CAT 360

Catastrophe Risk from Every Perspective

The CAT 360 is a quarterly newsletter that features articles developed by our Research and Development Team and covers topics that relate to Catastrophe Modeling, Natural Perils and Information Technology on a global basis. Please feel free to contact the editors if you have any questions or comments regarding any of our publications.

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Feature Stories

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Beneath the Surface: the New Madrid Seismic Zone

On 28 May 2009, the US Geological Survey (USGS) conducted its semi-annual outreach event - The New Madrid Earthquake Insight Field Trip. The field trip participants were educated on the earthquake history of the central United States and current exposures to earthquake hazards in this area. Sophia Zhang, PhD - Senior Research Scientist - ACE Tempest Re, was one of the participants on this trip, and was able to gather first hand information on the earthquake hazard issues facing this region.

The field trip route included the St. Louis metro area, Maryland Heights, St. Charles and East Alton, Illinois. Stops were made at these sites with the group studying the geologic evidence of past large earthquakes as well as cost-effective engineering solutions which minimize earthquake risk to certain structures. The group also viewed and discussed damage from the 18 April 2008 Mount Carmel earthquake. Information directly obtained from the field trip was used in the development of this issue of the CAT 360. We hope that our business partners and clients find this article valuable in understanding the issues of earthquake hazards in the New Madrid region.

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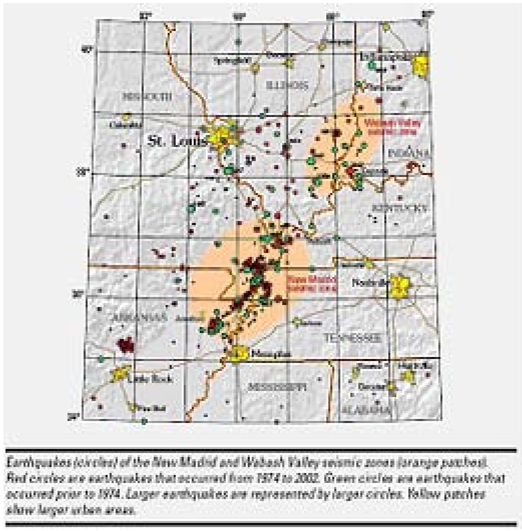
< Shaken from their Beds

In the early hours of 16 December 1811, violent earthquake shocks awakened people in St. Louis from their sleep. These tremors were just the start of some of the strongest earthquakes in the history of the United States. Four powerful earthquakes occurred between December 1811 and February 1812 in the central Mississippi Valley. These earthquakes, as well as the seismic zone,

The landscape has altered a great deal since the early 19th century, starting with the Mississippi River itself, which changed course following the four big quakes. Back then, the total population of the settlements on the Mississippi River was less than 4,000. Now millions of people live along the banks of the great river.

were named for the Mississippi River town of New Madrid, which was at the epicenter of one of the quakes. (Figure 1 shows the New Madrid Seismic Zone and historical earthquakes).



Credit: USGS

Figure 1 - New Madrid Seismic Zone and historical events.

The wooden houses of early settlers have been replaced by buildings from various periods. Since the four big earthquakes, the New Madrid Seismic Zone (NMSZ) has been quiet, with small quakes occurring sporadically. On average, only one earthquake a year is large enough to be felt in the area. However, the threat of the next "Big One" remains.

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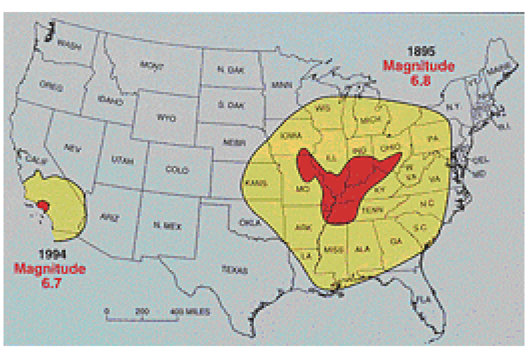
< The Hazard

The underlying mechanism of the NMSZ is not clear. It is postulated that it was formed as a result of the weaknesses in the North American Plate. This series of deeply-buried, ill-defined faults runs roughly parallel to the Mississippi River Valley. The old, rigid bedrock that sits beneath allows an earthquake in the NMSZ to affect a far greater area than an earthquake of a similar magnitude in California (see figure 2).



Credit: USGS

Figure 2 - The red region indicates minor to major damage to buildings and their contents. The yellow region indicates shaking felt, but little or no damage to objects, such as dishes and fragile objects.

Over the past two million years, the majority of the NMSZ has been dominated by the Mississippi River. During this long period of time, sediments (alluvium) have been

The recurrence rate is roughly every 500 years. To fully explain the discrepancy between the historical events and the new GPS data, it is necessary to understand the basic mechanisms at play in the NMSZ.

It is well known that soft soils can amplify ground motion. For similar magnitude earthquakes, the ground motion in soft soil can be five to six times greater than that on rock. The alluvial soil can give way in an earthquake, causing liquefaction.

In NMSZ, large cities such as Memphis and St. Louis are built on soft soils. In fact, liquefaction was well documented during the 1811 and 1812 events. According to the Center for Earthquake Research and Information (CERI), more than 10,000 square kilometers of ground liquefied as a result of the four earthquakes.

A more recent example is the 1995 Kobe earthquake. During the earthquake, severe liquefaction caused damage to the port and wharf facilities (see figure 3). To better understand the liquefaction, scientists from USGS along with local geologists have developed a new detailed hazard map for the area, with a horizontal resolution up to 500 meters in Memphis and St. Louis. These maps allow a more accurate assessment of liquefaction potential in urban areas where deposited and have built up across a wide area, with up to 300 feet of alluvium present in certain zones. The alluvial soil makes the faults invisible from the surface and has a significant impact on the characteristics of an earthquake.

Scientists have installed global positioning systems (GPS) on the land surface to detect and measure the movement of the New Madrid Faults. A recent study of NMSZ found that ground movement has been less than 0.2mm per year since the early 20th century (Calais and Stein, 2009), compared with 2cm to 6cm per year on the San Andreas Fault. The recurrence rate of a large earthquake on the San Andreas Fault is 180-300 years. The GPS data in the NMSZ suggests a recurrence rate of about 10,000 years, much longer than the 500 year intervals inferred from historical events.

Historical events can be investigated by examining sand blow data in the NMSZ. Sand blows are cones of sand that are formed when sand explodes onto the surface during an earthquake. They are more likely to form where there is alluvial soil as it is susceptible to liquefaction. Liquefaction is the process by which soils become weakened and almost liquid in state as a result of ground shaking or other rapid loading. Past earthquakes left their mark on the landscape via sand blows.

By examining sand blows in the NMSZ area, scientists have found evidence of earthquakes with a similar magnitude to the 1811 and 1812 events, dating back to AD 1450, AD 900, AD 300 and possibly a fourth at around 2350 BC (Tuttle et al 2002, Tuttle et al 2005).

concentrations of value are high.

Figure 3 - The result of damage caused by liquefaction during the Kobe earthquake in Japan on January 17, 1995. Liquefaction will be a significant issue during a major earthquake event in the New Madrid Region. Credit: Great Hanshin Bridge Collection, Earthquake Engineering Research Center, University of California, Berkeley.

Large cities on the Mississippi River are susceptible to both flood and earthquake risk. In 1993, St. Louis and the surrounding area were subjected to a devastating flood as the Mississippi and River Des Peres burst their banks, destroying 10,000 homes and resulting in 32 deaths. As a result, bridges and levees need to be built to withstand both flood and earthquake.

This has had a significant impact on local infrastructure. The Missouri section of Interstate 64 from 14th Street to Mississippi River is retrofitted to resist a 1-in-500 year quake, for example. Illinois is doing a similar retrofit on the first half-mile of Interstate 64 in East St. Louis. However, a major flood could weaken a bridge or levee, making it vulnerable to subsequent earthquakes, and vice versa.

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< The Exposure

Memphis and St. Louis stand out in NMSZ as having the largest exposures. Although some NMSZ states, such as Missouri and Illinois, do not have state building code, they allow local adoption of seismic code. Other states, such as Tennessee and Arkansas, have state building codes. Both Memphis and St. Louis adopted the 2003 International Building Code (IBC) that contains modern seismic design standards in 2005.

St. Louis County's seismic enforcement began with the adoption of the 1987 Building Officials and Code Administrators (BOCA) National Building Code in 1988. The 1993 National Building Code was adopted in April

The year of construction is an important indication of a building's design standard. In general, the cities in NMSZ exhibit a large variation of buildings from different eras. St. Louis is a veritable mixture of century-old unreinforced masonry (URM) buildings, old concrete frame building and new reinforced concreted buildings (see figure 4). Some of the old buildings have been retrofitted and some have not. It is very difficult to tell from the outside. In addition, most buildings are situated close together, which increases pounding potential during an earthquake.

Many of the buildings in St. Louis have parking lots or shops with expansive glass windows on

1994. BOCA code has been subsequently replaced by IBC. New commercial structures are primarily affected by seismic regulations while single-family homes are exempt.

The State of Tennessee has had a mandatory state building code since 1982. Before 2003, the state used the latest Standard Building Code (SBC). The 1988 version of this code first introduced seismic provisions and was adopted in 1990. With the 1994 SBC, Memphis was brought up to a seismic zone 3 designation. Then, in 2003, the IBC 2000 code was adopted at a state level.

Figure 4 - Downtown St. Louis contains a diverse collection of buildings, from classic masonry buildings to modern buildings made from glass and steel.

the first floor. Based on experience from earthquakes in California, we know buildings with a parking garage on the first floor (soft story) are highly susceptible to damage in an earthquake-prone region. Many of these garages do not provide adequate support to the building. What makes things worse is that the weight of a garage is less than the upper level structure, which amplifies the movement of the building during an earthquake.

Even with proper building code, its enforcement cannot always be taken for granted. During the magnitude 5.4 Mount Carmel earthquake last year, the school gym of East Alton Elementary School, about 140 miles west of the epicenter, sustained structural damage. Large cracks formed in the wall and engineers determined that the gym was unsafe and needed to be repaired or rebuilt, although no cracks were found outside the building. Investigations showed that the building had been poorly constructed and had performed like a URM building during the earthquake. The issue of poor building quality was also reported in the May 2008 earthquake in Sichuan, China and the more recent May 2009 earthquake in L'Aquila, Italy.

Figure 5 - From the outside, there appears to be little damage to the gym of East Alton Elementary School. However, a closer inspection to the interior reveals cracks that formed in the walls of the gym. As a result, the building is declared as unsafe to enter until major repairs are made. Almost a year and a half after the Mount Carmel Mw 5.4 earthquake in April 2008, the gym remains closed.

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< Modeling the Risk

Insurers and reinsurers rely on catastrophe models to evaluate earthquake risk. Commercial cat models adopt the USGS hazard map, but often apply their own adjustment or implementation. As has been discussed, there is considerable uncertainty in the recurrence rate of NMSZ. Some of the uncertainty has or develop their own in-house. The data resolution varies from model to model. While there are some engineering studies on modeling building damage due to liquefaction, it is less extensively studied than ground shaking. In addition, real-event damage data is less readily available. For these reasons, been accounted for in the USGS hazard map and cat models.

Another uncertainty comes from the local conditions. The soil map in the models in NMSZ varies from 100 to 1,000 (or more) meters. The resolution in urban areas is higher than in rural areas. The effect of soil amplification on ground motion is explicitly modeled. Seismic provisions of most building codes focus on the effect of ground motion on building structure. Liquefaction, on other hand, can cause structural damage due to ground failure. In some cases, the integrity of a building can be compromised even if the structure is still intact.

Damage due to liquefaction is estimated by considering the susceptibility to liquefaction and the magnitude of earthquake in the cat models. Cat models utilize liquefaction susceptibility maps from third parties modeling liquefaction damage is subject to a large amount of uncertainty.

One of the biggest challenges cat modelers face is patchy historical data. Large earthquakes happen far less frequently than hurricanes. With earthquakes, there are fewer tests of how buildings with modern seismic design standards perform in a real event. However, damage data from earthquakes in California and other parts of the world indicate that buildings that are built to seismic design codes perform much better than those that are not.

However, truly robust buildings require experienced design professionals and skilled builders who know how to conform to the building code. It is unlikely that the issue of building quality will emerge until a real event happens.

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< Conclusion

Millions of people live in the NMSZ where large earthquakes can occur. Although historical events indicate that the recurrence rate is about 500 years, there is considerable uncertainty in that estimate. Because of local geological conditions, a New Madrid earthquake can affect far greater areas than a quake of a similar magnitude in California. The loose soil in the Mississippi Valley amplifies ground shaking and could lead to liquefaction in some areas. While liquefaction damage is explicitly modeled, there is less confidence in the outcomes than with ground shaking due to a lack of damage and engineering data. What we do know is that in NMSZ, loss due to liquefaction can be significant.

Large communities have adopted building codes with seismic design provisions. Unfortunately, large cities such as St. Louis have a significant number of buildings dating from eras where they did not have seismic building codes. These older buildings are likely to contribute to a large proportion of the loss in an earthquake event. Although evidence from previous earthquake events suggests that seismic design can dramatically reduce loss, the performance of modern seismic building codes and the issue of construction quality will remain largely unanswered until these buildings are tested by a real event.

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