Analysis of catastrophic earthquake characteristics and countermeasures in China

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Abstract: Using the 2000-2020 Chinese earthquake disaster population death data as the research object, we conducted an analysis of the characteristics and causes of earthquake disaster population death in mainland China, and put forward targeted countermeasure suggestions for earthquake disaster mitigation.

1. The basic situation of catastrophic earthquakes in China

Since the founding of the People's Republic of China in 1949, earthquakes have accounted for more than 50% of the deaths from all types of natural disasters. Earthquakes cause incalculable damage and loss to people's lives and properties. The work of earthquake prevention and mitigation has a long way to go, and how to further reduce earthquake disasters, especially to reduce casualties, has become a topic of concern [1-5]. This paper presents the first summary, statistical and characterization analysis of catastrophic earthquakes in China, with problem-oriented recommendations to further reduce human casualties.

The catastrophic earthquakes described in this paper are those that result in human fatalities. Table 1 gives the statistics of earthquakes with fatalities in China from 2000 to 2020, with a cumulative frequency of 62 and an annual average of nearly 3. Three earthquakes in some of China's offshore waters and neighboring countries also caused fatalities, as shown in Table 1 for earthquake disasters with serial numbers 35, 48, and 49. Earthquakes in China killed 73,853 people in 21 years, an average of 3,517 people per year. The smallest earthquake that caused fatalities was a 3.4 magnitude earthquake on January 17, 2010 at the junction of Zhengfeng, Guanling and Zhenning in Guizhou, which killed six people. The largest earthquake to cause fatalities was the 8.1 magnitude earthquake in Nepal, which killed 27 people in the Tibetan region of China. The earthquake that caused the most deaths was the Wenchuan 8 magnitude earthquake in Sichuan on May 12, 2008, which killed 69,227 people. The number of earthquakes with less than 50 fatalities was 54, or 87.1%. The number of earthquakes with a death toll greater than (including equal to) 50 people and less than 100 people was 2, or 3.2%. The number of earthquakes with a death toll greater than (including equal to) 100 people less than 500 people was 3, or 4.8%. The number of earthquakes with a death toll greater than (including equal to) 500 was 3, or 4.8%.
Table 1  List of earthquakes with fatalities in China, 2000-2020

| No. | Moment of earthquake onset (Beijing time) | Latitude /° | Longitude/° | Depth of earthquake /km | Magnitude /M | Location of the earthquake | Deaths/numbers |
|-----|-----------------------------------------|-------------|-------------|-------------------------|--------------|----------------------------|----------------|
| 1   | 2000/1/15 7:36 | 25.6 | 101.1 | 30 | 6.5 | Yaoan, Yunnan | 7 |
| 2   | 2000/4/29 11:54 | 33.2 | 112.1 | 16 | 4.2 | Nanyang, Henan | 1 |
| 3   | 2000/8/21 21:25 | 25.8 | 120.2 | 0 | 5.1 | Wudin, Yunnan | 2 |
| 4   | 2001/2/23 8:09 | 29.7 | 101.2 | 6 | 6 | Yajiang, Sichuan | 3 |
| 5   | 2001/4/12 18:47 | 24.8 | 99.02 | 5 | 5.9 | Shidian, Yunnan | 4 |
| 6   | 2001/5/24 5:10 | 28 | 101.5 | 5 | 5.8 | Border between Yangyuan County, Sichuan and Ninglang County, Yunnan | 1 |
| 7   | 2001/10/27 13:35 | 26.2 | 100.6 | 15 | 6 | Yongsheng, Yunnan | 1 |
| 8   | 2002/12/14 21:27 | 39.8 | 97.33 | 22 | 5.9 | Southwest of Yumen, Gansu | 2 |
| 9   | 2003/2/24 10:03 | 39.6 | 77.27 | 20 | 6.8 | Border between Batu County and Gashi County, Xinjiang | 268 |
| 10  | 2003/7/21 23:16 | 26 | 101.2 | 6 | 6.2 | Dajao, Yunnan | 16 |
| 11  | 2003/8/16 18:58 | 43.9 | 119.9 | 20 | 5.9 | Border between Barinzuo Banner and Aruqorqin Banner, Chifeng City, Neimenggu | 4 |
| 12  | 2003-1016 20:28:05 | 25.9 | 101.3 | 5 | 6.1 | Dajao, Yunnan | 3 |
| 13  | 2003/10/25 20:41 | 38.7 | 101.3 | 33 | 6.1 | Border between Minle County and Shandan County, Gansu | 10 |
| 14  | 2003/11/13 10:35 | 35.2 | 104.5 | 22 | 5.2 | Minxian, Gansu | 1 |
| 15  | 2004/3/24 9:53 | 45.4 | 118.4 | 5 | 5.9 | Dongwuqi, Neimenggu | 1 |
| 16  | 2004/8/10 18:26 | 27.2 | 103.6 | 10 | 5.6 | Southeast of Ludian, Yunnan | 8 |
| 17  | 2004/12/26 15:30 | 24.7 | 101.5 | 7 | 5 | Shuangbai, Yunnan | 1 |
| 18  | 2005/7/25 23:43 | 47.5 | 125 | 16 | 5.1 | Lindian, Heilongjiang | 1 |
| 19  | 2005/10/27 19:18 | 23.6 | 107.6 | 9 | 4.4 | Pingguo, Guangxi | 1 |
| 20  | 2005/11/26 8:49 | 30.2 | 116.2 | 11 | 5.7 | Border between Jiuzhang County and Ruichang City, Jiangxi | 13 |
| 21  | 2006/5/21 0:52 | 33.1 | 104.9 | 33 | 5 | Wexian, Gansu | 1 |
| 22  | 2006/7/22 9:10 | 28.2 | 104.1 | 9 | 5.1 | Yanjin, Yunnan | 22 |
| Date       | Time  | Latitude | Longitude | Depth | Magnitude | Location                          |
|------------|-------|----------|-----------|-------|-----------|-----------------------------------|
| 2006/8/25  | 13:51 | 104.1    | 7         | 5.1   | Yanjin, Yunnan | 2 |
| 2007/6/3   | 5:34  | 23.1     | 6         | 6.7   | Ninger, Yunnan | 3 |
| 2008/5/12  | 14:28 | 31       | 14        | 8     | Wenchuan, Sichuan | 69227 |
| 2008/8/21  | 20:24 | 24.9     | 14        | 5.9   | Yingjiang, Yunnan | 5 |
| 2008/8/30  | 16:30 | 26.3     | 19        | 6.3   | Sichuan Renhe District and Huili County border | 41 |
| 2008/10/6  | 16:30 | 29.8     | 11        | 6.7   | Dangxiong, Xizang | 10 |
| 2009/7/9   | 19:19 | 25.6     | 6         | 6.3   | Yaoan, Yunnan | 1 |
| 2009/8/8   | 21:26 | 29.4     | 5         | 4.4   | Rongchang, Chongqing | 2 |
| 2010/1/17  | 17:37 | 25.6     | 7         | 3.4   | Junction of Zhengfeng, Guanling and Zhenning, Guizhou | 6 |
| 2010/1/31  | 5:56  | 30.3     | 10        | 5     | Sichuan Sinming City and Chongqing Tongnan County border | 1 |
| 2010/4/14  | 7:49  | 33.2     | 14        | 7.1   | Yushu, Qinghai | 2968 |
| 2011/3/10  | 12:58 | 24.7     | 10        | 5.8   | Yingjiang, Yunnan | 25 |
| 2011/9/18  | 20:40 | 27.7     | 20        | 6.8   | Sikkim, India | 7 |
| 2012/6/24  | 8:15  | 27.7     | 10        | 5.7   | Ninglang, Yunnan | 4 |
| 2012/7/20  | 20:11 | 30.1     | 5         | 4.9   | Gaoyou, Jiangsu | 1 |
| 2012/9/7   | 11:19 | 27.5     | 10        | 5.7   | Yiliang, Yunnan | 81 |
| 2013/4/20  | 8:02  | 30.3     | 13        | 7     | Lushan, Sichuan | 196 |
| 2013/7/22  | 7:45  | 34.5     | 20        | 6.6   | Minxian, Gansu | 95 |
| 2013/8/31  | 8:04  | 28.2     | 10        | 5.9   | Shangri-La, Yunnan | 3 |
| 2014/8/3   | 16:30 | 27.1     | 10        | 6.5   | Ludian, Yunnan | 617 |
| 2014/10/7  | 21:49 | 23.4     | 10        | 6.6   | Jinggu, Yunnan | 1 |
| 2014/11/22 | 16:55 | 30.3     | 20        | 6.3   | Kangding, Sichuan | 5 |
| 2014/12/6  | 18:20 | 23.3     | 10        | 5.9   | Jinggu, Yunnan | 1 |
| 2015/3/14  | 14:13 | 33.1     | 10        | 4.2   | Fuyang, Anhui | 2 |
| 2015/4/15  | 8:35  | 35.4     | 9         | 4.5   | Lintao, Gansu | 1 |
| 2015/4/20  | 9:42  | 24.1     | 10        | 6.4   | Sea off Hualien County, Taiwan | 1 |
| 2015/4/25  | 14:11 | 28.2     | 20        | 8.1   | Nepal (Xizang disaster area) | 27 |
| 2015/7/3   | 9:07  | 37.6     | 10        | 6.5   | Pishan, Xinjiang | 3 |
| 2016/2/6   | 3:57  | 22.9     | 15        | 6.7   | Gaoxiong, Taiwan | 117 |
| 2016/10/17 | 15:14 | 32.9     | 9         | 6.2   | Zhaodao, Qinghai | 1 |
2. Characteristic analysis of human fatalities in catastrophic earthquakes in China

The probability statistics of 11 catastrophic earthquakes with different magnitude classes causing fatalities between 2000 and 2020 are given in Table 2. As can be seen from Table 2, the probability of fatalities caused by earthquakes of magnitude less than 5 in mainland China and Taiwan is less than 1%, and the probability of fatalities caused by earthquakes increases gradually with the increase in magnitude. During this period, there were two earthquakes of magnitude 8 or higher, except for the Wenchuan 8 magnitude earthquake in Sichuan on May 12, 2008, which caused serious casualties and property damage, and the other one was the 8.1 magnitude earthquake that occurred on November 14, 2001, at the border of Xinjiang and Qinghai. The earthquake was felt by people, but no casualties were caused. Figure 1 gives the statistics of the change in human fatalities with increasing magnitude of earthquakes in mainland China and Taiwan between 2000 and 2020, and it can be seen from Figure 1 that there is an exponential increase in the number of fatalities with increasing magnitude. Figure 2 shows the distribution of the number of fatalities over time for different magnitudes of earthquakes, from which it can be seen that the number of fatalities does not decrease over time for most magnitudes.

There are two main reasons for the fatality characteristics in Figure 2. First, a significant percentage of houses in China have not yet met the requirements for seismic protection. The earthquake hazard in China is severe, with more than 58% of the continent’s land area and nearly 55% of the population in a high seismic risk zone of 7 degrees or higher. With China’s urbanization rate exceeding 60% in 2019, a large number of buildings built during the rapid urbanization phase are at risk of concentrated “aging”; a large number of large high-rise settlements built in the 1990s and early 21st century have gradually exceeded or reached 30 years of age and are in urgent need of seismic strengthening; nearly 19 billion square meters of houses in rural areas have not yet met seismic requirements. In rural areas, nearly 19 billion square meters of houses have not yet met the seismic requirements. As a result some earthquakes of low magnitude caused casualties still occur. Second, the public’s awareness and ability to prevent and mitigate disasters is insufficient. The public’s awareness of earthquake safety risks and crises is still not strong, and the knowledge and ability to deal with earthquake disasters still needs further improvement.

| Table 2 | Statistics on the probability of catastrophic earthquakes with different magnitude classes causing fatalities from 2000 to 2020 |
|----------|----------------------------------------------------------------------------------------------------------------|
| Magnitude (M) | Frequency of earthquakes causing fatalities | Actual frequency of earthquakes | Percentage of earthquakes with fatalities (%) | Instructions for using the material |
| 3.0-3.4 | 1 | 3474 | 0.03 | Mainland China |
| 3.5-3.9 | 0 | 2161 | 0 | Mainland China |
| Magnitude Class | Count | Casualties | Fatality Rate | Location |
|----------------|-------|------------|---------------|----------|
| 4.0-4.4        | 4     | 1409       | 0.03          | Mainland China |
| 4.5-4.9        | 3     | 353        | 0.9           | Mainland China |
| 5.0-5.4        | 10    | 338        | 3             | Mainland China and Taiwan |
| 5.5-5.9        | 15    | 115        | 13            | Mainland China and Taiwan |
| 6.0-6.4        | 10    | 48         | 20.8          | Mainland China and Taiwan |
| 6.5-6.9        | 12    | 28         | 42.9          | Mainland China and Taiwan |
| 7.0-7.4        | 3     | 8          | 37.5          | Mainland China and Taiwan |
| 7.5-7.9        | 0     | 0          | 0             | Mainland China and Taiwan |
| 8.0-8.4        | 1     | 2          | 50            | Mainland China and Taiwan |

Figure 1  Statistics of deaths caused by earthquakes in mainland China and Taiwan during 2000 to 2020

Figure 2  Distribution of the number of deaths caused by five earthquakes with different magnitude classes over time

3. Suggestions and Measures to Reduce Earthquake Disasters in China

The number of deaths caused by an earthquake is related to the intensity of the earthquake, the seismic performance of buildings, the distribution of the population, the socio-economic situation, the physical and geographical environment, the public awareness of earthquake prevention and mitigation, etc. The higher the intensity of the earthquake, the more serious the casualties it may cause. The geography and population density of the earthquake location have a large impact on the scale of the disaster; The number of collapsed houses and buildings directly affects the number of casualties; geological secondary disasters such as landslides and avalanches can aggravate casualties and economic losses; if people have the awareness and knowledge, methods and skills to deal with earthquake disasters, it is possible to achieve the goal of reducing casualties in the same disaster environment.

(1) Take strong measures to grasp the seismic protection of buildings is the fundamental way to reduce the earthquake disaster. Statistics show that 95% of the total number of casualties caused by earthquakes are caused by the collapse of buildings, so the killer is not the earthquake but the building. The specific measures include: ① All types of projects should be sited to avoid active faults. Strengthen the seismic safety management of new expansion projects, from the project site selection on the
gatekeeper, avoiding seismic activity fault zone. For major projects, lifeline projects and projects prone to serious secondary disasters, seismic safety evaluation must be carried out. Various types of architectural design documents require increased seismic content to ensure the quality of seismic engineering. For super high-rise buildings must be seismic special review. ②Reasonably determine the seismic parameters and moderately improve the seismic standards. China's seismic protection standards are significantly lower than those of other developed countries, and in areas where the national seismic intensity is above VII degrees, and in and around areas that are classified as key national seismic surveillance and defense zones, the design of new expansion projects, especially schools, hospitals, key departments and other densely populated units, should be 1 degree higher than the general building design when designing seismic intensity. In the construction plan review, adhere to the seismic design review veto system, where the seismic intensity design level does not meet the requirements of the project, all returned to redesign, re-approval. The school at all levels as a place of refuge from earthquakes and comprehensive urban disaster prevention. Minimize earthquake disaster losses. ③Carry out seismic hazard risk surveys and key hidden danger investigation projects, especially to strengthen old houses in urban and rural areas prone to earthquakes, strictly implement the fifth generation of zoning maps, and comprehensively improve the seismic performance of all types of houses. ④Improve the seismic resistance of rural dwellings. Strengthen the seismic resistance of agricultural houses. In the construction of rural revitalization, the seismic resistance of rural houses should be taken as an important element. Strengthen the construction of the supervision system of rural housing construction, especially the self-built houses, and focus on guiding farmers to build houses according to the design drawings to ensure that the newly-built farmers' houses meet the seismic requirements set by the state.

(2) Establish an earthquake early warning mechanism. Targeted and predictable measures are taken to reduce the degree of damage, so as to achieve the purpose of prevention before it is too late. If it takes some time for seismic waves to propagate, informing neighboring areas at the first time of an earthquake can effectively reduce all kinds of losses. When the earthquake secondary disasters come before, if there is a perfect early warning measures will greatly reduce the casualties.

(3) Improve the ability of earthquake avoidance, escape and self-rescue to reduce casualties. In addition to financial and human resources, the government should use many ways and means, such as conferences, TV, radio, newspapers, magazines, internet, lectures, training courses, community bulletin boards, brochures, etc., to carry out propaganda and education, and professional departments to produce comprehensive, scientific and practical earthquake prevention and mitigation propaganda and education films and We can also organize different levels and forms of highly targeted earthquake emergency drills and training to improve people's comprehensive ability to deal with earthquakes.

4. Conclusions
The number of earthquakes causing loss of life in China during the period 2000-2020 is 62, with an average of nearly three per year; the number of deaths caused by fatal earthquakes in mainland China is prominent, the role of severe earthquakes on the cumulative number of earthquake deaths is obvious, and the loss of life from earthquake disasters is highly concentrated. In China, 16 provinces out of 32 provinces and autonomous regions have had earthquakes that killed a total of 73,853 people, with Sichuan, Qinghai and Yunnan provinces accounting for up to 99% of the cumulative deaths due to earthquake disasters nationwide, and in provinces with few earthquakes there are also small earthquakes that cause a larger death of life instead. The death toll tends to increase exponentially as the magnitude of the earthquake increases. The number of deaths caused by earthquakes of the same magnitude has not decreased over time; a large proportion of houses in China have not yet met the requirements for seismic protection and the lack of public awareness and ability to prevent and mitigate disasters are the main causes of deaths caused by earthquakes. Take strong measures to tighten the seismic protection of buildings is the fundamental way to reduce the earthquake disaster, the establishment of an earthquake early warning mechanism to improve the public's ability to avoid earthquakes, escape and self-rescue is an important measure to reduce the earthquake disaster.
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