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ASSESSMENT OF BUILDINGS AFTER GORKHA-EARTHQUAKE-2015: A CASE STUDY OF CENTRAL BUILDINGS OF KATHMANDU UNIVERSITY, NEPAL

Pradhan P.M.*, Adhikari R., Bhat D.R.
Department of Civil and Geomatics Engineering, Kathmandu University

*Corresponding author's email: prachand@ku.edu.np
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ABSTRACT

The major earthquake in April 25, 2015 of M_w 7.8 and aftershock of intensity M_w 7.3 on May 12, 2015 caused damages to the buildings of Kathmandu University, located at Dhulikhel, Nepal. The immediate assessment of those buildings was required in order to assure whether the buildings were safe for continuing academic and administrative activities. Rapid visual assessment was performed for each building and on that basis; preliminary recommendations for repairs were suggested. Buildings where heavy damages incurred, detailed investigation were sought, until then the restriction of occupancy in that building was recommended. Those buildings which experienced minor damages, were recommended for minor repair and retrofitting works.

Key Words: Gorkha Earthquake, Rapid Visual Assessment (RVA), Kathmandu University, Earthquake, Failure Pattern, Preliminary Recommendations

INTRODUCTION

The Gorkha earthquake of Magnitude M_w 7.8 on April 25, 2015 and its major aftershock of magnitude M_w 7.3 on May 12, 2015, shook Kathmandu valley and its neighboring districts heavily causing 8,219 human casualties (MoHA, May 13, 2015) and huge loss of property. The earthquake propagated from west to east and as a result heavy shaking was experienced in and around Kathmandu City [USGS]. The earthquake had a devastating impact on the existing infrastructures. Lot of Reinforced Concrete, load bearing structures and adobe structures suffered severe damages. In this paper, effort is focused on investigating the damage assessment of structures in Kathmandu University, Dhulikhel premises.

STUDY AREA

Kathmandu University is located 30 km east of Kathmandu City surrounded with magnificent view of the Himalayan range. It primarily houses academic blocks for School of Engineering, School of Science, and residences to staffs and students.

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Figure 1: Location of Kathmandu University (Source: Google Maps.)

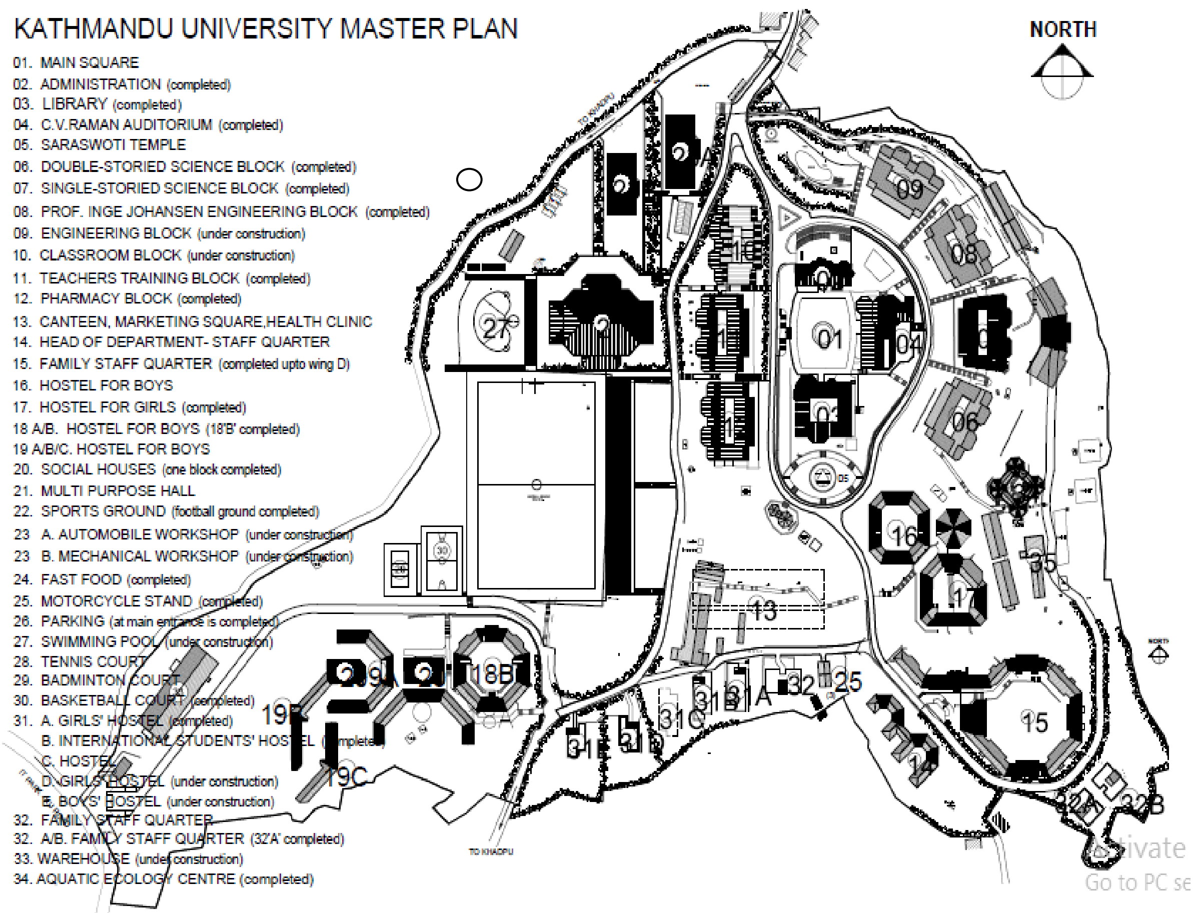

Figure 2: Kathmandu University Master Plan

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BUILDING ASSESSMENT METHODS

The first step in the investigation of the damage assessment was to perform a Rapid Visual Assessment (RVA). RVA helps identify the key spots where damages are very severe to no damages at all. It was also a means to declare whether the building was ready for reoccupancy or needed some treatments and/or required demolishing.

A form was prepared (Figure 3) that included the type of building, and types of damages incurred in that particular building. Observations were primarily made in Beam Column joints, Columns, Beams, Slab and walls. Each observation was noted along with its photographs.

Name of Building:			
Building type:			
Number of Storey:			
Observations:			
SN	Particulars	Description of Failure	Recommendation

Figure 3: RVA form

OBSERVATION AND DISCUSSION

Classification of Buildings

The types of building taken into observation is summarized and presented in the Table 1.

Table 1: Classification of Building

SN	Building Description	Building Type
1	Main Administrative Block (Block No. 2)	RCC
2	Library Building (Block No. 3)	RCC
3	Dept. of Civil and Geomatics Engineering (Block No. 11)	Combination of RCC and Load bearing
4	Staff Quarter, Building A	RCC
5	Staff Quarter, Building B	RCC

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6	Staff Quarter, Building D	RCC
7	Girls' Hostel	RCC
8	New Girls' Hostel	RCC
9	Technical Training Centre (TTC)	RCC
10	Pharmacy Building (Block No. 12)	Combination of RCC and load bearing
11	Staff Quarter (Block No. 32)	RCC
12	Turbine Testing Lab (TTL)	RCC
13	Prof. Inge Johansen Engineering Building, Block 8	RCC

The figures 4, 5, 6, 7 and 8 are some of the floor plans of few buildings under the study. The plans are presented to give some understanding of building configuration and shapes.

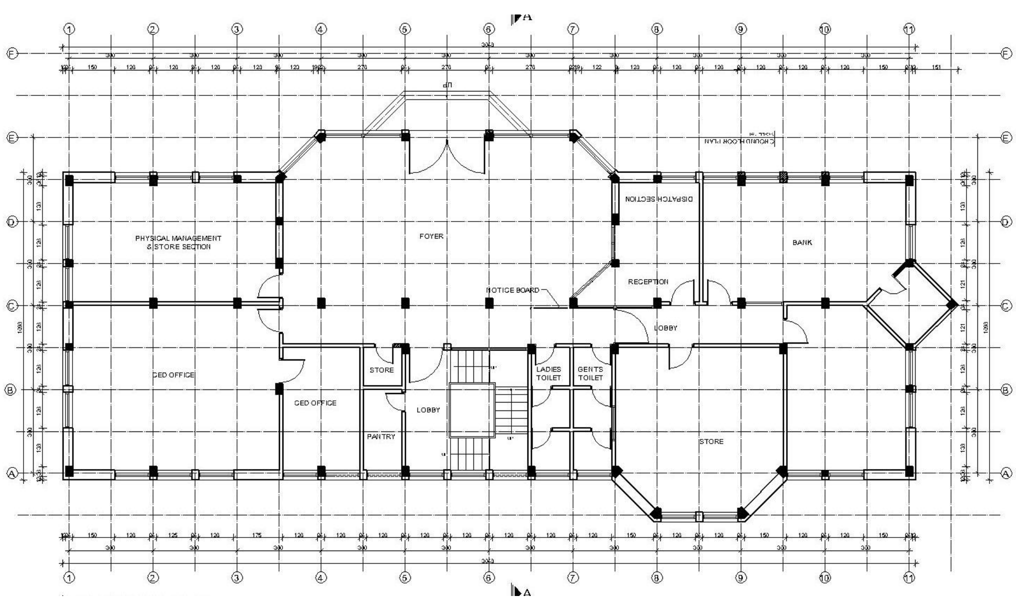

Figure 4: Block 2 Floor Plan

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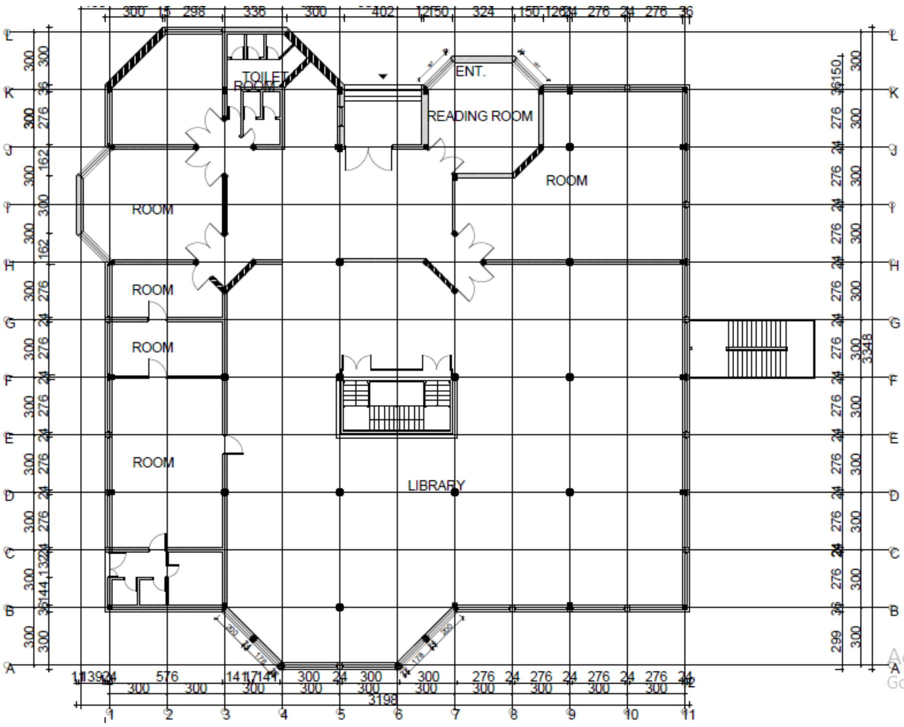

Figure 5: Block 3 Floor Plan

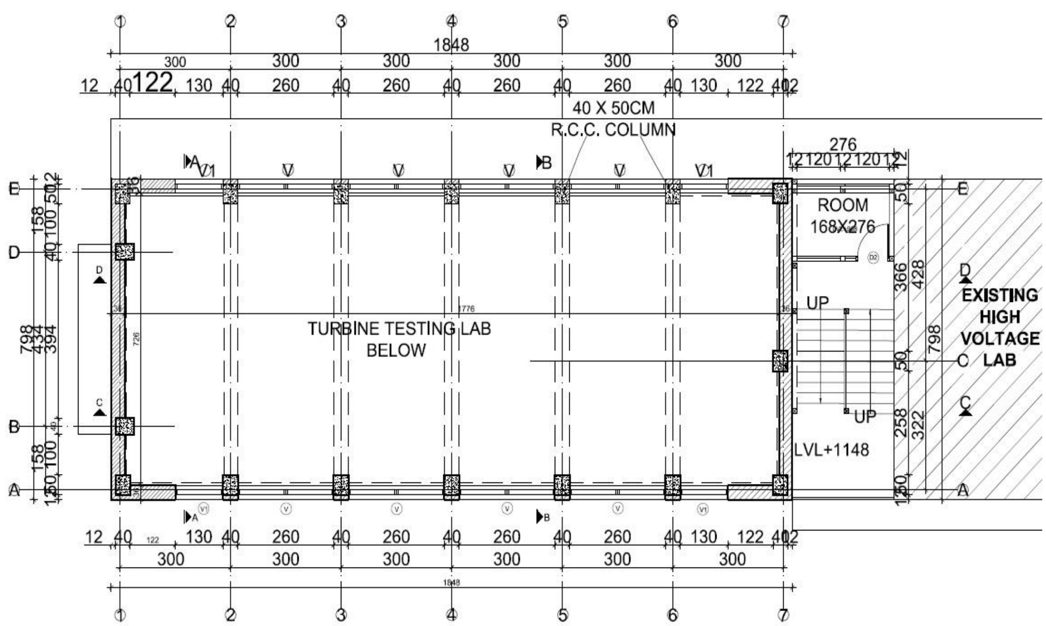

Figure 6: Floor Plan TTL

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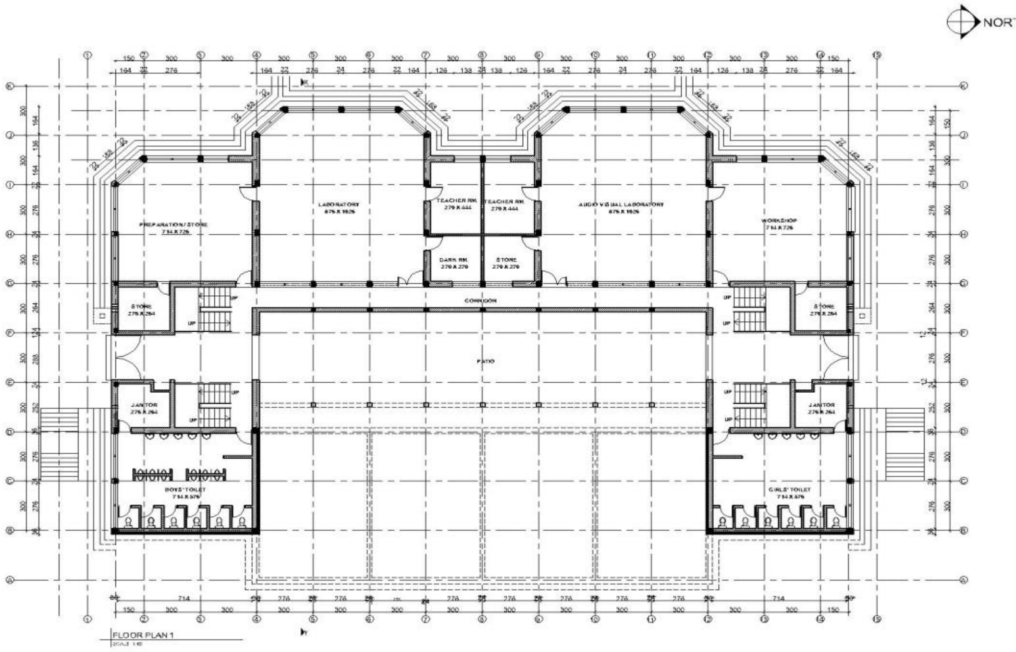

Figure 7: Ground Floor Plan Block 11

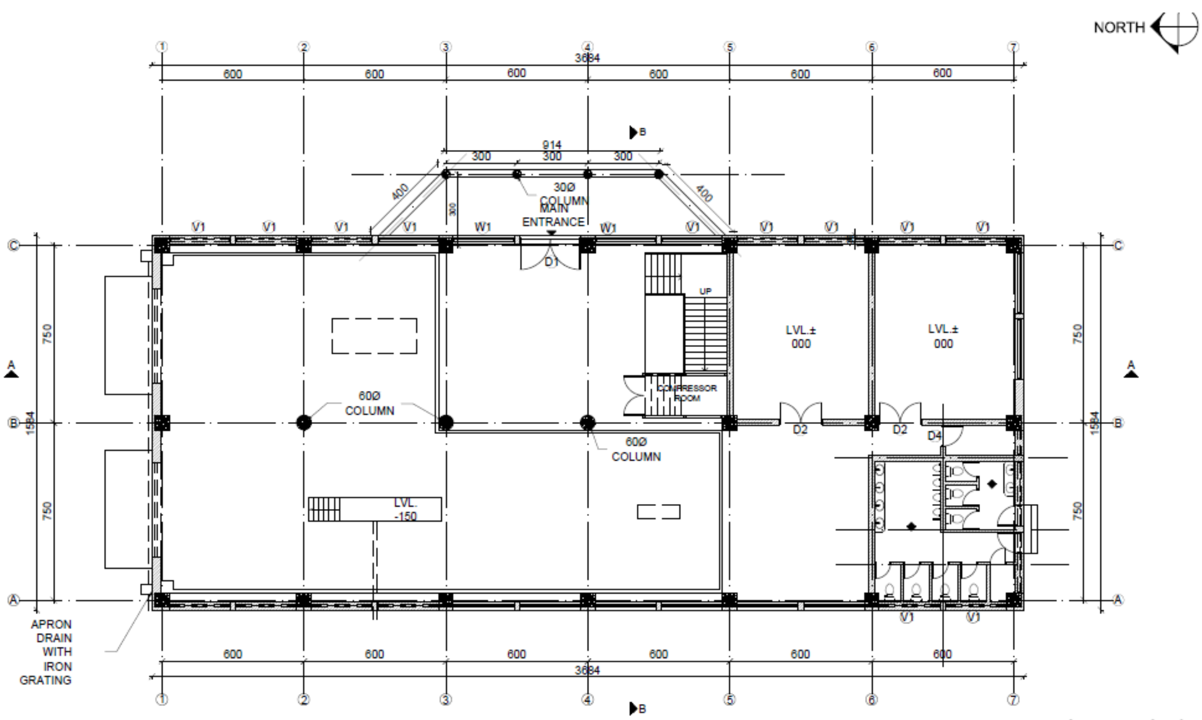

Figure 8: TTC floor Plan

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Post-Earthquake Observation

There are more than 13 buildings in the central campus of Kathmandu University. However 13 buildings as portrayed in Table 1, was made visual inspection by the assessment team. The observations are listed in Table 2.

Table 2: Post Earthquake Observation

S.N.	Building Description	Observation Details
1	Main Administrative Block (Block No. 2)	• Cracks in inclined beams. • Lot of diagonal cracks in brick walls.
2	Library Building (Block No. 3)	• Lot of column cracks was observed in the ground floor. • Lot of short column effect were observed • In and Out of plane failure of walls were also observed.
3	Dept. of Civil and Geomatics Engineering (Block No. 11)	• Horizontal cracks in the walls was observed in various parts of the block
4	Staff Quarter, Bldg A	• Column cracks seen at the beam column joint and at the bottom of the column • Short column effect observed
5	Staff Quarter, Bldg B	• 6 cases of beam column joint cracks and short column effect observed in columns
6	Staff Quarter, Bldg D	• Short column effect was observed • Minor beam cracks were observed
7	Girls’ Hostel	• Heavy Crack at beam column joint
8	New Girls’ Hostel	• First floor columns observed with cracks
9	Technical Training Centre	• Diagonal cracks observed in various parts of the wall
10	Pharmacy Building (Block No. 12)	• Minor cracks in roof slab and cracks observed in walls

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11	Staff Quarter (Block No. 32)	• Short column effect observed • Beam cracks observed
12	Turbine Testing Lab	• No sign of distress
13	Prof. Inge Johansen Engineering Building, Block 8	• Minor wall cracks

Failure Pattern

The library building was the most affected block due to this particular earthquake. The ground floor of the library was provided with wide spaces with no partition brick walls (Figure 5). This resulted in reduction of stiffness and eventually column cracks were observed. The building faced damages due to multiple deficiencies such as short column/captive column effect, soft storey, heavy mass on roof, pounding effect and slender columns. The Main administrative block (block 2) and the library block of different heights were connected by a passageway (Label 1 in the Figure 2), which was attached rigidly with the column on both the blocks. This resulted in hammering/pounding of the columns by the passageway beams, causing severe column cracks (Figure 10).

Columns in Library block showed the captive column effect (Figure 9) due to the presence of partial height masonry walls. The brick masonry walls were built up to partial height. The height of the masonry walls being as tall has 648 cm. without any horizontal band, failed in many locations due to crushing and sliding. The walls are mainly found failing in plane in many locations while in the regions where pounding have occurred, the cladding bricks have failed out of plane.

Figure 9: Short Column/Captive column Effect

Figure 10: Pounding Effect

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Figure 11: Out of Plane wall failure of cladding

Figure 12: Minor Beam Cracks

During the earthquake motion, the reinforced concrete frame deformed first and cracks appeared on the plaster along the contact of infill wall with frame. When the deformation became bigger, it then separated the infill wall from the frame, resulting the cracking (diagonal or horizontal) of the wall. Further the pounding effect of the corridor in between Block 2 and library block (Block 3) caused the cladding wall to spall out of plane from its initial alignment. (Figure 11).

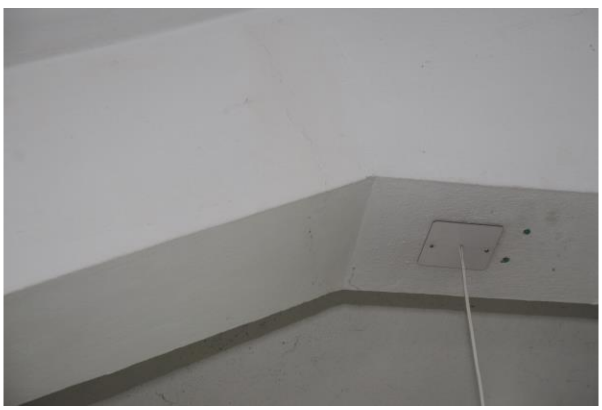

Figure 13: Cracks observed in inclined beam

Figure 14: In plane wall cracks

The Technical Training Centre block (TTC) suffered numerous in plane wall cracks (Figure 14). Central columns, despite having long spacing without masonry infill wall between the columns (Figure 8), there was no major structural failure observed. The exterior infill walls cracked heavily. It was observed that the wall heights being too tall, the failure of infills occurred heavily. In blocks 6 and 11, horizontal wall cracks were observed. These structures were not 100 percent RCC framed structures therefore, the wall heights were about 648 cm high without presence of horizontal bands. The masonry walls however did not collapse. The Turbine Testing Lab (TTL), did not show any sign of distress and Girls' Hostel and Boys' Hostel, did not suffer significant damages. The Staff Quarter Block Building D suffered minor vertical beam cracks (Figure 12). Block 32 was found effected majorly in its top story beams. Some minor cracks are observed in the top storey beams which need to be retrofitted.

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The inclined beams present in the top floor of Block 2, showed minor vertical cracks near the bends (Figure 13). The building suffered numerous in plane wall cracks.

Figure 15 shows the failure pattern of the Buildings, thus indicating majority of damages were due to soft storey, pounding effect, captive column effect and large height wall cracks.

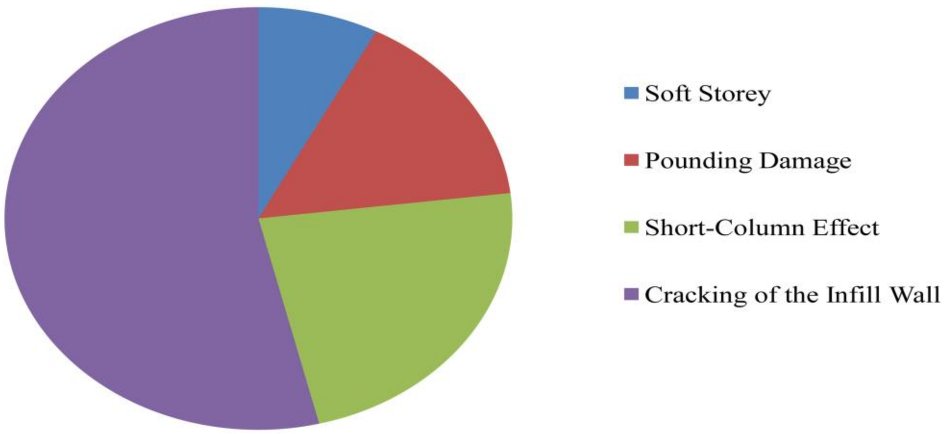

Figure 15: Failure pattern of the Buildings

RECOMMENDATIONS

Most of the buildings within the Kathmandu University premises suffered partition wall cracks. Cement plaster spall off was another main consequences of the earthquakes. However neither of these failures is considered major structural failures. These failures can be treated either by completely dismantling the walls or by using the wire mesh along with the cement grouting, depending upon the extent of the cracks (Figure 16). The figure 16 is an example of wire mesh strengthening with cement grouting in block 11.

Figure 16: Retrofit of wall using wire mesh and cement grouting

Figure 17: Retrofit of column by jacketing method.

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In the main campus area, the corridor portion between Block 2 and Block 3, located around the courtyard, was recommended for proper separation from the main structures, so that further pounding effect do not lead to cracks in column in the future earthquakes.

Column and Beam cracks however requires special treatment. In the block number 3, also referred to as the Library block had several column cracks. The initial design underestimated the seismic load acting on the building which eventually caused the columns to crack. The sizes of column were not found to be sufficient, and hence required the increase of the column size, by the method of jacketing (Figure 17). Those columns which were found to be cracked were recommended for retrofit. The initial observation indicated that there were 26 columns urgently in need of retrofitting. It was also observed that the beams were unaffected by the lateral shaking, which further indicated that the building had strong beam and weak column, a deficient approach of design. Beam and slab cracks were recommended for epoxy grouting or cement grouting, depending upon the extent of the cracks. The beams which had more than 0.5 mm cracks were recommended for Fiber Reinforced Polymer wrapping.

CONCLUSION

Gorkha Earthquake-2015 has affected several buildings of Central campus of Kathmandu University, Nepal. In this study, 13 major affected buildings (i.e., 11 RCC and 2 RCC mixed with Load Bearing Buildings or composite type) were considered. The detail assessments of these buildings were done by using the Rapid Visual Assessment (RVA) method. Based on that, the details observation was carried out to understand the failure pattern of the buildings. It was found that most of the buildings are damaged due to the damage of non-structural elements such as cracking of the infill wall. However, the Library block and main block were damaged by pounding/hammering and short column effect. Soft storey effect was observed on Library block only. Finally, it is recommended for the strengthening and retrofitting of the buildings in the near future for safe operation of the building.

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