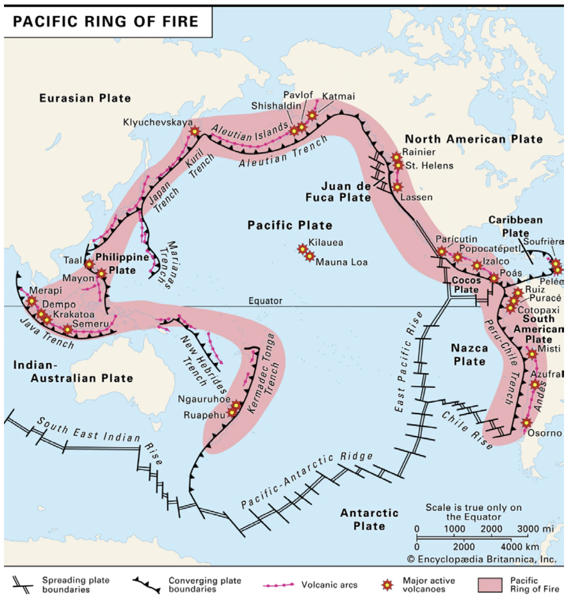

Figure 1: Image of the Pacific Ring of Fire from (Metych, 2023)

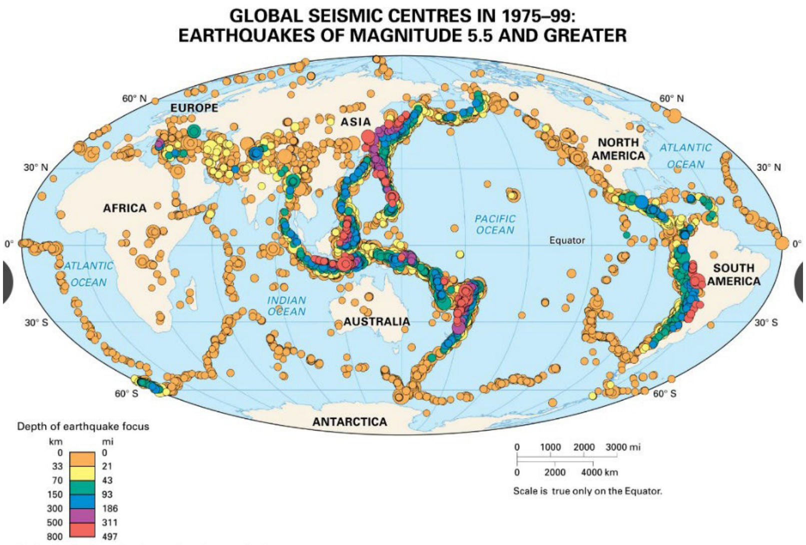

Figure 2: Image of earthquake locations between 1975 and 1999 from (Earthquake - Intensity and Magnitude of Earthquakes, n.d.)

History of Earthquake Architecture

Earthquakes are the result if a release in built-up in energy created by moving plate tectonics in the earth's crust (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.; Geoscience Australia, 2022; Metych, 2023). This release of energy causes the ground to suddenly shake (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.), creating destabilization in the environment in the form of landslides, infrastructure damage and collapse. For countries that sit on fault lines, these seismic events are frequent, damaging, dangerous and therefore costly. If regular architecture techniques were used in those areas, they can pose as a hazard as without appropriate support, buildings can fracture and collapse.
For modern day buildings, electrical wiring, sewerage and water pipes can become a hazard to human safety as well as significantly disrupt wildlife systems if harmful chemicals flow into the environment. Prolonged exposure to dust, debris and other airborne chemicals release from damaged infrastructure can lead to an increase in respiratory issues such as pneumonia (Keisaku Fujimoto, 2019).

The Italian Ferrara earthquake in 1570 caused the damage of 40% of infrastructure and led to architect Pirro Ligorio to design the first earthquake-resistant house (Admin-pikta, 2020). His design consisted of a house made of "stones and bricks, divided into six rooms (five of which are reinforced at the corners) characterized on the outside by powerful corner reinforcements and double brick arches with stone keystone to protect the openings below" (Figure 3) (Admin-pikta, 2020). Additionally, for further protection, a low brick arch and a "brick architrave with central stone segment" (Admin-pikta, 2020)was also implemented. The addition of reinforced corners and arches created additional support during seismic events, mitigating damages as the structure not only provided support vertically, but also horizontally. Ligorio's design was generally quite environmentally friendly as the use of natural materials meant that if it was damaged, the disposal process would've been simple and safe for the environment.
The introduction of Pirro Ligorio's earthquake-resistant architecture in 1570 has influenced the architectural strategies used in today's earthquake architecture.

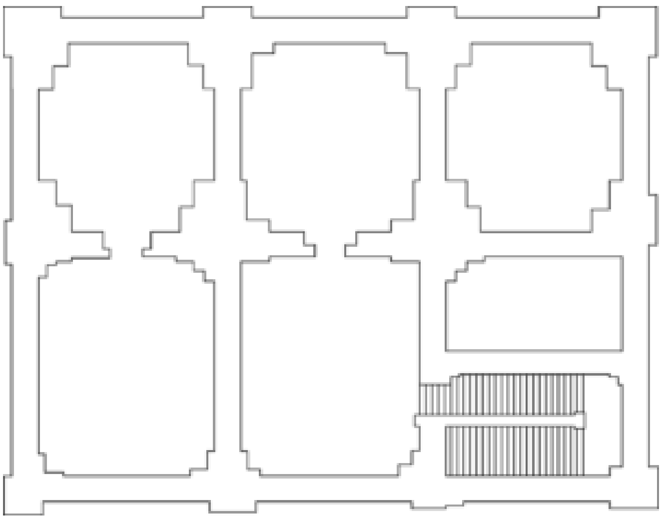

Figure 3: Image of the first earthquake resistant architecture by Pirro Ligorio from (Admin-pikta, 2020)

Existing Architecture and Development

Earthquake mitigation strategies today include architectural supports in buildings, waning systems, and evacuation protocols. Natural earthquakes are generally difficult to predict as most tectonic plate movement is underwater and deep within the Earth's crust (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.). The intensity and magnitude of a seismic event are first recorded using seismometers before translating the graphs into the Mercalli and Richter scales respectfully. Earthquake intensity measured using the 12-grade Mercalli scale can differ from area to area depending on magnitude and location. Magnitude measured by the Richter scale on the other hand measures the size of the earthquake and categorises the event ranging from 1.0 to 8.0 (*Earthquake - Intensity and Magnitude of Earthquakes*, n.d.).

Earthquake architecture today is common in countries located in and around the Pacific Ring of Fire such as Japan and Taiwan. Both of these east Asian countries experience frequent earthquakes, and their architectural techniques reflect that. Taiwan's most well-known landmark, Taipei 101 is located in Taipei, Taiwan and is 508 meters tall (Chen, 2019). The exterior is an example of biomimicry, where it was made to resemble bamboo. However, as a tall building, it is "susceptible to oscillation caused by earthquakes or strong winds" (Chen, 2019). Inside the building between the 87th and 92nd floors, is a giant wind damper that was made from welding 41 layers of 12.5-centimetre-thick steel boards (Figure 4) (Chen, 2019). The wind damper itself weighs 660 metric tonnes and is 5.5 meters in diameter (Chen, 2019). The purpose of the wind damper is to not only provide stability during extreme weather events and disasters, but to provide comfort for the users inside as well. An example of this in effect was on April 18th 2019, when a 6.1 magnitude earthquake caused the wind damper to swing 20 centimetres in both directions and prevented the people inside from experiencing harm or discomfort (Chen, 2019; 天下雜誌 Future City, 2019).

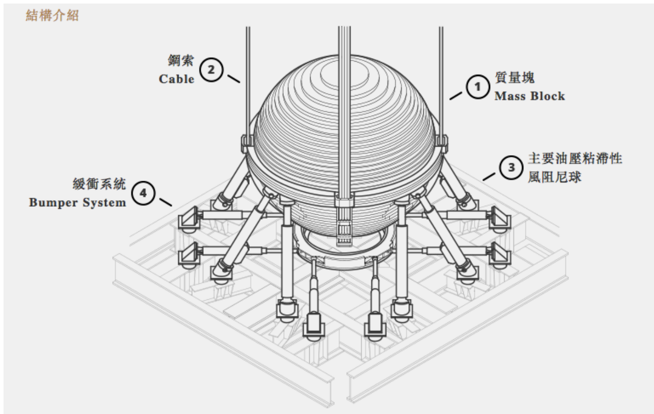

Figure 4: Image of Taipei101's wind damper from (Chen, 2019)

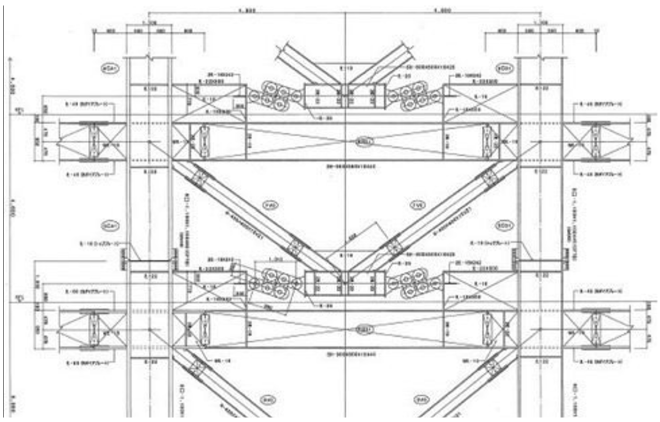

Figure 5: Image of the high-capacity dampers in Japan's Abeno Harukas from (Damptech, n.d.)

Similarly, Japan is also located in an earthquake-prone area with the country experiencing "about 18% of all earthquakes of magnitude 7 or more between 1997 and 2006" (OECD, 2009). Abeno Harukas is the tallest building in Japan, standing at a height of 300 meters, containing 62 floors and has "seismic resistance capable of withstanding earthquakes 1.5 times large than the level specified in government regulations" (Damptech, n.d.). The building contains high-capacity dampers throughout its height and the structural frame "can withstand earthquakes with an intensity of 7 on the Japanese 7-stage seismic scale" (Figures 5&6) (Damptech, n.d.). Some of Japan's infrastructure implements a process called seismic isolation that involves a form of shock absorber, such as thick rubber blocks to be placed underneath columns (Henriques, 2019). Additionally, the inclusion of motion dampers implemented throughout a building's height also improves resilience and reduces motion (Figure 7) (Henriques, 2019).

Earthquake Frequency and Damage

Since the industrial revolution, the average global temperatures have increased by at least 1.1 degrees Celsius since 1880 (NASA, 2023), leading to a rise in sea levels and consequently, extreme weather events. Industrialisation has seen the introduction and production of new materials such as plastic, which today makes up the majority of landfill. The burning of fossil fuels such as coal and oil increase the amount of greenhouse gasses in the air, thereby impacting the temperature regulation system that the greenhouse effect provides. An increase in greenhouse gasses effectively traps more solar radiation and therefore heat in the earth's atmosphere, creating a gradual increase in global temperatures (Figure 8) (United States Environmental Protection Agency, 2021). This rise in temperature negatively impacts the effectiveness of the earth's ozone layer, making certain areas more suspectable to damaging solar rays. The global temperature of 2022 sees a global temperature anomaly of 0.89 degrees Celsius (Figure 9) (NASA, 2023). Though that temperature anomaly seems insignificant, that change requires a "vast amount of heat to warm all of the oceans, the atmosphere, and land masses by that much" (NASA, 2023).

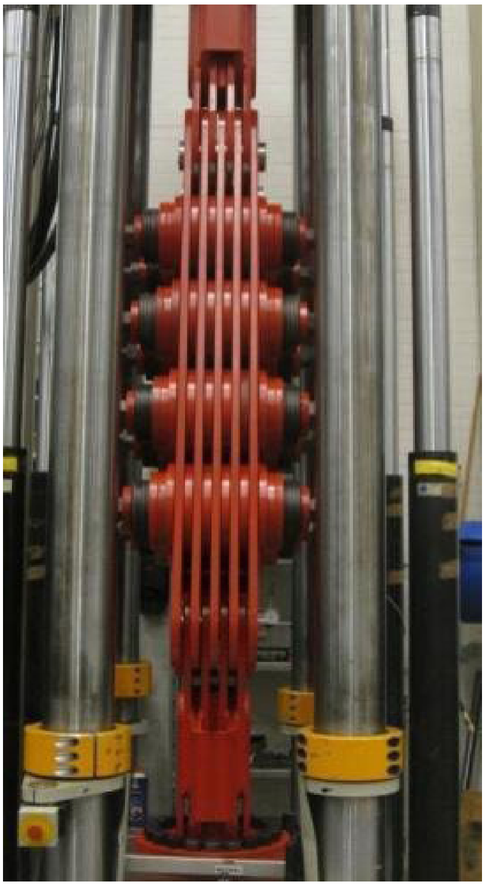

Figure 6: Image of the high-capacity dampers in Japan's Abeno Harukas from (Damptech, n.d.)

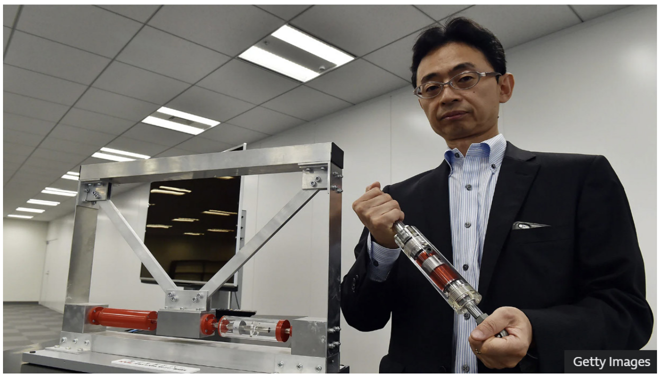

Figure 7: Photo of motion dampers from (Henriques, 2019)

Though climate change is a natural process, it's effects are being enhanced to damaging levels due to human intervention. The rise in sea levels impact seismic activity as it "deforms the earth through surface as well as subsurface loading" (Aoki & Corné Kreemer, 2024). This increase in global sea and temperature levels enhance the water cycle, creating stronger weather events more frequently. Earthquake frequency and intensity are also a direct influence of climate change. The rise in ocean temperatures not only negatively impact the environment but it's temperature-sensitive inhabitants.

Though uncommon, countries that aren't directly on fault lines, such as Australia, can experience earthquakes formed by intraplate movement. "In the 50 years 1968 and 2018 Australia experienced eleven known surface rupturing earthquakes" (King et al., 2019), most of which were located in Western Australia (Figure 10). In 2023 Melbourne, Australia experienced a magnitude 3.8 earthquake that was felt by over 22,750 people. As seen in figure 11, Australia has experienced quite a significant number of earthquakes over the last 10 years, all of which were greater than a magnitude 3.

Though a magnitude 3 is not very strong, it could still inflict a decent amount of damage to infrastructure, especially since Australian architecture was built to be breathable. In 1989, Newcastle in NSW was "hit by a 5.4 magnitude earthquake, which resulted in the deaths of 13 people and a damage bill of $4 billion" (Bahr, 2023). This amount of damage from a 5.4 magnitude earthquake, could've resulted in a significantly lower amount of damage if Australia adopted earthquake architecture in their infrastructure.

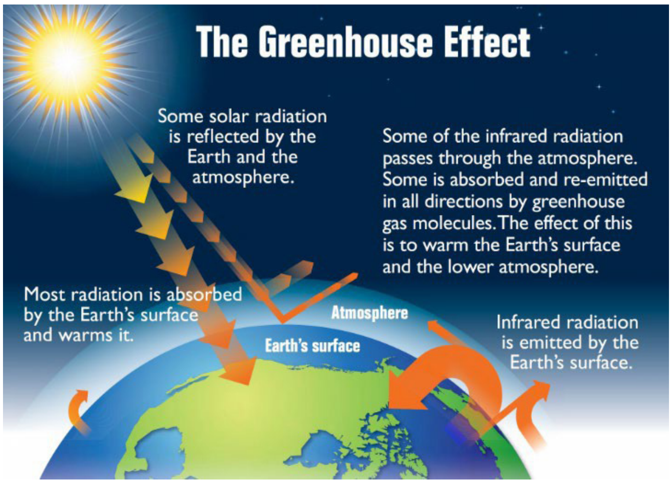

Figure 8: Diagram of the greenouse effect from (United States Environmental Protection Agency, 2021)

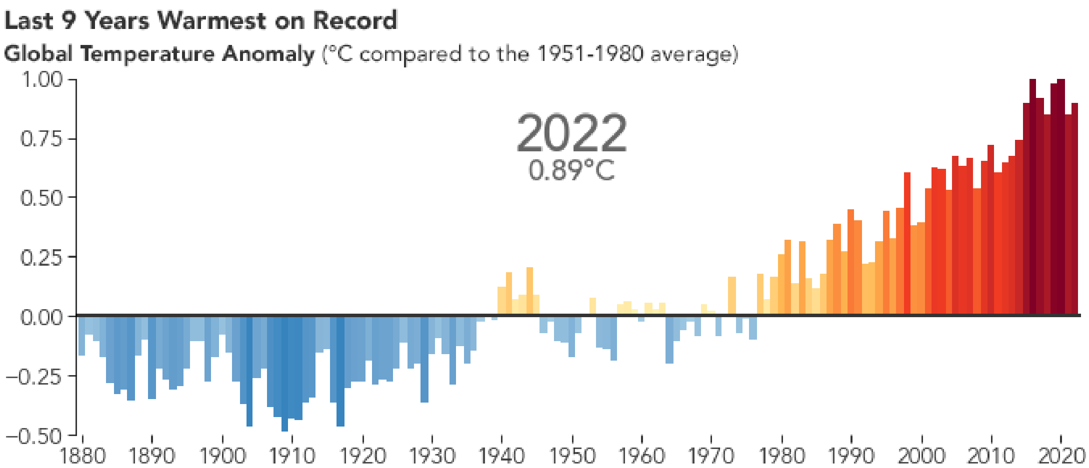

Figure 9: Graph of global temperature anomalies from (NASA, 2023)

Future Development and Predictions

In 20 years, if temperatures continue to rise, all natural disasters will become more frequent and intense, particularly in places in and around the Pacific Ring of fire. East Asian countries in the Ring of Fire like Taiwan and Japan for example, will be subject to intense earthquakes more frequently. And as a result, earthquake architecture will continue to develop, first in countries that currently use these mitigation techniques, then everywhere else. Intraplate earthquakes will become more commonplace with places like Australia experiencing higher magnitude earthquakes that may create mass devastation if precautionary measures aren't taken. High rises all over the world would become a hazard and for safety reasons, either be rebuilt to include structural support or implement features such as wind and motion dampeners. Some of the leading causes of injury during an earthquake are falling furniture and glass breaking (Karimoku, 2024) therefore in 20 years, most if not all buildings will be required to have stronger window supports. Additionally, miscellaneous furniture stabilization products will become common place.

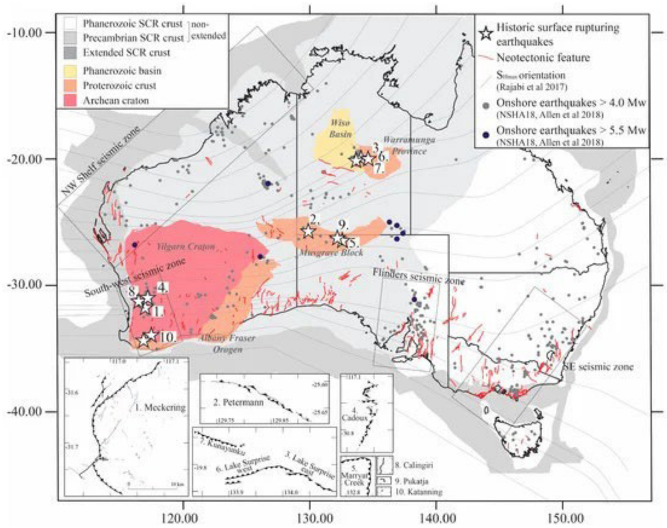

Figure 10: Map of earthquake distribution in Australia from (King et al., 2019)

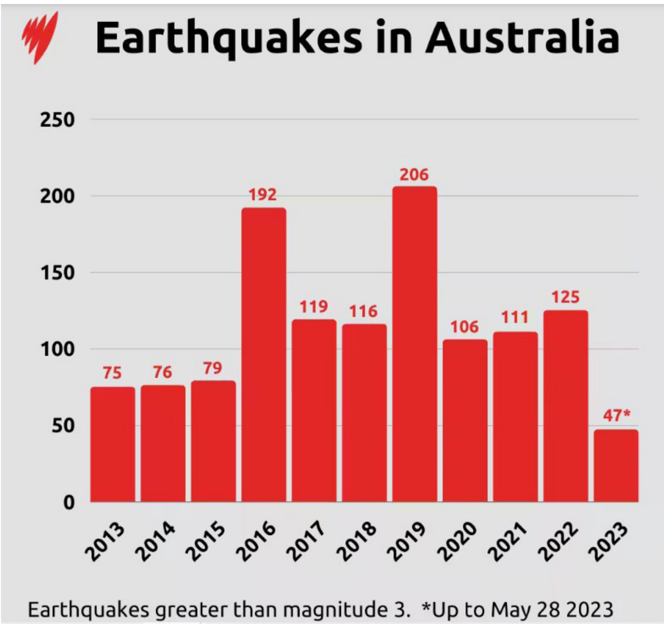

Figure 11: Graph of earthquake frequency in Australia from (Bahr, 2023)

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