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Investigation and Analysis of Building Structures Damaged in Nepal M_s8.1 Earthquake on April 25th, 2015

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Abstract

On April 25th, 2015, the M_s8.1earthquake occurred in Nepal. This earthquake caused a lot of casualties. As the neighboring country, some Chinese persons also had been hurt by this earthquake. After the earthquake, the site investigation has been carried out. As we know, the building structures collapsed in earthquake is the main reason of casualties. Compared the differences of the building structures in the disaster areas between two countries, and the damage characteristics and shortages in design and construction of building structures have been pointed out. Finally, some conclusions have been given to improve the seismic performance of building structure in the further. Some conclusions have been drawn out: (1) In the disaster area, the proportion of buildings with poor seismic performance is bigger. (2) Most of the buildings are self-built by the residents without adequate seismic design. (3) The influence of ground and foundation is an important cause of building damage. (4) The structure design can also cause the deficiency of the seismic vulnerability, such as the effects of short column, the lack of structural measures, small size of beam and column, high stiffness of filled wall, etc... (5) There are many old houses existing in the city, includes some historical buildings. Due to the poor seismic capacity, most of them damaged seriously. (6) Comparison has been done with the damage of buildings in Tibet China. It is important to increase input for improving seismic capacity of buildings.

Key words: Nepal M_s8.1 Earthquake, 2015; site investigation; damage of building structures; comparison; seismic performance

1. Introduction

On April 25th, 2015, the M_s8.1earthquake occurred in Nepal. The epicenter was located in tourist town Pokhara, with maximum intensity X according to the Chinese Seismic Intensity Scale [1]. Due to the strong aftershocks with more than M_s7, the heavy disaster area went eastward from Pokhara. More than nine thousand people died in this earthquake, as the neighboring countries, casualties and economic loss also could be found in China, India, Bangladesh, Bhutan, etc.

According to the earthquake aid project, after the earthquake, the damage investigation organized by the China Earthquake Administration had been carried out. The survey areas mainly focused on Sindhupalchok district and Rasuwa district.

In this paper, the main structure types and damage phenomenon of this earthquake were shown. Comparing the differences of the building structures in the disaster areas between Nepal and China, the damage characteristics and shortages in design and construction of building structures have been pointed out. Finally, some conclusions have been given.

2. Site investigation

Because of the mountain area, population density is lower, and more people live in the big cities. As the symbol，the pink points show the distribution of population in Fig.1 and the red point is the symbol of the epicenter.

Considering the working area, earthquake disaster and traffic conditions, the survey points is shown in Fig.2 by yellow triangle symbols [2, 3]. There are about forty survey points in this map, most of them distribute in Sindhupalchok district and Rasuwa district, and only three points locate in Kathmandu.

As the contents of this investigation, include the building structure type, seismic damage, seismic geological disaster, etc.

Fig. 1 – Distribution map of population

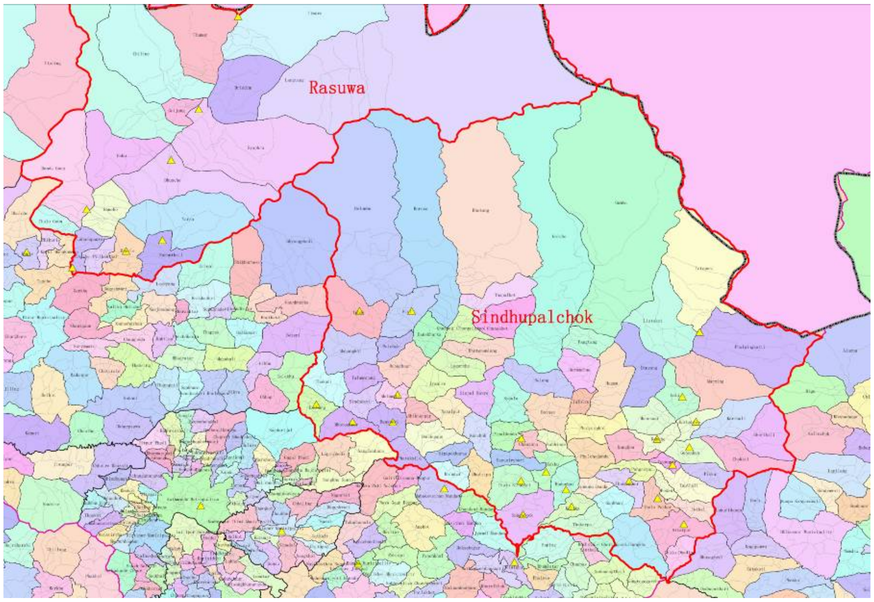

Fig. 2 – Distribution map of survey points

2.1 Types of buildings

Main types of buildings existing in Nepal include rubble structures, brick-wood structures, raw soil structures, reinforced concrete frame structures.

In rural regions, the rubble structure with wood roof is the main type of buildings, which uses rubbles to construct external wall. Some of those buildings mix internal timber frame in the wall. This type building has poor seismic capacity, and will be damaged in low intensity areas. In addition to rubble structure, brick-wood structures, raw soil structures also can be found easily in rural regions. Similar to the seismic capacity of rubble structure, in high intensity areas, these buildings were damaged seriously in this earthquake.

In the cities, the reinforced concrete frame structures are more common especially in recent years. Compared with the others types, their seismic performance are better. As the old houses, some the rubble buildings and brick-wood buildings are still used, but most of them in intensity areas were damaged seriously, even collapsed.

In addition, Most of the buildings are self-built by the residents without adequate seismic design.

In table1 and table 2, as two survey points, the statistics number of different type of buildings had been list. Survey point 1 is Sipaghar Deupur (N85.60413°, E27.74598°) with intensity IX, which locates in Sindhupalchok district. More than half buildings are rubble houses and brick-wood houses, and almost are destroyed. The RC buildings have the better seismic performance, but the damage is still higher than expected due to the building design and construction. Most of them have been damaged seriously or moderately. Survey point 2 is Necpane (N85.62397°, E27.73799°) with intensity VIII, which also locates in Sindhupalchok district. But almost all of the houses are rubble structures and destroyed in this earthquake.

Table 1 – Seismic damage statistics of buildings in survey point 1

Type of building	Destroy	Serious damage	Moderate damage	Slightly damaged	Intact	Total
RC	1	11	12	3	0	27
Rubble	22	4	0	0	0	26
Brick-wood	1	2	1	0	0	4

Table 2 – Seismic damage statistics of buildings in survey point 2

Type of building	Destroy	Serious damage	Moderate damage	Slightly damaged	Intact	Total
RC	0	0	0	2	2	4
Rubble	36	12	9	0	0	57

2.2 Damage analysis

After site investigation and the analysis of damage of buildings, a lot of experience and lessons are summarized, common problems will be discussed below.

2.2.1 Poor seismic capacity

As we know, in disaster area, the rubble structures, brick-wood structures, raw soil structures have poor seismic capacity, couldn't against the attack by destructive earthquake. Even the damage could be found in low intensity areas. For reinforced concrete frame structures, have better seismic performance relatively, but larger space with small size of columns would reduce seismic capacity. [5]

In Fig.3 the brick-wood house is damaged seriously and walls of second floor are complete failure. There are two collapsed rubble houses in Fig.4. The reinforced concrete frame house shown in Fig.5 is serious damaged. For the business, this building has a larger space, but the columns constructed in small size. Most columns of it are failure in ground floor.

Fig. 3 – Serious damaged brick-wood house in Deupur

Fig. 4 – Collapsed rubble houses in Deupur (left) and Necpane (right)

Fig. 5 –Serious damaged RC houses in Deupur

2.2.2 Lack of seismic measures

In the disaster areas, most buildings are self-built by owners without adequate seismic design, and lack necessary seismic measures, such as ring beam and structure columns, and the size of wall thickness is insufficient, 240 mm wall is commonly used as external wall, and 120 mm wall as internal partition.[6]

There are many old houses existing in the city, includes some historical buildings. Due to the poor seismic capacity, most of them damaged seriously. In Fig.6, some brick-wood houses collapsed, which locate in Kathmandu. The damage can be found easily in some old blocks and the peri-urban areas. In this earthquake, a large number of historical buildings had been damaged. In Fig.7, some historical buildings in Kathmandu and Gorkha are shown.

Fig. 6 – Collapsed brick-wood houses in Kathmandu

Fig. 7 –Serious damaged historical buildings in Kathmandu and Gorkha

2.2.3 Influence of ground and foundation

According to the mountainous terrain, there are lack smooth grounds for buildings construction. Most houses are built in the slope and river valley areas. Sometimes, those can enlarger the action of earthquake, if the ground and foundation are damaged by earthquake, which would lead to the upper structure damage further.

For convenient, some houses in the slope had been connect with roads on the second floor or above by stiffness platforms, the collision between the building and platform usually cause structural damage. In addition, the landslide and the rolling stones are dangerous for these houses.

In Fig.8, two building locates slope in Talakhu（N 85.44856°, E 27.82579°）, which connect with roads by platform, the left one collapsed, and the second floor disappeared. Compared with this building, the right one with filled room near the road, it is basic intact. And in Fig.9, several RC buildings locate on the top of a hill, after earthquake, most of them collapsed due to the ground instability.

Fig. 8 – Two buildings damaged by platform in Talakhu

Fig. 9 – Several RC buildings collapsed due to the ground instability

2.2.4 Influence of design and construction

The structure design can also cause the deficiency of the seismic vulnerability, such as the effects of short column, the lack of structural measures, small size of beam and column, high stiffness of filled wall, etc... And the unreasonable construction also explores the weak links of seismic capacity after this strong earthquake.

In Fig.10, a teaching building is a RC structure and constructed in valley terrace. Lacking of structural columns, the external walls of first floor are damaged seriously. the columns of aisle are almost failure at the connection with low wall. The stirrups set in the top of columns are not enough. In Fig.11, the columns of a RC building are broken, because the stiffness of the stone wall is larger than the columns'.

Fig.10 – Serious damaged teaching building in Gorkha

Fig.11 – RC building of higher secondary school in Sindhupalchok

2.3 Comparison

While Tibet is far away from the epicenter, but there are still a lot of buildings damaged, especially in Nielamu County, Dingri County, Jilong County of Rikaze City in Tibet, China. Compared with the seismic damage of the buildings in Nepal, some comments are given as the following.

(1) There is a high proportion of the self-built houses without or lack of enough seismic measures.

(2) The rubble structures and raw soil structures also exist commonly in Tibet.

(3) The seismic performance of public buildings with formal design is better.

(4) The ring beam and structural column have been used to improve seismic capacity in the construction of some brick-concrete buildings and brick-wood buildings.

(5) The size of beam and column of reinforced concrete frame structures in Tibet is larger than that of the same type building in Nepal.

In Fig.12, there are two common type structures in Tibet, the left structure is rubble house and another one is raw soil house. And in Fig.13, slightly damaged RC buildings are shown, the filling wall of the building in right photo has crack, and two buildings are damaged by the collision of each other in left photo.

Fig.12 – Collapsed rubble building (left) and soil building (right) in Tibet

Fig.13 – RC buildings damaged in Tibet

3. Conclusions

After investigation and analysis of the damaged buildings in disaster area, some main conclusions have been drawn out as the following.

(1) In the disaster area, the proportion of buildings with poor seismic performance is bigger. The buildings couldn't against the attacks of earthquake in high intensity, even in low intensity area, the damage would be found.

(2) Most of the buildings are self-built by the residents without adequate seismic design.

(3) The disaster area is located in the mountain area, the influence of ground and foundation is an important cause of building damage.

(4) The structure design can also cause the deficiency of the seismic vulnerability, such as the effects of short column, the lack of structural measures, small size of beam and column, high stiffness of filled wall, etc...

(5) There are many old houses existing in the city, includes some historical buildings. Due to the poor seismic capacity, most of them damaged seriously.

(6) Compared with the seismic damage of buildings in Tibet China,

a. There is a large proportion of the self-built houses without or lack of enough seismic measures.

b. The rubble structures and raw soil structures also exist commonly in Tibet.

c. The seismic performance of public buildings with formal design is better.

d. The ring beam and structural column have been used to improve seismic capacity in the construction of some brick-concrete buildings and brick-wood buildings.

e. The size of beam and column of reinforced concrete frame structures in Tibet is larger than that of the same type building in Nepal.

According to the reasons mentioned above, it is important to increase input for improving seismic capacity of buildings, and then the casualties and economic losses would be reduced as far as possible when the destructive earthquake occurs. The necessary technical support should be given to Self-built housing, for choosing the structure type with good seismic performance, increasing enough seismic construction measures. Site condition and the foundation of buildings should be paid more attention. Formal design and construction would avoid some weak links of seismic capacity mentioned above, especially in those high dangerous zones of earthquake.

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