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A Case study of Building Damage Pattern in Nepal: Insights from the Nov 3, 2023 Jajarkot Earthquake

Dr. Govind Prasad Lamichhane[1*], Uttam Neupane[2]

[1]Professor, Faculty of Science and Technology, Pokhara University, Nepal
[2]PhD Scholar, IIT Kanpur, India

**Corresponding email: govindkhec@gmail.com*

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Abstract

The Federal Democratic Republic of Nepal is situated in the Himalaya, one of the world's most active zones of continental collision, where there is a significant likelihood of earthquakes. The historical records of the Himalayan arc contain several reports of devastating earthquakes. Research shows that the mid-western and eastern region of Nepal has the higher seismic hazard whereas the southern regions of the country have the lowest seismic hazard. Jajarkot and Rukum West district which were most affected areas due to recent November 3 earthquake lie in mid-western part of Nepal. The Nov 3, 2023 Jajarkot Earthquake of Magnitude 6.4 in 26,557 households fully damaged and 35,455 households partially damaged. 154 individuals have perished, and 364 have sustained injuries in the earthquake that struck Jajarkot. During field inspect the main cause of collapse of buildings is found as: old age and non-engineering buildings, in plane failure and out of plane failure of building, disconnection of joint between stone mud and wood and failure of corner of building. During earthquake reconstruction, the utilization of local quality standards and adherence to national building codes and measurement criteria has been observed as essential. Enforcing code compliance and involving expert engineers in all stages of building design is crucial, as the majority of collapsing structures were not engineered. It is important that appropriate seismic design, good-quality construction materials and approved construction methods are used to minimize damage to engineered buildings.

Keywords: Flexural, in plane, RC frame, Masonary

1. Introduction

The Federal Democratic Republic of Nepal is situated in the Himalaya, one of the world's most active zones of continental collision, where there is a significant likelihood of earthquakes. The historical records of the Himalayan arc contain several reports of devastating earthquakes. Of them, two happened in the Nepal Himalaya: the 1934 Bihar-Nepal Earthquake and the 2015 Gorkha Earthquake, magnitude 7.6 (Mw 7.8). Nepal is characterized by three major fault systems—the Main Central Thrust (MCT), Main Boundary Thrust (MBT), and Himalayan Frontal Thrust (HFT)—along with numerous smaller faults, totaling ninety-two, across the country's limited width (Parajuli et al., 2021). The mid-western and eastern region of Nepal has the higher seismic hazard whereas the southern regions of the country have the lowest seismic hazards (Chaulagain et al., 2015). Jajarkot and Rukum West district which were most affected areas due to recent November 3 earthquake (see figure1) lie in mid-western part of Nepal. The Nov 3, 2023 Jajarkot Earthquake of Magnitude 6.4 in 26,557 households fully damaged and 35,455 households partially damaged. 154 individuals have perished, and 364 have sustained injuries in the earthquake that struck Jajarkot.

Scientific investigations conducted across affected areas during the April 25, 2015 Gorkha earthquake prompted a comprehensive examination of the construction and damage characteristics inherent in five prevalent building types in Nepal: reinforced concrete (RC) frame structures, rubble structures, brick-wood structures, raw soil structures, and historic brick-wood structures (Sun & Yan, 2015).

The April 25, 2015, Gorkha Earthquake in Nepal damaged 700,000 buildings, with 96% being masonry and 4% reinforced concrete with masonry infill (Guragain et al., 2017). Similar studies shows that compared to RCC building unreinforced random rubble and abode buildings account for around 95 % of the damage caused by the earthquake in Nepal (Gautam et al., 2015).

Key findings indicate that masonry buildings primarily suffered corner separation, diagonal cracking, out-of-plane failure, in-plane flexural failure, and delamination. Non-engineered reinforced concrete buildings faced soft-story damage, joint failure, lap splice issues, column shear failure, beam failure, and infill wall failure (Guragain et al., 2018) . Most of the houses were constructed with local masons without proper supervision from technical manpower (Liu et al., 2021) . Several construction and structural deficiencies are the primary contributors to building failure (Gautam et al., 2016). Majority of the damaged buildings were not designed or constructed in compliance with the national building codes of Nepal (Sharma et al., 2016) (Rai et al., 2017).

A field reconnaissance was carried out from November 6 to 15 in the earthquake-affected regions of Jajarkot and Rukum West, focusing on various municipalities, namely Bheri, Kuse, Chhedagad, Sani Bheri, Chaurjahari, and Musikot. We observed seismic damage on building structures in highly affected areas and other areas impacted by earthquake.

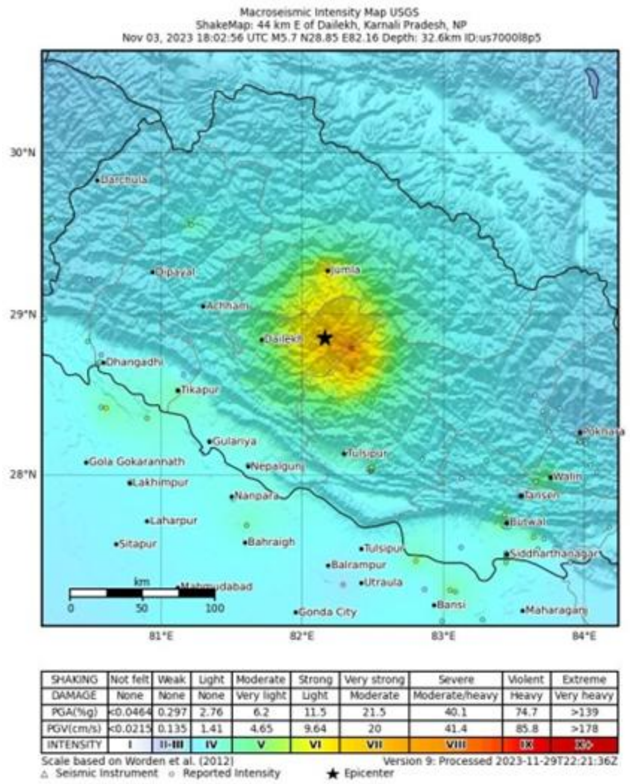

Figure 1: Seismic intensity map (Source: United States Geological Survey).

2. Damage Patterns of Building

According to National Population and Housing Census 2021, there are 366,255 households in Karnali Province which accounts for 83.1% of mud bonded bricks/stone types of foundation in building. Jajarkot accounts for 95.6 % of Mud bonded bricks/stone type of foundation and West Rukum 90.9 %. The past earthquake also shows that such types of buildings were severly affected and the figure 2 and 3 shows that most of the buildings in Karnali Province are vulnerable.

2.1 Unreinforced Stone Masonry Building

Most of the buildings in the badly affected areas were made of unreinforced stone masonry which suffered high degree of damage. The buildings were made of round stones directly collected from the river and such stones lack bonding and are unstable units. Less resistance to withstand to lateral force effect during Earthquake leads both out of plane and in plane failure of building.

2.2 Mud-wooden building

Other buildings consisting mud stone in the district are also badly affected areas were made of mud, wood which are suffered with high degree of damage. The buildings were made up of wooden joist without any band and directly collected from the forest those are weak in hilly areas to resist gravity and lateral loads; also known as unstable units. Mainly the joint between wood and mud are not created as rigid node thus whole building undergoes collapse during Earthquake.

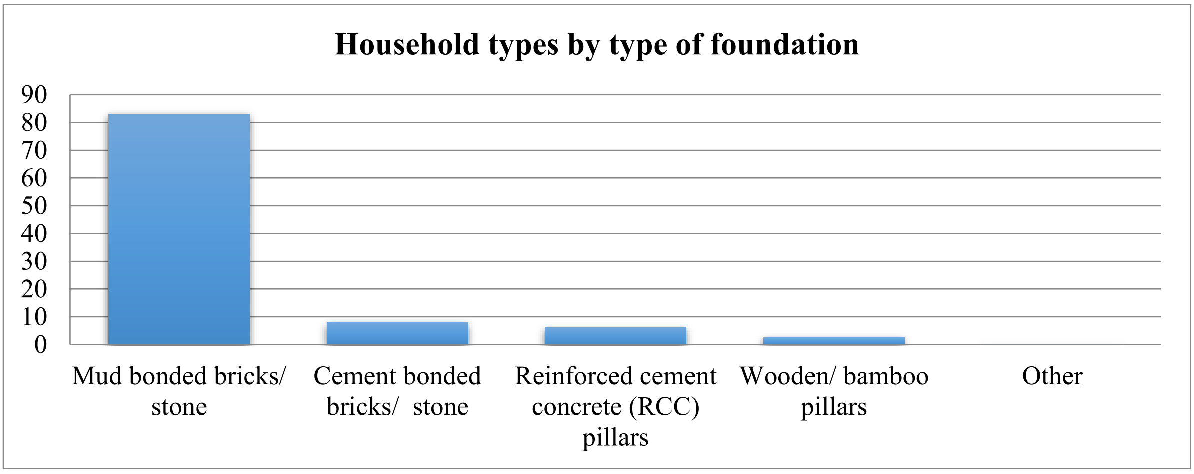

Figure 2: Household types in Karnali Province.

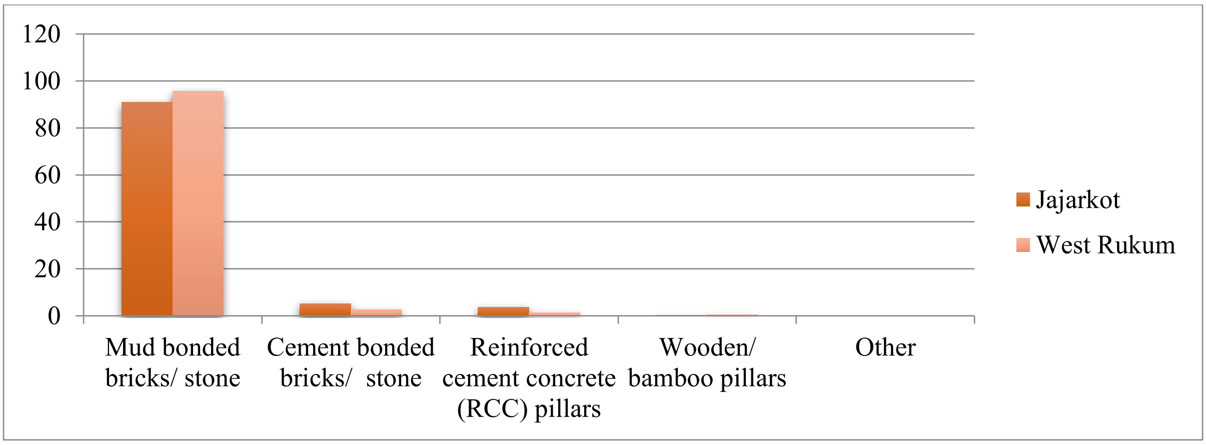

Figure 3: Household types in Earthquake affected districts.

2.3 Damage to historic Palace:

The earthquake has damaged historic palace known as "Jajarkot Durbar" as shown in figures 4, 5, 6 and 7. The bands provided in the palace prevented it from complete collapse. It was built in 1769 AD by the King of Jajarkot Hari Shah. Originally it was seven storey and reduced to four storey due to the 1934 earthquake. The April 25 Earthquake in Nepal further damaged the palace.

Figure 4: Diagonal crack near sill level

Figure 5: Flexural crack

Figure 6: Flexural crack

Figure 7: Diagonal crack

3. Results and Discussion

During field inspection, the damage was seen devastating in unreinforced masonry buildings and minor cracks and wall failures were observed in Reinforced Concrete Building. The main cause of collapse of buildings is found as:

i) Old age and non-engineering buildings.

ii) Heavy gable and roof construction

iii) In plane failure and out of plane failure of building

iv) Disconnection of joint between stone, mud and wood

v) Failure of corner of building

Those building which are collapsed 90 % of their components will cost severely high if retrofit process is conducted. But for those building with some diagonal cracks may be retrofitted with proper bands of RCC.

4. Conclusions

During earthquake reconstruction, the utilization of local quality standards and adherence to national building codes and measurement criteria has been observed as essential. Enforcing code compliance and involving expert engineers in all stages of building design is crucial, as the majority of collapsing structures were not engineered. It is noted that compliance with these standards is crucial for rebuilding both at the local and national levels. Additionally, awareness among the general public about the technical aspects and support from trained professionals and technicians are deemed necessary for earthquake-resistant house construction. It is important that appropriate seismic design, good-quality construction materials and approved construction methods are used to minimize damage to engineered buildings.

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