Earthquake damage analysis of school buildings in Jiuzhaigou

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Abstract. Based on Jiuzhaigou seismic building damage investigation data, this paper analyzes the typical earthquake damage characteristics of school buildings. It summarizes main features of destruction to middle and primary school buildings from the earthquake. In addition, it puts forward the aseismic building design and gives some suggestions on building site selection and construction engineering design, which can provide a reference for structural seismic strengthening.

1. Introduction
On August 8, 2017, in Jiuzhaigou Sichuan, a magnitude 7.0 earthquake occurred. A total of 25 people were killed, and 525 were injured. Through on-the-spot investigation for 27 middle schools, elementary schools and kindergartens and 106 buildings, this paper analyzes the typical earthquake damage characteristics of school buildings. Also, it inspects the earthquake-prone area and makes a recommendation on building site selection, structure design, construction and seismic strengthening for schools. Besides, improvement of construction’s quakeproof ability has practical significance and guiding importance. Through the analysis of earthquake damage to school buildings, primary and middle schools in the quake zone (kindergarten) are used to evaluate building’s seismic capacity. At the same time, for seismic construction design of high earthquake intensity area, school Ann engineering provides experiences and reference.

2. The school building earthquake damage statistical analysis
Jiuzhaigou is located in the transitional zone of Sichuan basin and Qinghai-Tibet plateau. Its geological structure is complicated, and the geomorphologic type is diverse. The region is an earthquake-prone area. According to the ground motion parameter zoning map of China (2015) and "building aseismic design code (2010)" the provisions of the buildings in this area, seismic fortification intensity of 8 degrees design necessary earthquake acceleration of 0.2 g.

Through the field investigation of the school buildings after the earthquake in Jiuzhaigou, the author analyzed the disaster situation of the school buildings. The authors surveyed 27 schools (including secondary schools, primary schools, and kindergartens) and 106 school buildings in Jiuzhaigou county and Wenxian county.

The statistical analysis results of building structures are as follows. The number of buildings with frame structures is 77, accounting for 72.6%; The number of masonry buildings is 28, accounting for 26.4%; The number of buildings at the bottom of the frame structure is 1, accounting for 0.9%.
The analysis results of school buildings time are as follows. 19 buildings were built before 2002, accounting for 17.9%; 64 buildings were built after 2008, accounting for 60.4%. The remaining 23 buildings were constructed between 2002 and 2008, accounting for 21.7%. All the buildings built after 2008 were designed and constructed according to the requirements of "school safety engineering" (2009), and the buildings are of good quality.

According to the requirements of the building earthquake damage grading standard (GB/T 24335-2009), the author divides each building into a hierarchy. The analysis results of the damage grade of buildings are as follows. 78 buildings are basically intact, accounting for 73.6%; 22 buildings were slightly damaged, accounting for 20.8%; 4 buildings were moderately destroyed, accounting for 3.8%; Only two buildings were severely destroyed, accounting for 1.9%. It is worth noting that in the Jiuzhaigou earthquake, no building collapse occurred in secondary schools, primary schools, and kindergartens.

3. Typical building damage features and patterns

During the Jiuzhaigou earthquake, the school buildings were destroyed most seriously in Zhangzha. Its primary school’s secure building was located in the magistoseismic area with seismic intensity IX degree. Therefore, the ground motion intensity was so intense and violent that it destroyed buildings easily. In addition to the slightly damaged dining room, other structures were moderately or severely destroyed. Among them, the teaching, science, technology and art building experienced relatively serious and visible damages. It can be seen from the apparent fracture (crack width is about 2 mm) of a few beams and columns, spalling of concrete, steel bar, and filler wall. Moreover, the ground of them was serious cracks (about 3 mm width), and the foundation had non-uniform deformation. Furthermore, the overall structure tilted, which severely affected basic utility function and was difficult to repair. First, the primarily severe damage was assessed. The bearing structure of students' dormitory had no apparent damage, but the building of filler wall damage was devastated, and fractured development (width is about 2 mm). Metope ceramic tile broke seriously, and some basic function was affected, however, still can be used after repair. Secondary damage was the X type fracture of bearing structure of teacher dormitory. It appeared more uneven settlement in the foundation. The third level of damages was kindergarten and teachers' dormitory building new houses. Damages to filler wall near the door and window were relatively serious in the transverse. Longitudinal wall with an X type had more fractures (width is about 2 mm).

4. The level of damage to buildings analysis

The Jiuzhaigou earthquake had a magnitude of 7.0. Relative to the Yaan earthquake (occurred in April 20, 2013, Sichuan Yaan county, magnitude is 7.0), the number of casualties and damaged buildings in Jiuzhaigou earthquake is much smaller. The two main reasons are as follows. 1. After the Wenchuan earthquake, the Chinese government rebuilt or strengthened the primary and secondary school buildings. The reinforcement of the school buildings is strictly according to the requirements and requirements of the "school safety project." This makes the seismic fortification level of buildings in the earthquake zone generally improved, and the seismic performance is usually enhanced. This phenomenon has been particularly prominent in various secondary schools, primary schools, and kindergartens in Jiuzhaigou county. 2. Schools in the earthquake zone typically pay attention to earthquake emergency drills and have received excellent effects of earthquake prevention and mitigation. In the Jiuzhaigou earthquake, only one student died outside the school, and one teacher suffered minor injuries outside the school. Therefore, it is a significant way to improve the seismic fortification level of school buildings and enhance the consciousness of teachers and students to prevent earthquake and disaster.
5. Conclusions and Suggestions

5.1. The structural damage of the primary school buildings in Zhangzha town; Other buildings are right, and the structure is functional.

Solid construction for primary school is necessary for Jiuzhaigou suffered from IX degree of earthquake intensity. The strong ground motion effect made buildings show uneven settlement of foundation, which is the leading reason for earthquake damage, especially in the teaching, science and art building of Zhangzha primary school. Therefore, we suggest that in the future, the procedure of building new houses should be carried out by critical fortification to construct the standard construction design. Also, we should adequately prepare for the locations of the schools and the ground foundation treatment. Based on this kind of landfilling, it is recommended to use pile foundation to avoid the uneven settlement of foundation during an earthquake. In comparison with Sichuan Jiuzhaigou located in Wenzxian Gansu, the seismic fortification intensity was an octave. All elementary and middle schools conformed to the principle octave fortification, nine degrees structure to carry on the design, thus building construction quality is good and generates excellent seismic performance. The results of the survey show that the buildings in different seismic intensity areas are mostly intact or slightly damaged, however, the earthquake disaster in Jiuzhaigou is greater. Except for Zhangzha primary school, other schools in the earthquake zone have a little degree of fragmentation and do not affect regular use.

5.2. Strengthen the investigation, monitoring, management and prevention of geological disasters such as collapse, landslide, and debris flow.

While the overall seismic performance in the earthquake zone of middle school, elementary school and kindergarten building is good, there are still some schools with potential threat from geological disasters, such as the third primary school in Jiuzhaigou. The strong ground motion results in the internal fissure of the rock mass, also the looseness increases and stability decreases. Therefore, it is suggested to strengthen investigation, monitoring, management, and prevention work of geological disaster around the school. Moreover, it should increase the safety of geological disasters in the school of drill content and raise awareness of teachers and students to geological disaster prevention. Besides, it should be considered to reduce the seismic risk of geological hazards, and further improve the overall adaptability and response ability of disaster prevention, reduction and relief.

5.3. Strengthen the construction of school infrastructure.

Education is the cornerstone of national rejuvenation and social progress. It is a fundamental way to enhance the national level and promote the all-round development of people. Furthermore, it is the only hope of millions of low-income families struggling for a better life. A powerful destructive earthquake can destroy a school in an instant and kill thousands of lives. It is advised that the government departments of the earthquake zone should further spread the knowledge of primary coping methods to the earthquake and invent technology for more accurate earthquake forecast. Also, the government should continue to implement the school safety project and select the safest building site construction schools. Finally, the earthquake damage survey noted that some schools are weak infrastructure, indicating that the necessary infrastructure should be modified and improved. The goal is to strive for building the safest and the most beautiful and comfortable school for students to stay.

5.4. The site selection criteria should be adjusted

A detailed geological survey should be carried out before building the schoolhouse. Identify topography, geology and groundwater levels, and then build in areas where the building is earthquake-resistant. Try to avoid the aseismic location of the building as much as possible. It should be noted that in any case, schools are not allowed to be built on active faults, landslides, or liquefaction of soil, which are in earthquake-resistant areas. This will prevent the school building from being severely damaged in the earthquake. A stable rate of the school building should meet the following criteria, it is
not only to ensure the security of the student's life, and the school's playground, gymnasium, classroom buildings should also be earthquake emergency refuge for rest of local residents.

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