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Case Study on Behavior of a Masonry Buildings Under Seismic Loading October 2023 Earthquake in Nepal

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Abstract: This paper assesses the behavior of the corners of unreinforced masonry walls during a magnitude 5.3 earthquake that struck western Nepal on October 3 at 14:40 local time. A strong aftershock with a 6.3 Richter scale occurred immediately after the main shock at 15:06, followed by a second aftershock of 5.1 Richter scale. The epicenter of the quake was located in Bajhang district, with tremors felt in neighboring districts (Doti, Achham, Bajura, Dadeldhura, Baitadi, and Darchula), as well as in Kathmandu.

According to the National Society of the Red Cross, 334 houses have been fully damaged, and 1,185 have been partially damaged. The assessment is still ongoing in the affected areas, with displaced people staying in schools or with neighbors. The response is slow due to access constraints, requiring one to two days of walking to reach the affected communities.

The majority of the buildings in the affected region are constructed with masonry, most of which were formed with random or coursed stone and mud brick walls without any reinforcement. Many of these buildings were damaged or had collapsed. The cracking and failure patterns of the buildings are examined and interpreted according to current provisions for earthquake resistance of masonry structures. The damages are attributed to several factors, such as poor construction quality and workmanship.

This study aims to contribute to the body of knowledge necessary for improving earthquake resilience in Nepal and similar regions around the world.

Keyword: Unreinforced masonry walls, aftershocks, corner failure, old masonry buildings, Richter scale

I. INTRODUCTION

"Earthquakes are among the most devastating natural disasters, characterized by their unpredictable nature. Nepal, a nation nestled in the lap of the Himalayas, is no stranger to seismic activity. Throughout its history, this geographically diverse and culturally rich country has experienced numerous earthquakes, some of which have left indelible marks on its landscape and people. In the annals of Nepal's seismic history, the year 2023 stands out as a critical juncture, marked by a significant earthquake that not only tested the resilience of its inhabitants but also posed new challenges for disaster preparedness and mitigation strategies.

This research thesis aims to delve into the seismic event that occurred in Nepal in 2023, analyzing its causes, impacts, and the response measures taken in its aftermath. By doing so, we hope to gain a deeper understanding of the complex dynamics that underlie earthquakes in this region, providing valuable insights for future disaster risk reduction and recovery efforts.

The 2023 earthquake in Nepal was not an isolated incident; rather, it was a reminder of the ever-present threat posed by the tectonic forces at play beneath the Himalayan range. With a history of devastating earthquakes, including the catastrophic event in 2015, Nepal is located on the seismically active boundary between the Indian and Eurasian tectonic plates. This precarious positioning makes it susceptible to seismic tremors of various magnitudes, with the potential to cause widespread damage to infrastructure, loss of life, and disruption to the socio-economic fabric of the nation.

Unreinforced masonry walls, often referred to as URM walls, represent a significant architectural and construction technique that has been utilized for centuries. These walls are constructed using materials such as bricks, stones, or concrete blocks, bound together by mortar, with no additional reinforcement or structural support. While URM walls have a rich historical legacy and offer unique aesthetic appeal, they also pose inherent structural vulnerabilities that can have serious consequences in the face of seismic activity or other external forces.

II. AFTERSHOCK

A magnitude of 5.3 earthquake hit far western Nepal on 3 October 2023 at 14.40 pm and strong aftershocks occurred at regular intervals during the day which has increased fear among local people. The epicenter of the earthquake was Bajhang district of the Sudurpaschim Province and the tremors were felt in six neighboring districts (Bajura, Achham, Doti, Baitadi, Darchula and Dadeldhura). The continuous aftershocks have forced people to leave houses and live in open spaces. On the 7 October, a 5.3 Richter scale aftershock was felt which created constant fear in the affected people. As of 8 October 2023, 36,250 people of 7,250 families are affected where, 1,567 houses fully destroyed and 5,601 house partially destroyed. Due to the extreme remoteness of the affected areas, the impact of the earthquake is yet to be completely understood. NRCS has already mobilized ERT members who are in the field collecting data and the impact will be clear in the coming days.

An earthquake of 5.2 M (6.1 M as reported by the authorities of Nepal) at a depth of 25 km occurred in Dhading District, central Nepal, close to the capital Kathmandu, on 22 October at 1:54 UTC (7:39 local time). The epicentre was located approximately 2 km south-west of Darbhung Town, Gorkha District. (source: reliefweb.int)

The National Earthquake Monitoring and Research Center of Nepal (SeismoNepal) recorded at least six aftershocks of magnitude between 4.1 M and 5.1 M.

According to the national authorities, one person has been injured in Gorkha District while 24 families have been impacted and more than 20 houses have been damaged in the neighbouring District of Dhading.

III. BUILDING TYPOLOGY IN NEPAL

Nepal is a seismically active region located in the seismically active Himalayan belt. The country has experienced several devastating earthquakes in its history, and as a result, building design and construction in Nepal take seismic considerations into account. However, the level of seismic resilience in buildings can vary, especially in rural or less developed areas.

In urban canters and areas with more stringent building codes, structures are often designed to withstand seismic forces. This involves engineering practices such as incorporating flexible building materials, using seismic bracing systems, and ensuring that buildings can absorb and dissipate seismic energy. In addition, modern construction practices in Nepal aim to adhere to earthquake-resistant standards.

In rural and less developed areas, especially in older buildings or traditional construction, there may be a higher risk of inadequate seismic resilience. Traditional construction materials like unreinforced masonry or adobe may be more vulnerable to earthquake damage.

After significant seismic events, there is often a reassessment of building codes and construction practices to incorporate lessons learned from the earthquake. This is particularly important in regions like Nepal, where earthquake risk is a constant concern.

It's worth noting that the effectiveness of building codes and their enforcement can vary, and in some cases, economic factors may limit the extent to which earthquake-resistant measures are implemented. Overall, efforts are made to improve the seismic resilience of buildings in Nepal, but challenges persist, especially in less affluent and rural areas.

According to the data obtained from the census, mud-bonded brick or stone masonry buildings account for a major portion of about 44.2%, followed by wooden buildings accounting for 24.9%. In urban areas for example, in Kathmandu valley, buildings with cement-bounded brick or stone account for 17.6%, followed by cement concrete at 9.9%. The reinforced concrete (RC) building concept being a modern form of construction in Nepal, began in late 1970s. Most of the conventional RC constructions are nonengineered that is, not structurally designed, and thus lack sufficient seismic resistance. The engineered RC buildings, which are relatively new, often adopt the Indian standard code with seismic provisions.

IV. IMPACT

At least 153 people were killed; 101 deaths occurred in Jajarkot District while 52 deaths occurred in Western Rukum District. The deputy mayor of Nalgad Municipality in Jajarkot, Sarita Singh, was among the fatalities. At least 78 or nearly half of those killed were children. A total of 51 people died in the municipality while 200 houses were destroyed. Another 375 people were injured. Despite the earthquake's relatively low magnitude, the high levels of damage and casualties were attributed to substandard construction in the region and because it occurred at night when people were asleep.Many of the collapsed houses were made of stacked logs and rocks.

About 62,039 houses were affected across thirteen districts of Nepal, of which 26,550 collapsed, mostly in Rukum West District. Forty-two people, including five members of a single family were killed and 100 others were injured in Aathbiskot. More than 5,000 houses were damaged or destroyed in the municipality. Eight others died in Sani Bheri. At least 40 percent of houses near the epicenter were damaged.[30] At the earthquake's epicenter in Barekot municipality, only five injuries were reported and no fatalities, while nearly all 3,500 houses in the municipality were damaged, 1,000 of them severely. Several homes were damaged or destroyed in Jajarkot District. Among municipalities severely affected were Bheri, where 42 people died and 344 houses were destroyed, Kushe, where seven died and 95 houses were destroyed, and Chedagad, where one person died and 100 houses were destroyed. At least 13 people died in Chiuri, and the village's 40 houses were either destroyed or heavily damaged. In Chiuritol, 13 people were also killed while 56 houses were destroyed. Five houses in Junichande and one house in Shivalaya were also destroyed.

Corner failure in masonry structures is observed in either isolated structures or if it is located at the end of a row of structures as there is lack of restraints at such positions to prevent the occurring of corner failure. Some of the corner failures are shown in Figure 1. Corner failure generally occurs when the walls located at the corners are subjected to the bidirectional lateral loads, i.e., during the simultaneous application of in-plane (IP) and out-of-plane (OP) lateral forces. In such failures, a failure portion is detached from the rest of the masonry structure where two orthogonal walls meet. Some of the past studies identify this type of failure (Bansal and Rai 2017, D'Ayala and Speranza 2003).

(a) (b) (c)

Figure 1. Corner failure observed in past earthquakes (a), (b) 2009, L'Aquila Earthquake (theaustralian.com.au) (c) 2011, Bhutan Earthquake (blogs.worldbank.org)

V. CONCLUSION

EFFECT ON CONERS OF UNREINFORCED MASONRY BUILDING

Unreinforced masonry buildings are particularly vulnerable to earthquakes, and Nepal, being situated in a seismically active region, faces significant risks in this regard. The effects of earthquakes on unreinforced masonry buildings can be severe, leading to structural damage, collapse, and potential loss of life. Here are some key considerations:

1) Lack of Ductility: Unreinforced masonry structures typically lack the ductility needed to absorb and dissipate seismic energy. Ductility is the ability of a material or structure to undergo significant deformation before failure. Without proper reinforcement, masonry structures tend to be brittle, making them susceptible to sudden and catastrophic failure during an earthquake.
2) Poor Construction Quality: In many cases, unreinforced masonry buildings may have been constructed with poor quality materials and workmanship. This can exacerbate the vulnerability of these structures during seismic events.
3) Ground Shaking: Nepal is located in a seismically active zone due to the collision between the Indian and Eurasian tectonic plates. When an earthquake occurs, the ground shakes, and this shaking motion can cause the masonry walls to crack, leading to partial or complete collapse.
4) Inadequate Foundation Design: The foundation of a building plays a crucial role in resisting seismic forces. Unreinforced masonry buildings often have inadequate foundation designs, making them more susceptible to settlement and tilting during an earthquake.
5) Historical Buildings: Nepal has a rich history with many historical and culturally significant buildings made of unreinforced masonry. While these structures may hold great cultural value, they are often more vulnerable to earthquakes due to their age and construction methods.
6) Mitigation Measures: The Nepalese government and various organizations have been working on earthquake risk reduction and mitigation measures. This includes promoting earthquake-resistant building practices, retrofitting vulnerable structures, and raising awareness about the importance of constructing buildings that can withstand seismic forces.

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The impact of earthquakes on unreinforced masonry buildings in Nepal can be severe due to factors like poor construction quality, lack of ductility, and the region's seismic activity. Efforts toward improving building codes, retrofitting vulnerable structures, and raising awareness about seismic risks are crucial for reducing the impact of earthquakes on such buildings.

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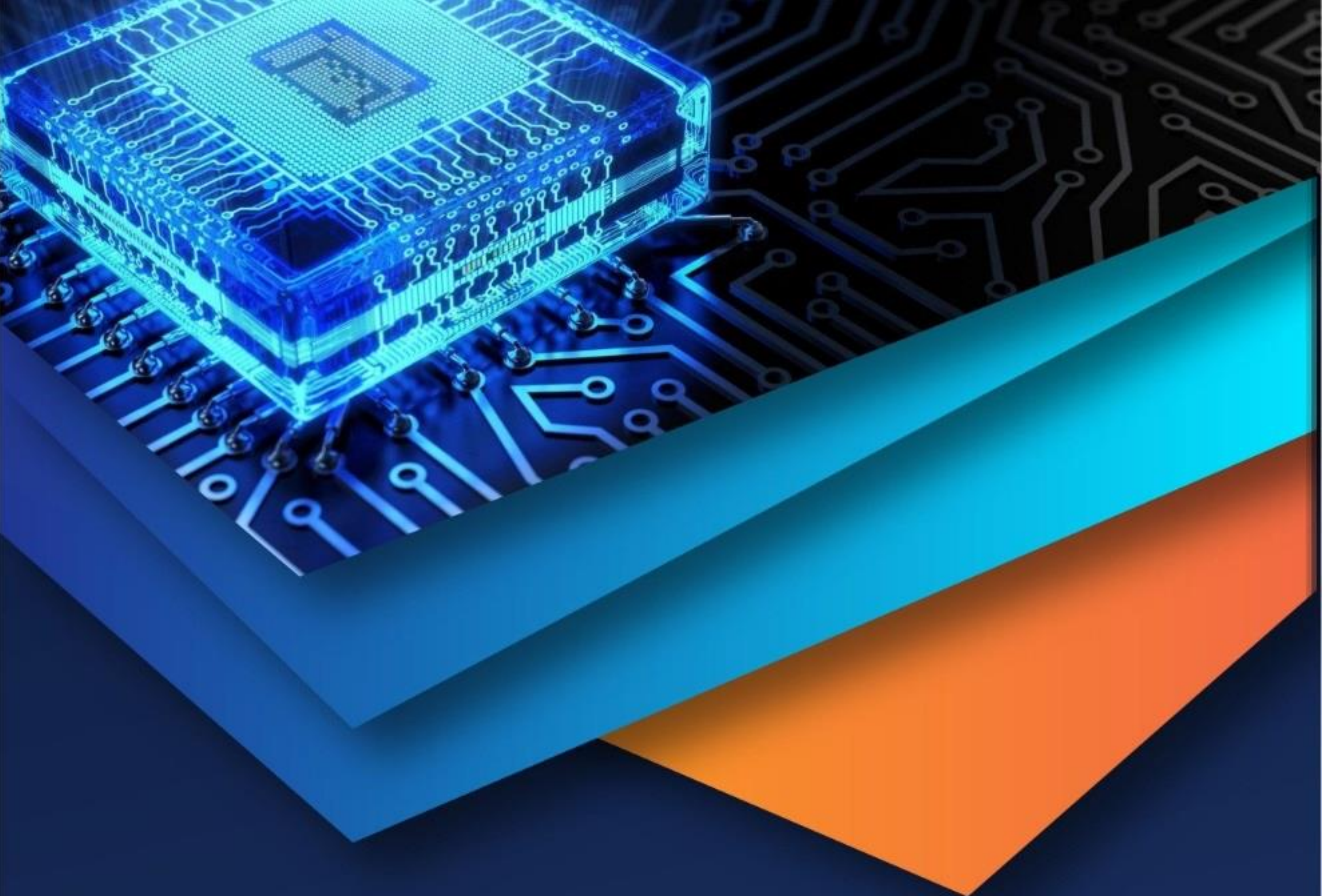

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