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SHORT COMMUNICATION

The earthquake in Jiuzhaigou County of Northern Sichuan, China on August 8, 2017

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Abstract Jiuzhai Valley National Park in the Aba Tibetan and Qiang Autonomous Prefecture of northern Sichuan, China, is well renowned both at home and abroad as "World Natural Heritage," "Man and Biosphere Conservation Network" and "National GeoPark of China." An earthquake with a magnitude of 7.0 struck Jiuzhaigou County on the evening of August 8, 2017. Its focal depth was 20 km and followed thousands of aftershocks. The earthquake had affected 17 townships and 120 villages in varying degrees. By the 8 p.m. on August 13, the death toll of the earthquake reached 25, with 525 injured. Being formerly described as "Fairy tale world," "King of waterscape," the beautiful scenic spot now had become "scars of wounds strung together like beads," and some of the beauty even disappeared. In this short communication, the incident background, casualties and scene are presented. Moreover, a brief investigation on the cause and seismic damage capacity of the earthquake as well as the earthquake early warning is conducted.

Keywords Natural disaster · Earthquake · Jiuzhai Valley National Park · Incident scene · Casualties · Seismic damage capacity · Earthquake early warning

1 Introduction

China locates in the southeast of Eurasia and between the two major seismic belts in the world, the Eurasian seismic belt and the circum-Pacific seismic belt (Liu et al. 2014; Gorum et al. 2011; Wu et al. 2017). Due to the compression of the Pacific plate, the Indian

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plate and the Philippines plate, the geological structures are complicated, while the seismic fault zones are well developed in China. Consequently, it is a country with severe earthquake disasters, which are characterized by high frequency, heavy intensity, shallow epicenter and extensive distribution and so on (Cui et al. 2017; Li et al. 2015; Lai et al. 2015, 2016b, d). Compared with the global large seismic activities, the seismicity with MS 7.0 or above in China and its neighboring regions has characteristics of quasi-synchronous evolutions (Li et al. 2017; Lai et al. 2017). Since 2008, continuous earthquakes occurred, which indicated that the mainland China has entered a newly active period of seismic activities (An et al. 2010; Lai et al. 2018).

China's land area accounts for 7% of the global land area, while the population accounts for about 20% of the total world population. However, China has to bear about 33% of the successive earthquakes occurred in the world, resulting in the number of people killed by these earthquakes reached more than 50% of all global earthquake death (Qiu et al. 2017, 2018a, b; Zhou et al. 2017). China has suffered serious damage and losses in numerous disasters. In China, the potential seismic activities are mainly distributed on 23 seismic belts in four seismic regions. The four seismic regions are: 1 southeastern Taiwan and coastal Fujian Province; 2 along Taihang Mountains in North China; 3 the Tibetan Plateau and its marginal Sichuan Province in southwest China; 4 Xinjiang, Gansu and Ningxia provinces in western China (Fig. 1) (Cui et al. 2011; Lai et al. 2016a, c; Zhao and Xu 2014). There is a dense seismic belt, called "*north–south seismic belt,*" with an approximate north–south orientation that runs through the mainland China, originating

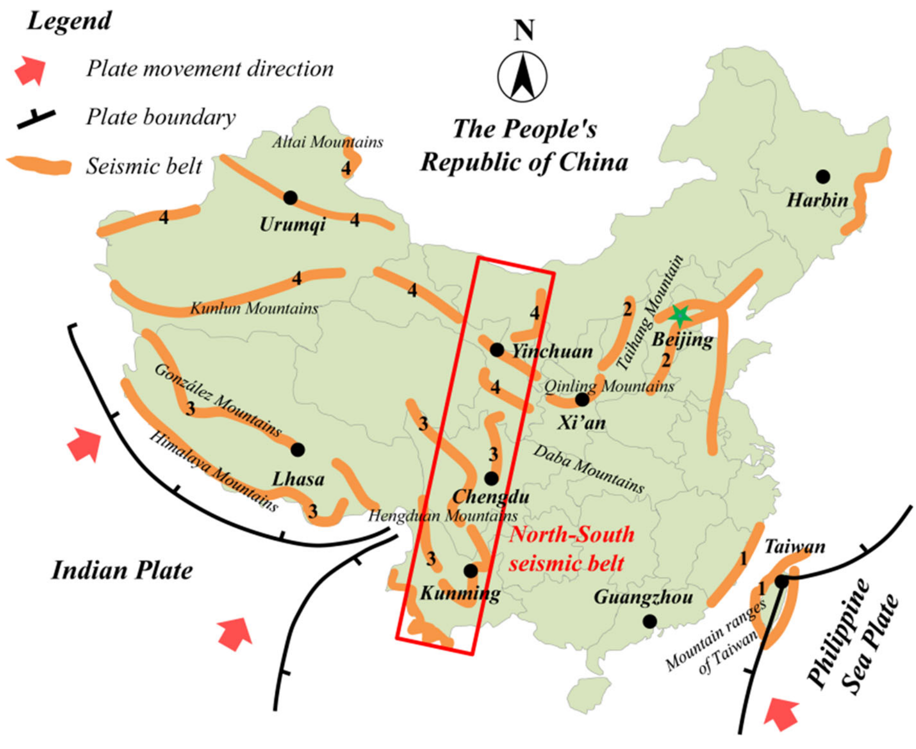

Fig. 1 Distribution of seismic belts in China. (Zhao and Xu 2014). Modified from "Why is the Sichuan earthquake so frequent?" in National Geographic. *Source*: http://www.nationalgeographic.com.cn/

from Ningxia Province, throughout eastern Gansu and Qinghai provinces, ending in Yunnan and Sichuan provinces. Historically, in this active belt, a series of destructive disasters emerge, including the most devastating earthquakes, such as the 2008 Wenchuan earthquake and 2010 Yushu earthquake (Zhang et al. 2010; Lai et al. 2014; Zhao and Xu 2014). The Eurasian plate is constantly squeezed by the Indian plate, causing a subduction of the Indian plate to northern region and thus making these belts active (Fig. 1).

2 Incident background and geological features

The report from China Earthquake Networks Center, at 9:19:46 p.m. (UTC + 08:00) on the evening of August 8, 2017, an earthquake with a magnitude of 7.0 occurred in Jiuzhaigou County (33.20°N, 103.82°E), about 210 km away from the Aba Tibetan and Qiang Autonomous Prefecture (Fig. 2). The average elevation of the epicenter around 5 km was about 3827 m. This earthquake was obviously felt in the Gansu, Sichuan, Qinghai, Ningxia and Shaanxi provinces while strongly felt in some surrounding areas of the epicenter.

Jiuzhaigou County, with an area of 5290 km^2, lies on the eastern Tibetan Plateau and in the territory in the southeast lower, northwest higher than the moderate middle, and belongs to a humid plateau climate, in which Jiuzhai Valley National Park is a famous tourist attraction in China as well as foreign countries. It is the national key scenic spot and the first nature reserve to protect the natural scenery as the main purpose in China. It was declared a UNESCO World Heritage Site in 1992; the park joined the Man and Biosphere Conservation Network in 1997 and has also received IUCN and ISO 14,001 accreditations

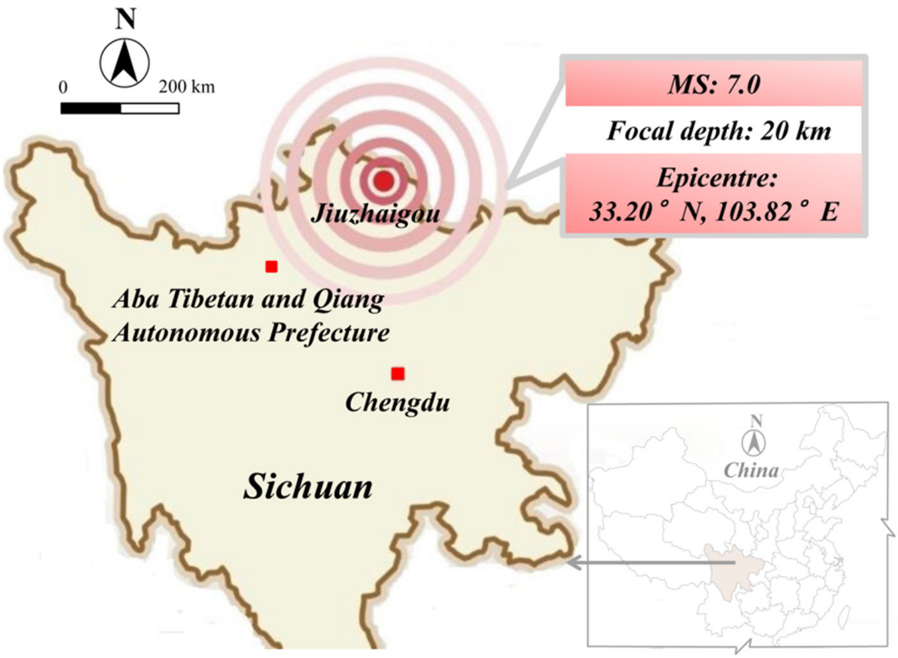

Fig. 2 Overview of Jiuzhaigou earthquake. *Source*: China Earthquake Networks Center http://www.cenc.ac.cn/

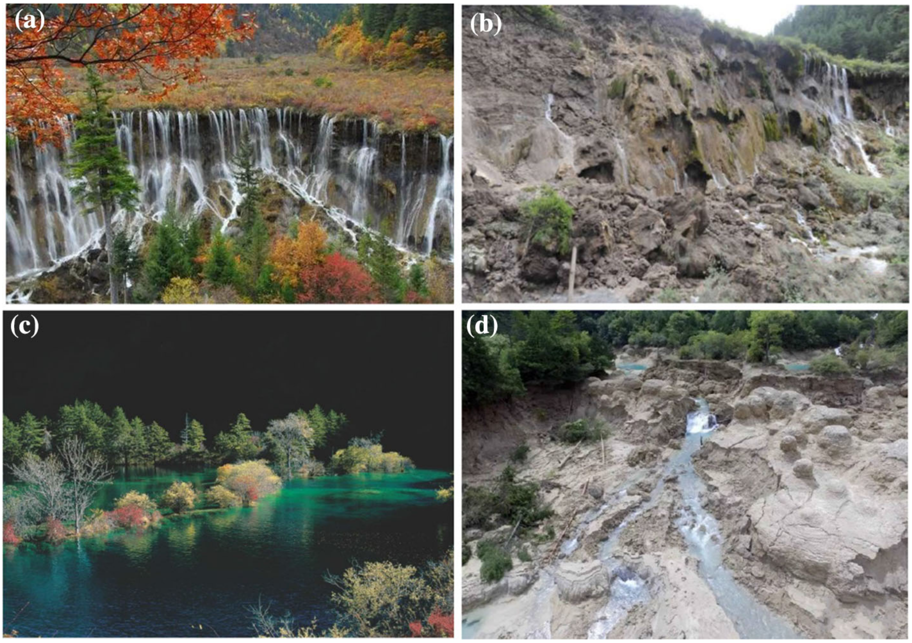

Fig. 3 Scenic spots in Jiuzhai Valley National Park before and after earthquake. **a**, **b** The Nuorilang Waterfall before and after earthquake; **c**, **d** the Sparkling Lake before and after earthquake. *Sources*: http://www.chinanews.com/ and http://www.people.com.cn/

(Fig. 3). Because the park location is in the transition zone from Tibetan Plateau to Sichuan Basin, its geological conditions are extremely complicated, carbonates are widely distributed, fold and fracture are developed, neotectonic movements are intense and crust uplift is large, which have created various landforms and developed large-scale tufa deposition of karstification.

The earthquake occurred in the north margin of Bayan Har block, which has already become the mainly active areas of the earthquakes in the western China since 1976 (Kappes et al. 2012; Kagan 2017; Ni et al. 2015; Yang et al. 2017). The series of recent earthquakes, such as the earthquake with MS 7.1 in 2010 in Qinghai Province and the earthquake with MS 7.0 in 2013 in Sichuan Province, are the result of the movement of the Bayan Har block. Historically, there were 26 earthquakes above MS 5 in the areas within 200 km of this epicenter. The nearest one was the earthquake with MS 6.5 occurred on August 11, 1973; the latest one was the earthquake with MS 6.6 on July 22, 2013, about 42 and 149 km away from the epicenter of the Jiuzhaigou earthquake, respectively.

3 An overview and brief investigation of the earthquake

3.1 Incident scene

The latest bulletin from Jiuzhaigou Earthquake Relief Headquarters confirmed that, by 8 p.m. on August 13, the earthquake had affected 17 townships and 120 villages in varying degrees and approximately 10,910 houses were seriously affected while 44,129 people were generally affected, causing 25 people died and 525 injured. In severely affected areas, some housing units were collapsed while the power, communications and road traffic were seriously affected in the epicenter (Fig. 4).

The earthquake had produced a greatly negative impact on the Jiuzhai Valley National Park. Infrastructures in scenic area were severely damaged, and some of the attractions even had passed out of existence. The most serious damage attractions are the Sparkling Lake and the Nuorilang Waterfall. In particular, the Sparkling Lake had dried up and there were many landslides along the rocky shore while massive collapse occurred in Nuorilang Waterfall (Fig. 3). The roads in the scenic area had been broken and blocked, and collapse of the mountain and the slope could be seen everywhere. Moreover, due to the serious damage of surrounding mountains, secondary disasters such as collapse, landslide and mudslides as well as other ones may occur at any time.

3.2 Emergency response and rescue

After earthquake, Sichuan Provincial People's government immediately established the emergency response center; the National Disaster Reduction Commission and the Ministry of Civil Affairs urgently launched the level-III emergency response; and joint working group, composed of National Disaster Reduction Commission and the National Headquarters for Earthquake Disaster Mitigation, firstly rushed to the disaster area to supervise rescue and relief work. The Central Military Commission sent the national disaster emergency rescue teams to perform emergency rescue missions in the earthquake areas. In addition, the following rescue works were also carried out: (1) personnel search and rescue

Fig. 4 Maps of damages after Jiuzhaigou earthquake. **a** Bus damaged by falling rocks; **b** infrastructure damage in scenic spot; **c** road collapse; **d** house damage. *Sources*: http://www.xinhuanet.com/, http://www.chinanews.com/ and China Earthquake Administration http://www.cea.gov.cn/

covered all areas; (2) concentrate on the wounded treatment; and (3) timely repairs on roads, power and communications as well as other infrastructure (Fig. 5). China Earthquake Administration established on-site task teams, emergency deployment of mobile observation and conducted mobile observations for earthquake disasters urgently. China Earthquake Administration built an emergency working group to provide emergency weather support services, and investigation of geologically secondary hazards induced by earthquake was also conducted timely. A large number of volunteers flocked into the disaster areas to provide rescue and assistance; various relief supplies were provided by caring people, groups and institutions. All these efforts will be the signification parts of post-earthquake reconstruction.

3.3 Cause of the earthquake

In recent years, a series of earthquakes occurred in Sichuan Province, such as the 2008 Wenchuan earthquake and the 2013 Lushan earthquake, including this 2017 Jiuzhaigou earthquake. In the past 9 years, three earthquakes with MS above 7.0 had struck the "Nature's storehouse"—Sichuan Province. The main reason is the movement of the Songpan fault, Mingjiang fault, Huya fault and Songpinggou fault, which created by the eastward slipping of the Bayan Har block. These faults come into being surround the Longmen Mountain, and this seismic zone is also called as "Eastern Tectonic Belt of the Tibetan Plateau" (Zhang et al. 2010).

The tremendous percussion force of the Indian plate collided with the Eurasian plate, resulting in the persistent uplift in the Tibetan Plateau and the Himalaya mountains while the Tibetan Plateau is moving to north and northeast under the force. And this force is

Fig. 5 Rescue operation scenes. **a** Road dredging; **b** earthquake disaster exploration; **c** medical assistance; **d** people relocation. *Sources*: http://news.cctv.com/, http://www.chinanews.com/ and http://www.people.com.cn/

dispersed toward Yunnan Province when the Tibetan Plateau runs into the hard and ancient Sichuan Basin during its movement. Accordingly, Sichuan and Yunnan provinces become the regions with the most earthquakes in mainland China. The previous Wenchuan earthquake, the Songpan earthquake and the Pingwu earthquake as well as the Jiuzhaigou earthquake, all occurred in this tectonic belt. In general, it is the concentrated release of earth crust stress in this belt that brings frequent earthquakes in Sichuan.

For the Jiuzhaigou earthquake, the focal mechanism of the earthquake is the horizontal fault pushing occurred near Minjiang fault, Tazang fault and Huya fault, i.e., strike-slip-type earthquake (Fig. 6). It is the most common earthquake type in mainland China. Correspondingly, it is supposed that the seismogenic structure was south branch of the Tazang fault and north part of the Huya fault.

3.4 Destructive analysis of the earthquake

In addition to destruction and possibly secondary disasters in the scenic spots, local building damage caused by the earthquake is also an important part of the disaster assessment and reconstruction. Based on the data in this earthquake and data accumulated previously as well as *Earthquake Disaster Stimulation V0.93* system (developed by Institute of Engineering Mechanics, China Earthquake Administration), the seismic data from the Bai River seismic station (the one closest to the epicenter) were inputted into the system stimulating typical building structures in countryside, villages and towns in seismic areas by Dr. Lu's team of Tsinghua University. The results of building conditions are shown in Fig. 7. (*Sources*: http://www.sciencenet.cn/ and http://mp.weixin.qq.com/s/yRwKxoggFYgCdsiClOXYRQ).

As shown in the simulation study of earthquake intensity that is same to this earthquake, the damage ratio of building in moderate or more seriously is approximately 70% in villages and towns while that is approximately 98% in countryside, which was indicated by the actual site situations of the disaster. The reason is that the buildings in villages or towns have better anti-seismic performance than those in countryside. Moreover, in Jiuzhaigou County region, there are 9 potential deformation points which became more seriously while 33 new points were found as a result of the earthquake.

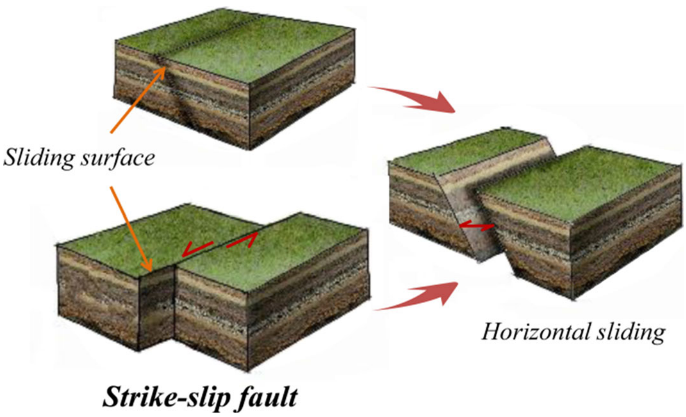

Fig. 6 Diagrammatic sketch of the strike-slip-type earthquake

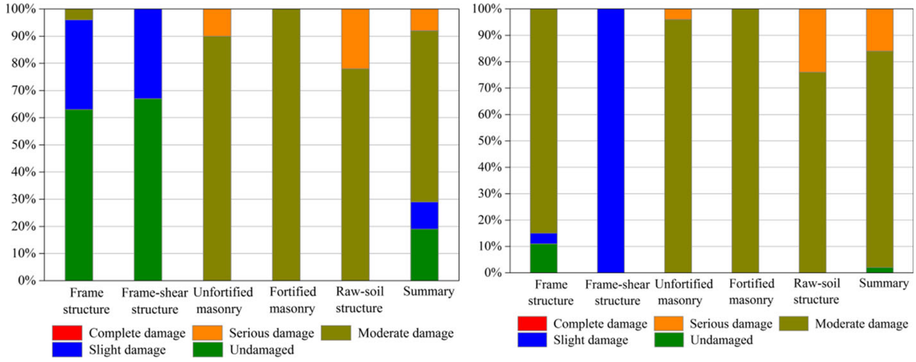

Fig. 7 Destruction of buildings in different regions. The left side provides the building conditions in villages and towns; the right side provides the building conditions in countryside. *Source*: http://mp.weixin.qq.com/s/yRwKxoggFYgCdsiClOXYRQ

4 Discussion and summary

Sichuan Province locates in the seismically active region of mainland China. The earthquake damages in history had been prominent, and this situation is still severe at present. Timely warning before earthquake is crucial to reduce economic losses and casualties in seismic areas, while pre-earthquake warning now is still a worldwide problem. Adequate response time before earthquake coming particularly can effectively guarantee evacuation and reduce casualties. In this serious earthquake disaster, its necessity and remarkable effect were verified by earthquake early warning system (EEWS), which was initiated by the 2008 Wenchuan earthquake and developed by Institute of Care-life (ICL) in Chengdu, Sichuan Province (Fig. 8).

EEWS, a system based on a network including monitoring stations for seismic waves, by using the fact that the electric wave speed is much faster than the S waves speed, can give seconds to dozens of seconds warning time prior to the arrival of S waves. The obtained warning information includes the estimated intensity and arrival time of S waves as well as the estimated magnitude and location of the epicenter. In Jiuzhaigou earthquake,

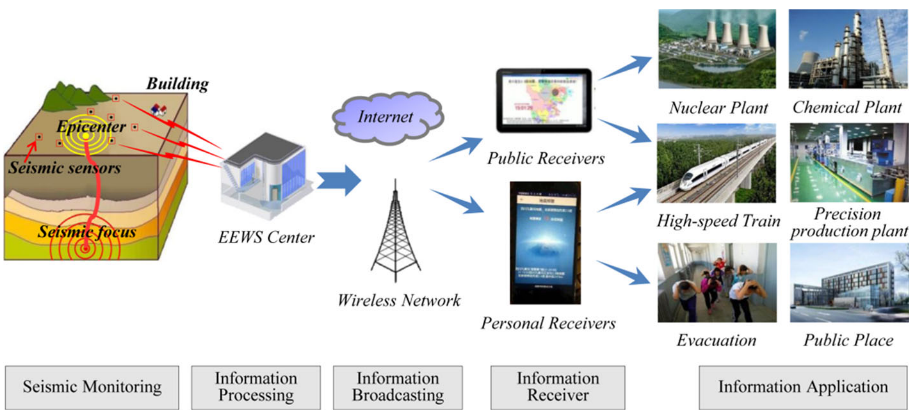

Fig. 8 Sketch map of the EEWS. Modified from Institute of Care-life, http://www.365icl.com/

19, 48, 49, 71 s before the earthquake waves spread to Longnan City in Gansu Province, Aba Tibetan and Qiang Autonomous Prefecture, Mianyang, Chengdu, respectively, the EEWS released warning information through various means such as computers, micro-blog and special acceptance equipment, which was beneficial to reduce the disaster damage.

In addition, based on the aforementioned statements, the following conclusions can be drawn: As shown in the aforementioned destructive study, reasonable building structure and fortification standards can effectively reduce the extent of earthquake damage and accelerate post-disaster reconstruction. For example, the traditional brick-wood buildings were damaged seriously and even collapsed, while the fortified and frame-structured buildings were damaged lightly.

Jiuzhai Valley originated from the quake lakes, which was formed by a violent earthquake in the region hundreds of years ago. These lakes constitute current beautiful sceneries, while they also illustrate that historical earthquakes were very frequent. The earthquake caused serious damage to the infrastructure and tourist spots (e.g., the Sparkling Lake and the Nuorilang Waterfall) and had a great impact on the locally natural landscapes and ecological environment. Because the Jiuzhaigou earthquake was located on the concentrated fault belts and morphologically abnormal zone, secondary disasters such as collapse, landslide and debris flow may occur after earthquake. Hence, the potential dangers of these secondary disasters to tourism security need to be investigated and prevented.

In seismic regions of Sichuan Province, the capability for earthquake prevention and disaster reduction has been continuously improved in recent years. The aseismic fortification level of building is higher, and aseismic performance is much better than ever before. The frame and frame-shear structures are mostly adopted in urban buildings, while the through-type timber frame is adopted in the traditionally rural houses; all of these improve aseismic performance of the buildings. The proportion of collapsed and badly damaged houses is pretty low, which effectively reduces casualties. Earthquake-induced casualties and building damage are far lower than the same level of earthquakes, such as Yushu earthquake with MS 7.1, Lushan earthquake with MS 7.0 and Ludian earthquake with MS 6.5. Particularly, after the Wenchuan earthquake, the new buildings after restoration and reconstruction have met the requirements of seismic fortification and damage. Moreover, in Sichuan Province, the local government and other related departments have strengthened seismic management and guidance of residential buildings in recent years, which showed success in this earthquake.

Therefore, the necessary methods for seismic prevention are significant and effective. The government should pay more attention to housing construction, establish appropriate earthquake prevention plans and set earthquake-resistant fortification standards according to historical data of local earthquakes. In the potential earthquake disaster areas, emergency shelters should be established and emergency drills for disaster prevention should be strengthened, enhancing national awareness of disaster prevention and avoidance.

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