Retrofitting of Gorkha Earthquake Damaged Residence Building at Purano Bhanjyang-13

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Abstract

The effect of “April 2015 Gorkha Earthquake” was devastating in terms of loss of life, heritage, buildings and emotions. More than 9,000 people were killed and injured nearly 22,000 people. Amongst many buildings, a residence located at Purano Bhanjyang-13, Kathmandu was severely damaged which was built in 2006 A.D. The building is Reinforced Concrete building with 3 stories plus 1 semi basement.

The main objective of the study is to analyze the structure to intervene with best retrofitting option to secure it from future earthquakes and to provide adequate strengthening construction technique during the vulnerable state.

Keywords: Retrofitting, Strengthening, Etabs, Epoxy Grouting, Anchorage

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1. INTRODUCTION

Nepal lies in an active fault/thrust zone due to the collision of Indian plate with Eurasian techtonic plate as a result of which earthquakes are frequent. Seismologists suggest that a major earthquake of magnitude greater than 8 Mw is likely to occur every 80-100 years in Nepal. The April 2015 Nepal earthquake (also known as the Gorkha earthquake) killed nearly 9,000 people and injured nearly 22,000. It occurred at 11:56 Nepal Standard Time on 25 April 2015, with a magnitude of 7.8Mw and a maximum Mercalli Intensity of VIII (Severe). A major aftershock occurred on 12 May 2015 at 12:50 NST with a moment magnitude (Mw) of 7.3. The epicenter was near the Chinese border between the capital of Kathmandu and Mt. Everest. More than 200 people were killed and over 2,500 were injured by this aftershock, and many were left homeless. More than 600,000 structures in Kathmandu and other nearby towns were either damaged or destroyed.

Amongst many buildings, a residence located at Naikap Purano Bhanjyang, Chandragiri-13, Kathmandu was severely damaged which was built in 2006 A.D. The building is a non engineered reinforced concrete building with 3 stories plus 1 semi basement. Structural damages included plastic hinge formation at beam column joint in centre column and hairline cracks in beams at first floor. Non structural damages included diagonal cracks in internal as well as external walls and falling of parapet walls. The masonry staircase was heavily damaged lacking the support.

It was necessary to provide immediate strengthening techniques to the structure as well as to design and analyse the structure for retrofitting process.
Fig1: Buckling of column  
Fig2: Plastic hinge formation at Column  
Fig3: Vertical cracks at wall-column joint  
Fig4: Diagonal crack at staircase wall

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2. METHODOLOGY

The intervention of the building was done in two stages i.e. Immediate Preventive and Supportive stage (to withstand the aftershocks) and Retrofitting stage.

I. IMMEDIATE PREVENTIVE AND SUPPORTIVE STAGE

After sustaining major structural damage from the earthquake of 25th April 2015, the building was not safe for accommodation and was considered for retrofitting. In the mean time, preventive and supportive measures were required to preserve itself from future expected aftershocks.

Metallic construction props were installed at the semi basement level under the beams and slab of first floor level. The disintegrated concrete was removed and the area was cleaned at the site of buckling and fresh micro concrete with super plasticizer (epoxy resin) was applied. All the live loads were removed from the floors above. Due to unavailability of construction workers and materials at that time, these steps were found to be effective to support the structure from further damages during the major aftershock of 12th May 2015 as well.

Fig5: Installation of Metal Props

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II. RETROFITTING STAGE

For retrofitting, the analysis and design was carried out using finite element software ETABS 2015 to create, modify, analyze, design, and optimize the structural elements in a building model. The structure design was intended to be based primarily on the then current National Building Code of Practice of India and is generally in conformance with NBC of Nepal. Input parameters for the objective of retrofitting process were Response Spectrum=5, Importance factor=1 and seismic zoning factor=1. Determination of deficit concrete/ rebar was done as per IS 1893:2002. Analysis of the building in computer analysis showed that the building was safe in strength related checks such as shear stress capacity, axial stress and out of plane capacity.

Retrofitting of two columns from foundation was concluded after the analysis. Thus in order to perform the strengthening process from the foundation, the existing structure needed to be strengthened by other means which is referred to as first stage. The retrofitting of columns from the foundation is referred to as second stage and the finishing as third stage.

![Modelling in ETABS](image)

Fig6: Modelling in ETABS
Fig7.1: Story-Deflection graph before(left) and after(right) retrofitting in x- direction

Fig7.2: Story-Deflection graph before(left) and after(right) retrofitting in y- direction

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1) FIRST STAGE

a) Strengthening of columns

For remaining columns, steel jacketing was provided. For jacketing, 33% extra detailing to the rebars and 50% extra concrete was provided. Original surface was chipped off, roughened and surface was coated with non shrink grout to provide bonding with steel and concrete. 4 Nos of ISA was provided at every corner and MS flat at 250 c/c was welded to ISA and then brickwall ewas engaged to the columns with microconcrete with super plasticisers.

Fig 8: Grouting in Column

Fig 9: Column Jacketing in process
b) Strengthening of beams

First floor beams were grouted with epoxy resins.

Fig10: Grouted columns with epoxy resins

Fig11: Nozzles installed at beam for grouting with super plasticizer

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c) Provision of 9” thick wall in the semi basement

As the semibasement had a 9 inch brick wall at the area of soil contact and 4 inch wall else where, it was required to provide a minimum of 9 inch walls at the exterior as well as interior partion wall in order to provide stiffness and reduce the effect of soft storey. Thus 9 inch wall was constructed below the beams leaving space for retrofitting of columns. Existing 9 inch wall in contact with soil wall was jacketed with wire mesh and plastered using micro silica.

![Fig12: 9” Thick wall below beams at semi basement level to support the retrofitting process of columns](image)

*d) Grouting on cracked walls*
Severely damaged walls were demolished whereas slightly damaged walls were grouted with microconcrete where necessary.

2) SECOND STAGE

The retrofitting of two columns started with an excavation to the foundation where the reinforcement was started from the footing. Anchor bars were added for better contact of existing and new added concrete. The existing size of column was 9” by 12” with 8 nos of 16 dia rebar. The retrofitted size of column was 17” by 20” with added 8 nos of 16 dia rebar. 8
diastirrups were placed at 100 mm c/c interval. The columns were retrofitted upto second floor level as suggested from structural analysis.

For retrofitting of columns, small portion of slab was broken which resulted in the vibration of slab. Thus, in order to strengthen slab, wire mesh was installed to the slab before screeding. The beam column joint was improved by providing haunches.

Fig13: Reinforcement added from footing                      Fig14: Reinforcement continued to upper floors through slab

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Fig 15: Column after retrofitting  
Fig 16: Rebars for first floor column  
Fig 17: Reinforcement at footing

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3. RESULTS:
Epoxy grouting, steel jacketing and wire mesh proved to be efficient for strengthening of structures. Addition of brickwall provided extra stiffness in the soft storey(semi-basement). Retrofitting of the columns from the foundation proved to be effective in terms of strength and cost than to demolish and reconstruct the structure in this case. Moreover, proper analysis and construction played an important role during the retrofitting process of this structure.

4. DISCUSSIONS
After the devastating earthquake, there was still fear of next large tremor/s as there had been occurrence of continuous aftershocks. The structure was susceptible to further damage if action was not taken immediately. There was no adequate manpower at the moment for construction which made it even harder. Price of construction materials was also hiked. Thus the application of props proved to be efficient to provide temporary support to the failed structure. Due to continuous aftershock the props needed to be tightened time and again typically once a day. The construction of brickwall was the most quick and reliable process to support the structure when the retrofitting was being carried out. Similarly epoxy grouting strengthened the beams and columns before the process.

5. CONCLUSIONS AND RECOMMENDATIONS
- The building was a typical 9”x12” column sized built as per the trend at that time. However, the building couldn’t withstand the April 2015 Earthquake where similar or worst detailed building survived well. After the detail observation it came to light that this building had an open storey at basement which contributed to the excess damage in that level.
- The whole process of retrofitting was carried out in two stages which placed a very crucial role in our retrofitting process. The first stage help strengthen the structure to endure the stresses which retrofitting was carried out from the foundation. The
immediate response after the quake is very important to ensure that there is no further fatal damage to the structure.

- The props used in the first stage wasn’t removed at once during the retrofitting process but removed gradually to support the structure and let the new retrofitting material gain its strength.
- No significance difference in story deflection was seen before and after retrofitting. Therefore, the damage of the building is predominantly caused due to open storey and low quality of concrete.

REFERENCES


DUDBC, Seismic Retrofitting Guidelines of Buildings in Nepal, 2016 RCC Structure