EVENT BRIEFING

Event: 17 June, 2019 Yibin City, Sichuan, China Earthquake

Region: East Asia

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Key Lessons

- Recorded ground motions clearly exceed the design basis (DBE) and maximum considered (MCE) earthquake levels. Severe ground shaking can be attributed to the shallow focal depth of the earthquake.
- Over 20,000 houses were damaged, including several collapses. While following the basic requirements of earthquake codes to achieve increased ductility and energy dissipation capability prevents collapse in the cases where the design forces and ground shaking exceed that used in design, in the case of Sichuan Earthquake, ground motions at some locales were an order of magnitude larger than the design level. This may explain the observed collapses, as could the presence of existing buildings that were not code compliant.
- Around 243,880 people were affected, and more than 52,000 people were relocated in impacted areas. Similar to previous earthquakes, these numbers highlight the social consequences of earthquakes, such as population displacement and the need for more research on regional-scale simulations of building and infrastructure performance in collaboration with social science experts.
- The early warning triggered in Chengdu and Yibin during the earthquake reinforced the benefits of earthquake early warning systems – a preparedness measure that should be adopted widely.
- Results of city-scale computational simulations generated shortly after the earthquake are reported herein and have great potential to aid efficient organization of response and recovery efforts. In the long-term, comparison of these estimations with actual damage distributions will be helpful in evaluating the accuracy of the regional-scale simulations and making any necessary improvements, such that similar simulations, along with social science studies, can be used for decision making purposes to prepare for future earthquakes.

StEER Response Strategy

The objectives of this event briefing are:

1. to summarize the seismic characteristics of the 17 June 2019 Yibin City, Sichuan, China earthquake
2. to overview damage to buildings and other infrastructure, as well as disruption to the community in terms of downtime and economic losses
3. to present city-scale computational simulations generated shortly after the earthquake
4. to summarize key lessons learned.

Information provided herein was gathered from various websites, news channels and USGS. Therefore, this briefing does not include insights from detailed field investigations. StEER may decide to continue to form a Virtual Assessment Structural Team (VAST) to collect and process additional public data relating to this earthquake and its aftershocks. These data will be used to develop a more detailed Preliminary Virtual Reconnaissance Report (PVRR) that will augment this event briefing. StEER is coordinating with other organizations and local universities to determine how best to collect on-site data for this event.

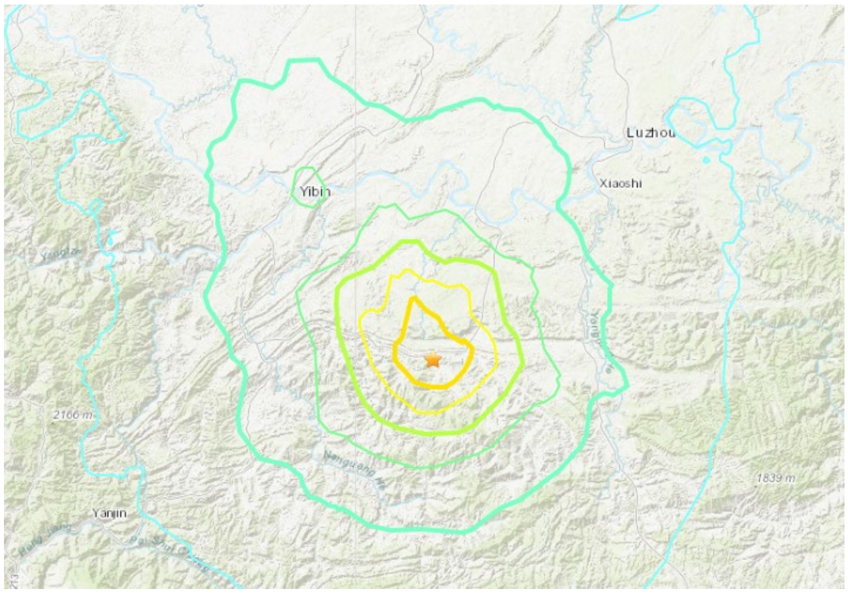
Earthquake Details

On June 17, 2019 at approximately 10:55 pm local time, a magnitude 6.0 earthquake with a depth of 16 km occurred in Changning County, Sichuan. The epicenter was located 19 km south of Changning at coordinates of 28.34 °N, 104.90 °E. USGS ShakeMap (Fig. 1) indicates Peak Ground Accelerations (PGA) in the range of 0.2g~0.3g, which was exceeded by the measured ground motions. The location, depth and preliminary focal mechanism reported by USGS suggests intraplate faulting within the Eurasia plate (USGS, 2019). The earthquake was followed by several powerful aftershocks.

The USGS PAGER tool estimated no fatalities with a probability of 19% and less than 10 and 100 fatalities with probability of 37% and 32%, respectively (Fig. 2). At the time this briefing was authored, there were at least 12 dead and 220 injured. PAGER estimated economic losses due to damage to be between $100 million and $1,000 million, between $1,000 million and $10,000 million, and between $10,000 million and $100,000 million with probabilities of 24%, 35% and 24%, respectively. According to the Sichuan emergency management, preliminary estimates of direct economic losses exceeded $1.4 million (USA Today, 2019).

Ground motions were recorded by the China Earthquake Network Center (CENC). Twenty-three ground motions near the epicenter of this earthquake were analyzed. Names and locations of the stations are listed in the Appendix. The maximum recorded peak ground acceleration (PGA) was 0.62g. The 5% damped acceleration response spectra of the recorded ground motions with comparison to the design spectra specified in the Chinese Code for Seismic Design of Buildings is plotted in Figure 3. It is observed that the recorded ground motions clearly exceed the design basis (DBE) and maximum considered (MCE) earthquake levels. The severe ground shaking can be attributed to the shallow focal depth of the earthquake. Traditional earthquake design philosophy allows damage in large earthquakes with the aim of preventing collapse. For this purpose, buildings are designed to prevent brittle damage modes, such as shear, axial or joint failures and to increase the ductility with adequate detailing and measures like strong column/weak beam member sizing.

Following these basic requirements towards increased ductility and energy dissipation capability prevents collapse in the cases where the design forces and ground shaking is much different than that used in design. However, in the case of Sichuan Earthquake, some of the ground motions are an order of magnitude larger than the design level, which may explain the few observed collapses. Collapses may also be attributed to existing buildings that were not code compliant.



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.05	0.3	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.02	0.13	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 7: Processed 2019-06-18T14:57:21Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Figure 1. Epicenter of the earthquake and Shakemap (USGS, 2019)

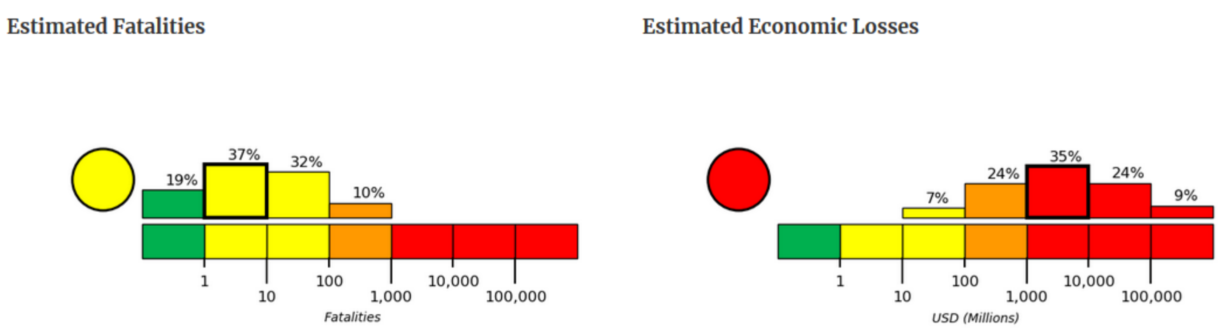


Figure 2. USGS PAGER loss estimates (USGS, 2019)

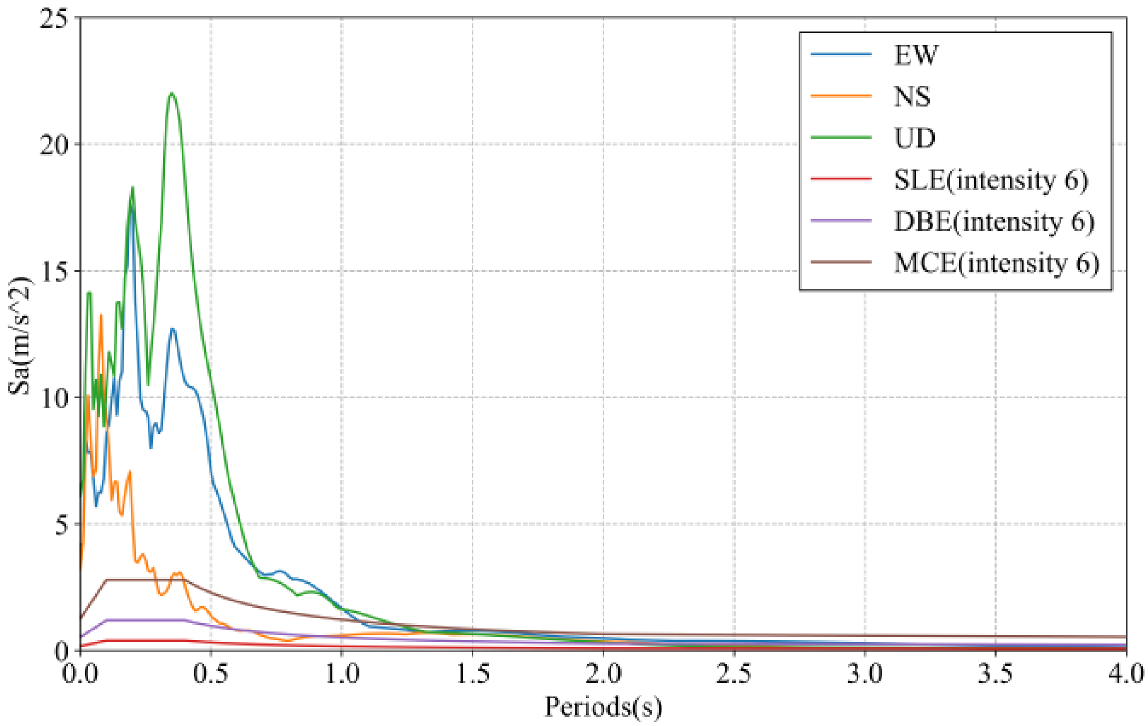


Figure 3. Response spectra of the highest PGA ground motion in comparison with the Chinese code response spectra

Damage to Structures

Over 20,000 houses were damaged with several collapses, e.g., Figure 4 (China Plus, 2019). Around 243,880 people were affected, and more than 52,000 people were displaced from impacted areas. Similar to previous earthquakes, these numbers highlight the social consequences of earthquakes, such as population displacement, highlighting the need for more regional-scale simulations of building and infrastructure performance in collaboration with social science experts.

Towards this direction, using the real-time ground motions obtained from the strong motion networks and the city-scale nonlinear time-history analysis tool developed by Lu et al. (2018), the damage ratios of buildings across the earthquake-affected region were simulated. The building damage distribution and estimate of shaking intensity felt by people near different ground motion stations are shown in Figures 5 and 6, respectively. These results, obtained in a fairly short time after the earthquake, have great potential to aid efficient organization of post-disaster response and recovery. In the long-term, comparison of these estimations with actual damage distributions will be helpful in evaluating the accuracy of the regional-scale simulations and making any necessary improvements, such that similar simulations, along with social science studies, can be used for decision making purposes to prepare for future earthquakes.

In Figure 5, it is observed that extensive damage is expected near the epicenter of the earthquake, which is consistent with the damage observed in residential construction near this location. In Figure 6, it is observed that the shaking levels could have been intolerable near the epicenter of the earthquake, highlighting the need for more psychology-related studies investigating the consequences of earthquakes and their impacts on human subjects.

Figure 4. Rescuers searching for people in the rubble of a collapsed building (BBC News, 2019).

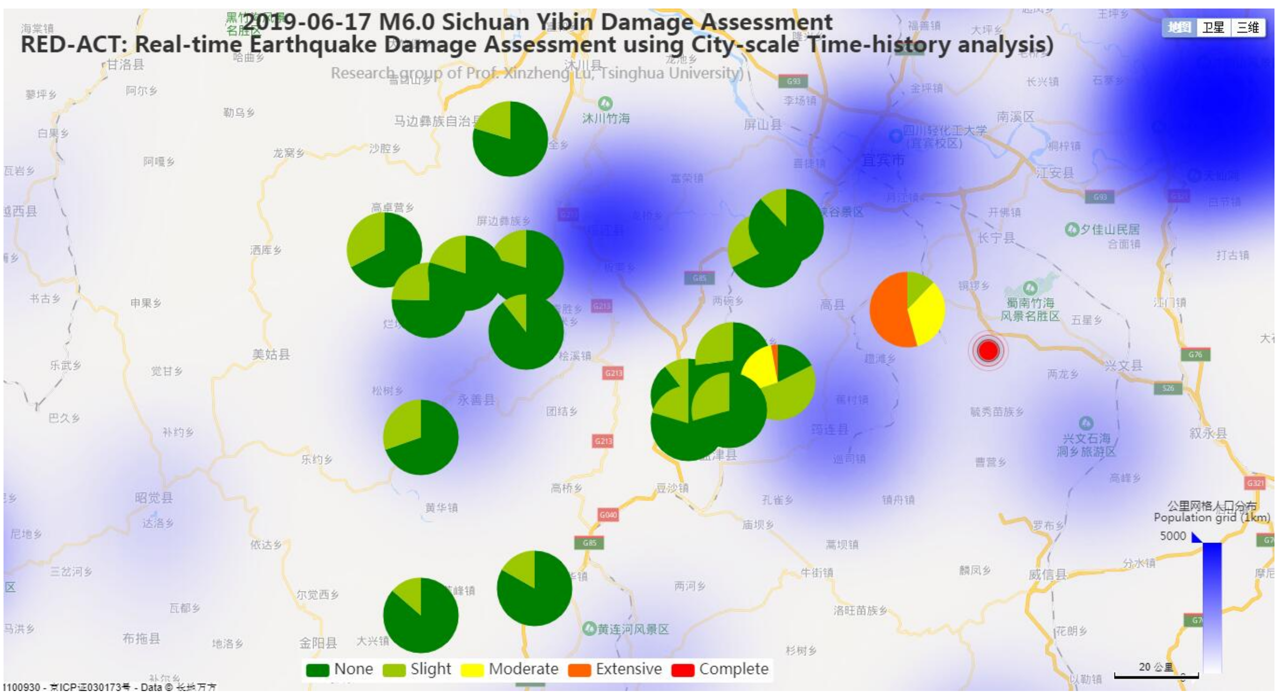


Figure 5. Damage ratio distribution of the buildings near different ground motion stations estimated from the city-scale nonlinear time-history analysis tool (Lu et al., 2018)

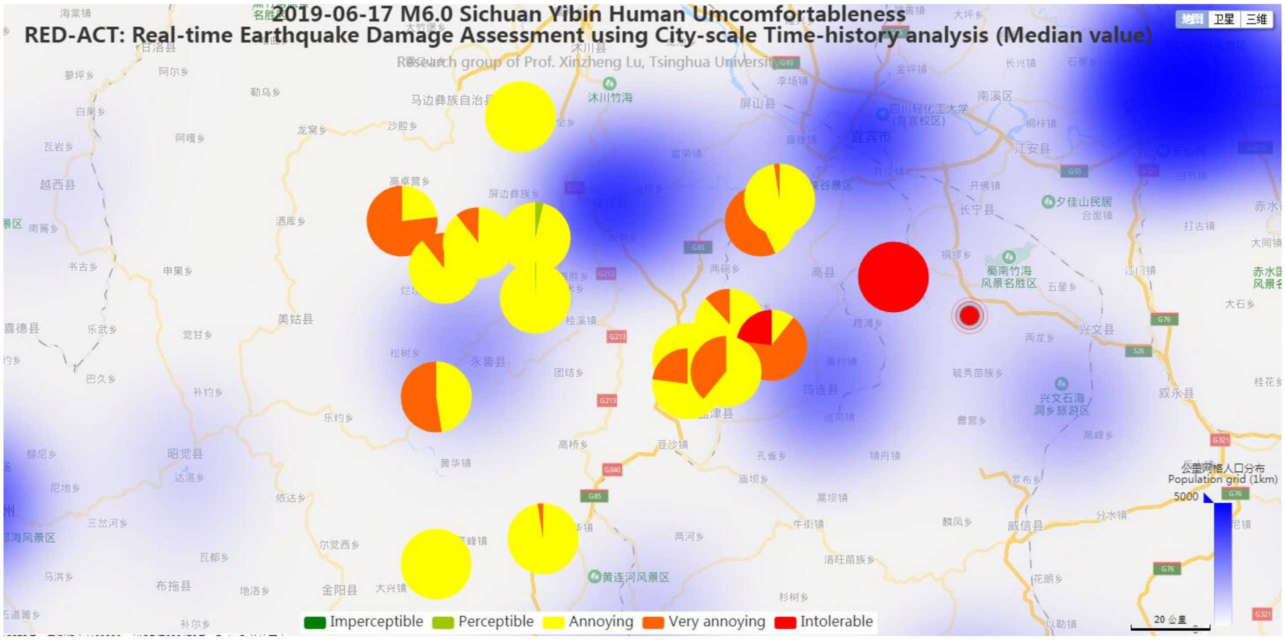


Figure 6. Human perception of shaking near different ground motion stations estimated from the city-scale nonlinear time-history analysis tool (Lu et al., 2018)

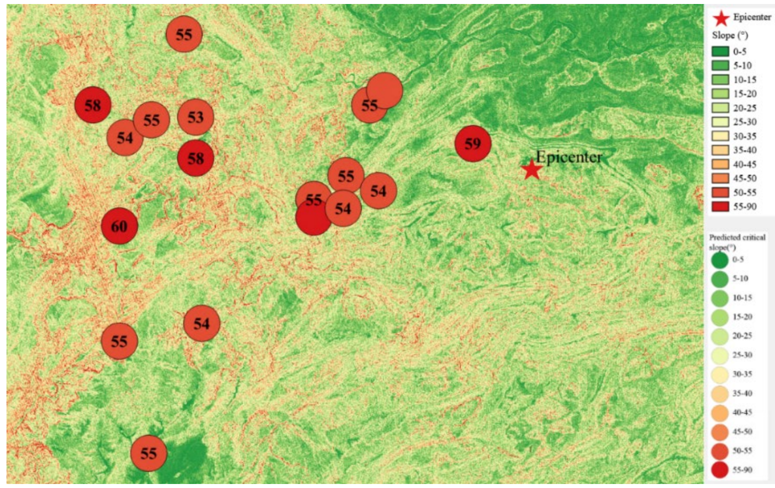
Other than buildings, several major roads were damaged including the official Xinhua News agency reports of damage to the highway between Yibin city and Xuyong county. In Chengdu, about 300km (186 miles) away from the epicenter, an early warning system triggered a siren that sounded across the city about a minute before the earthquake struck, as reported by the Xinhua News agency (BBC News, 2019). Residents in the city of Yibin, which is close to the epicenter, received alarms 10 seconds before the earthquake hit (China Focus, 2019). As commonly known, the earthquake early warnings are more effective in locations farther from the source of an earthquake, while the main advantage in the near-fault areas is the automated operations, such as train slow down/emergency braking or gas valves closure. The early warning triggered in Chengdu during this earthquake is a good indication of the benefits of earthquake early warning systems and the importance of their wide adoption.

On-the-ground reports documented several landslides after the earthquake. Figure 7 shows the aftermath of a landslide that had blocked a road and left a lorry engulfed in debris (BBC News, 2019).

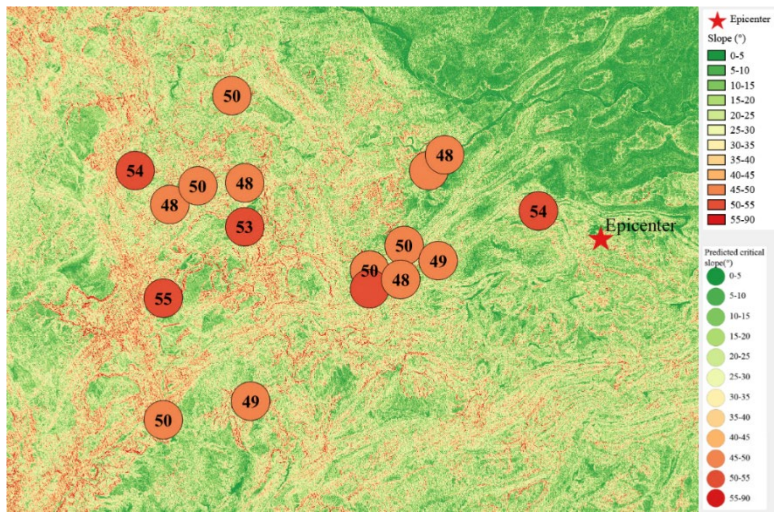
According to local topographic data, lithology data and the recorded ground motion records, the distribution of earthquake-induced landslide near different ground motion stations for different ratios of saturated soils are projected in Figure 8 using the Real-time Earthquake Damage Assessment using City-scale Time history analysis (RED-ACT, Lu et al., 2018): the basemap shows the distribution of the local slope, and the number in the circle represents the critical slope of the landslide. Earthquake-induced landslides tend to occur with a higher probability when the slope is larger than this threshold value.

Figure 7. Aftermath of a landslide that had blocked a road and left a lorry engulfed in debris (BBC News, 2019).

Saturated soil ratio of 0%:



Saturated soil ratio of 50%:



Saturated soil ratio 90%:

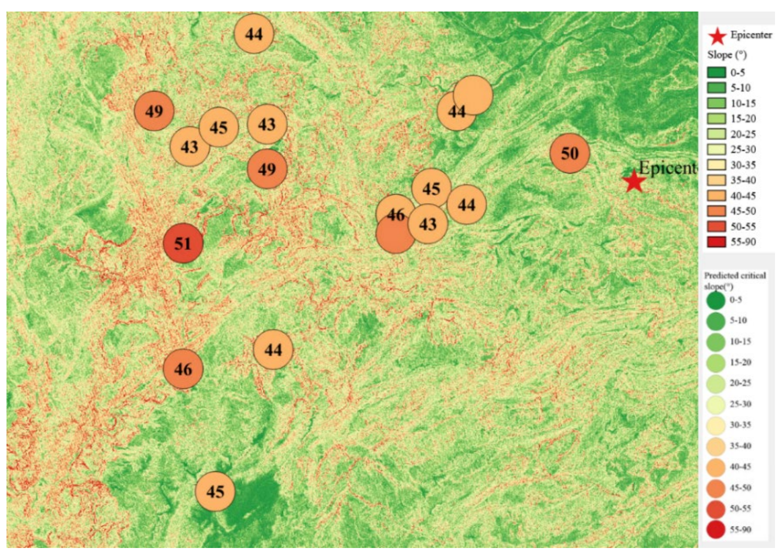


Figure 8. Estimation of the likelihood of earthquake-induced landslide near different stations for different levels of soil saturation (Lu et al., 2018)

References

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Appendix: Strong Motion Recording Stations

Table A1. Names and locations of the strong motion stations

No.	Station Name	Longitude	Latitude
1	L3301	103.72	28.8
2	L3304	103.41	28.56
3	W3702	103.76	28.52
4	W3703	103.52	28.45
5	W3707	103.76	28.38
6	W3709	103.5	28.15
7	W3713	103.61	28.51
8	C0206	103.6	27.38
9	C0207	103.71	27.21
10	C2301	104.16	28.24
11	C2303	104.16	28.18
12	C2308	104.27	28.32
13	C2309	104.38	28.27
14	C2311	104.26	28.21
15	C2406	103.78	27.82
16	C2505	103.5	27.76
17	C3003	104.35	28.56
18	C3004	104.4	28.61
19	51FSB	104.79	29.12
20	51YBG	104.4	28.8
21	51YBT	104.57	28.71
22	51YBY	104.56	29.02
23	51GXT	104.70	28.43