OUTLINE INTRODUCTION OF BUILDING DAMAGE IN HIGH INDENSITY AREAS OF WENCHUAN M8.0 EARTHQUAKE

Sun Jingjiang Meng Qingli Ma Qiang Shi Hongbin Sun Zhongxian

Institute of Engineering Mechanics, China Earthquake Administration, Harbin 150080, China
Email:jingjiangsun@sina.com

ABSTRACT :

The macro-epicenter intensity of Wenchuan M8.0 earthquake reaches XI, a great lot of buildings were damaged or collapsed in this disaster. The building damage of cities (or counties) and towns located in high intensity areas is introduced, and some damage characteristics and earthquake resistant problems of buildings are briefly discussed.

KEYWORDS: Wenchuan earthquake, building damage, earthquake intensity, buildings

1. INTRODUCTION

A big earthquake magnitude 8.0 occurred on May 12, 2008 in China about 76 kilometers northwest of Chengdu, 56 kilometers southeast of Wenchuan and caused a huge disaster to the earthquake area.

There mainly are three northeastward faults in the Longmenshan zone, namely central fault, mountain-front fault and mountain-behind fault. The seismogenic fault was central fault and large ground displacement, maximum about 5m, both horizontal and vertical directions could be seen along this fault. The earthquake also resulted in dislocation of mountain-front fault. The building damage has close relationship with the distance to these two faults.

It is mountain area on the west of central fault and a few cities and towns are located on that area. The most of cities and towns are concentrated on the basin area along the east of the fault. After the earthquake, the authors of this paper at first time arrived in Sichuan and conducted a detailed building damage survey to the cities and towns on the fault east. Earthquake almost completely destroyed the Beichuan city, Yingxiu town and some other towns and villages located on the central fault. The highest earthquake intensity of these areas has reached to XI according to Chinese seismic intensity scale, the buildings in surrounding cities and towns also suffered heavy damage.

The main structural types in surveyed cities are multi-story brick buildings, multi-story brick buildings with RC frame at first story (BBF), and RC frame buildings, in addition, there are a small number of self-built brick-wooden houses, in larger cities there are a few RC frame-shear wall (or tube) high-rise buildings also. In the towns the above-mentioned four types of structures are all existed except high-rise buildings, besides, there are some non-formal design or even no any drawing multi-story brick buildings.

The outline of building damage in the cities and towns located in high intensity areas of fault east is introduced and followed by discussions to typical damage in the following.

2.TYPICAL BUILDING DAMAGE OF CITIES AND TOWNS IN VARIOUS HIGH INTENSITY AREAS

SPONSORED BY: Public Service Research Project of Quality Inspection Field under Grant No. 10-110 and Public Service Research Project of Eearthqake Field under Grant No. 200708005.

2.1.Intensity XI areas

2.1.1 Beichuan County

Beichuan County is located just above the south part of Longmenshan central fault, which is called Yingxiu-Beichuan fault. The fierce fault dislocation leaded to a large number of landslide and devastating damage to buildings.

The county consists of old town and new town side by side. The buildings in old town were struck by strong ground shaking along with rolling stone and soil caused by landslide. The damage outline is shown in Fig.1 and Fig.2. The Fig.3 and Fig.4 show the different damaged multi-story brick buildings. A frame and a BBF buildings were hit by rolling stones and serious injured are shown in Fig.5. Very few buildings keeps basic intact, one of them can be seen in Fig.6.

Fig. 1 Heavy damaged and collapsed buildings

Fig. 2 Another scene of heavy damaged and collapsed buildings

Fig. 3 Front building collapsed;behind-left building heavy damaged, behind-right building slight damaged

Fig. 4 Partly collapsed brick building

Fig. 5 Buildings damaged mainly by rolling stones, left-frame, right-BBF

Fig. 6 Building keeps basic intact except one outwall hit by something

In the new town area, most of buildings were well designed and constructed. However because of the huge earthquake force, most of them collapsed or heavy damaged as shown in fig.7-fig.11. The difference of earthquake resistance ability between frame building and BBF building can be seen in fig.12.

Fig. 7 All the buildings collapsed or heavy damaged along the street

Fig. 8 Upper stories of BBF building collapsed

Fig.9 First story of BBF building collapsed

Fig. 10 Eight story frame building collapsed

Fig. 12a Two constructing buildings, left, RC frame, some columns became hinge in 2nd and 1st storys, but still well stand there; right, BBF, 1st story and central part collapsed

Fig. 11 First story of a constructing building collapsed

Fig.12b 2nd story local enlargement of frame building in Fig.12a

Fig. 12c 1st story local enlargement of BBF building in Fig.12a

2.1.2 Yingxiu Town

Yingxiu Town is also located on the Yingxiu-Beichuan fault. The fierce ground motion almost destroyed the entire town. The serious building damage is shown in Fig.13-Fig.17.

Fig. 13 All the buildings collapsed or heavy damaged along the street

Fig. 14 2nd story of a five story BBF building collapsed

Fig. 15 A five story brick building collapsed

Fig. 16 First story of a three story frame workshop collapsed

Fig. 17 Five story middle school frame building collapsed ►

2.1.3 Damage summary to intensity XI areas

All of old houses (including brick-wooden houses and no drawing self-built buildings) and non-formal design buildings collapsed; The seismic designed buildings, no matter brick or BBF or frame, can not resist such a powerful shaking, most of them collapsed or heavy damaged, few of buildings keep basic intact or slight damaged.

2.2.Intensity X areas

2.2.1 Hongbai Town

Hongbai Town is located between central fault and mountain-front fault, the distance to central fault is about 5.7km. The most buildings were seriously damaged in this earthquake. The Fig.18 and Fig.19 show lots of old brick-wooden houses and brick buildings collapsed. It can be seen from Fig. 20 that the damage is lighter than Beichuan and Yingxiu and new buildings still stand there, but in fact most of them were heavy injured as shown as one building enlargement part in the Figure. The workshop of a lecithoid factory collapsed and only some columns stood there as shown in Fig.21.

Fig. 18 Lots of old brick-wooden houses collapsed

Fig. 19 Many old brick buildings collapsed

Fig. 20 A street scene at Hongbai Town

Fig.21 Workshop of a lecithoid factory collapsed

2.2.2 Hanwang Town

The distance from Hanwang Town to central fault is about 13.0km and the town is also located on the mountain-front fault. The most buildings were seriously damaged like the Hongbai Town. The Fig.22 shows many collapsed brick buildings. Fig.23 gives out a street scene in the town and we can see that the damage is as same as the Hongbai Town. All the town government buildings collapsed and only the gate left (Fig.24). The comparison of seismic performance between brick-wooden houses and brick buildings can be seen from Fig. 25, obviously the former is easier to collapse than latter. One different damage pattern is shown in Fig. 26. Besides a lot of damages, there are still a few buildings to keep basic intact (Fig.27).

Fig. 22 Many brick buildings collapsed

Fig. 23 A street scene in Hanwang Town

Fig. 24 All the town government buildings collapsed, only the gate left

Fig. 25 Front brick-wooden houses collapsed, behind brick buildings heavy damaged

Fig.26 A damaged building, the same story is not on the same horizontal level ►

Fig. 27 A building keeps basic intact

2.2.3 Damage summary to intensity X areas

Almost all of old houses (including brick-wooden houses and no drawing self-built buildings) and non-formal design buildings collapsed; The most of brick and BBF buildings collapsed or heavy damaged; the collapsed ratio of concrete building is clearly lower than other types of buildings.

2.3.Intensity IX areas

2.3.1 Doujiangyan City

The distance of Doujiangyan City to central fault is about 8.6km. It is one of the most seriously damaged cities. The Fig.28-Fig.30 show the typical damage of brick buildings.

Fig.28 One side of a L-type building collapsed, now another behind damaged building can be seen

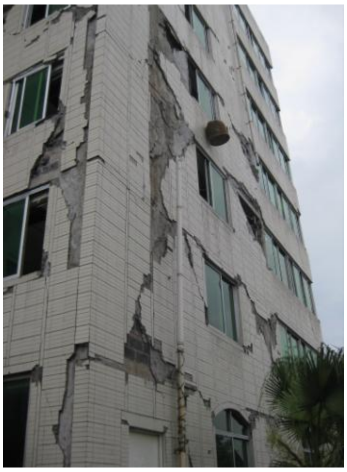
Fig.29 A brick building Heavy damaged at first story

Fig.30 Horizontal crack of a brick building

The damage of BBF buildings is shown in Fig.31 and Fig.32.

The damage of a six story frame building is shown in Fig.33, except the stairs beam, all the supporting columns and beams keep intact. Another damage of frame building is shown in Fig.34, all the damages occurred at several nodes and column ends at first story.

A frame and frame-shear wall united building can be seen in Fig.35, the enlargement pictures show the damages of a column top end of frame building and elevator shear wall of frame-shear wall building both at first story respectively.



(b) Stairs almost break off

Fig. 31 Column damage of a BBF building

Fig. 32 Out and inner wall damages of a BBF building

(a) Infill wall damage

(c) Stairs beam end damage

Fig. 33 Six story frame building damaged

Fig.34 First story damage of a five story frame building with local enlargement of one node of column and beam

Fig. 35 Damage of a frame and frame-shear wall united building

2.3.2 West region of Mianzhu City

The distances of Mianzhu City to central fault and mountain-front fault are about 22.5km and 9.0km respectively. It is one of the most seriously damaged cities. The damage of west region is obviously heavier than east part of the city and the former's earthquake intensity is IX.

Some typical damages are shown in Fig.36- Fig.38, others are about as same as Doujiangyan City.

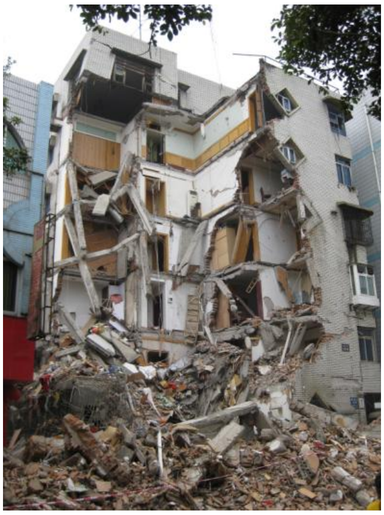


Fig. 36 Partly collapsed brick building

Fig. 37 Horizontal crack and dislocation at the bottom of 3rd story of a six story brick building

Fig. 38 first story of a six story BBF building heavy damaged

2.3.3 Damage summary to intensity IX areas

Most of old houses (including brick-wooden houses and no drawing self-built buildings) and non-formal design buildings collapsed or heavy damaged; There are no significant difference in damage ratios between brick and FFB buildings; The damage ratios of brick and BBF buildings in Doujiangyan City and west region of Mianzhu City are shown in Fig.39 and Fig.40 respectively according to our sample survey data; The concrete buildings show better seismic performance than other types of buildings.

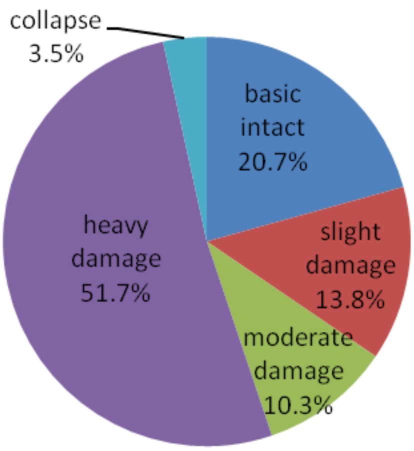


Fig. 39 Brick and BBF building damage ratios of Doujiangyan

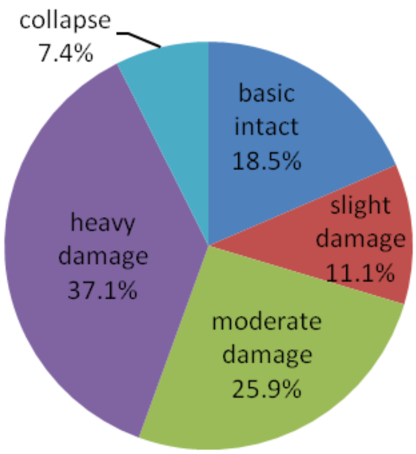


Fig. 40 Brick and BBF building damage ratios of Mianzhu west

3. SOME LESSONS FROM THIS EARTHQUAKE AND SUMMARY

3.1 New damage pattern of brick masonry building

According to past earthquake experience, the weak region of masonry building is the area between windows, therefore the building horizontal seismic loading capacity is determined by the cross sections of the total walls at windows level required by the seismic code. However, as the windows become larger and construction columns are built in between windows, the damage pattern has changed, this point can be seen from this earthquake that the most damage originally take place at the wall under the windows as shown in Fig.9, Fig.25

and Fig.29. The Figure 9 also shows that longitudinal external walls of this type of building act as a system of strong columns (walls and construction columns between windows) connected by weak thick beams (walls under windows) as shown in Fig.41. This damage pattern remind us that seismic force checking method of current code is not enough, the new design methods to improve the seismic performance of the walls under windows and to check building seismic forces should be developed.

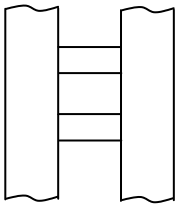


Fig. 41 Mechanical model of longitudinal external wall

3.2.Strong node, strong column and weak beam design principle

Strong node, strong column and weak beam design principle is always stressed in seismic design. However, in this earthquake survey it was found that the damages of nodes and columns are far more than beams as shown in Fig.12, Fig.20, Fig.31, Fig.34 and Fig.35. It tells us that the current design method could not ensure the realization of the principle, therefore, more studies should be concentrated on this problem.

3.3. Infill wall function

In seismic design the infill walls are considered as non-structure components and only their mass is taken into consideration. In fact, they dissipate a great deal of seismic energy and reduce the damage of main structural components by this earthquake experience. Thus it is important to study the action of infill walls further, in order to make them play a greater roles against earthquake.

3.4.Stairs damage

Many damaged stairs have been found in this earthquake, one of them is shown in Fig.33b. Clearly, it is acted mainly by vertical ground motion. Therefore, it is necessary to consider vertical earthquake action in stairs design in higher intensity areas.