Building damage patterns in Kathmandu Valley due to 25th April Earthquake

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This report presents the nature of the earthquake that struck Nepal on 25th April, 2015 and the damages observed in the buildings in Kathmandu valley.

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A. Nepal Earthquake

1) Introduction

A strong earthquake of magnitude 7.8 Richter scale struck the central part of Nepal on 25th April, 2015 at shallow depth of 15 km. The epicenter was located at Barkpak village of Gorkha district, 77 km NW of Kathmandu. *Early modeling of this earthquake implies dimensions of ~120x80 km, directed from the hypocenter eastwards, and towards Kathmandu. As a result, substantial seismic energy was generated by faulting very close to the city*[1].

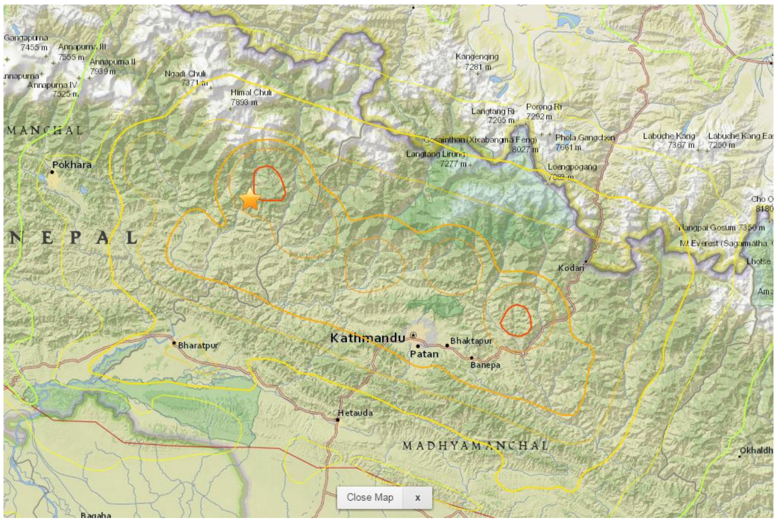


Figure 1: Map showing the location of the epicenter propagation of the rupture towards Kathmandu (Source: USGS)

2) Ground motion Record

As recorded at the station in Kantipath, Kathmandu, the ground motion plot is shown below. The ground motion is divided in to three components, two horizontal components and one vertical component.

The recorded PGA at the station was 0.16g, while the derived PGA in Kathmandu valley was 0.73g. The derived maximum PGA is 1.32g in Sindhupalchowk district, which suffered the maximum structural damages and casualties due to the shaking. As per UBC 97, the design PGA is 0.44g in Kathmandu valley.

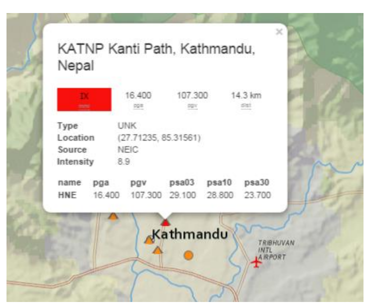


Figure showing the recorded PGA at the Kantipath station. (Source: USGS)

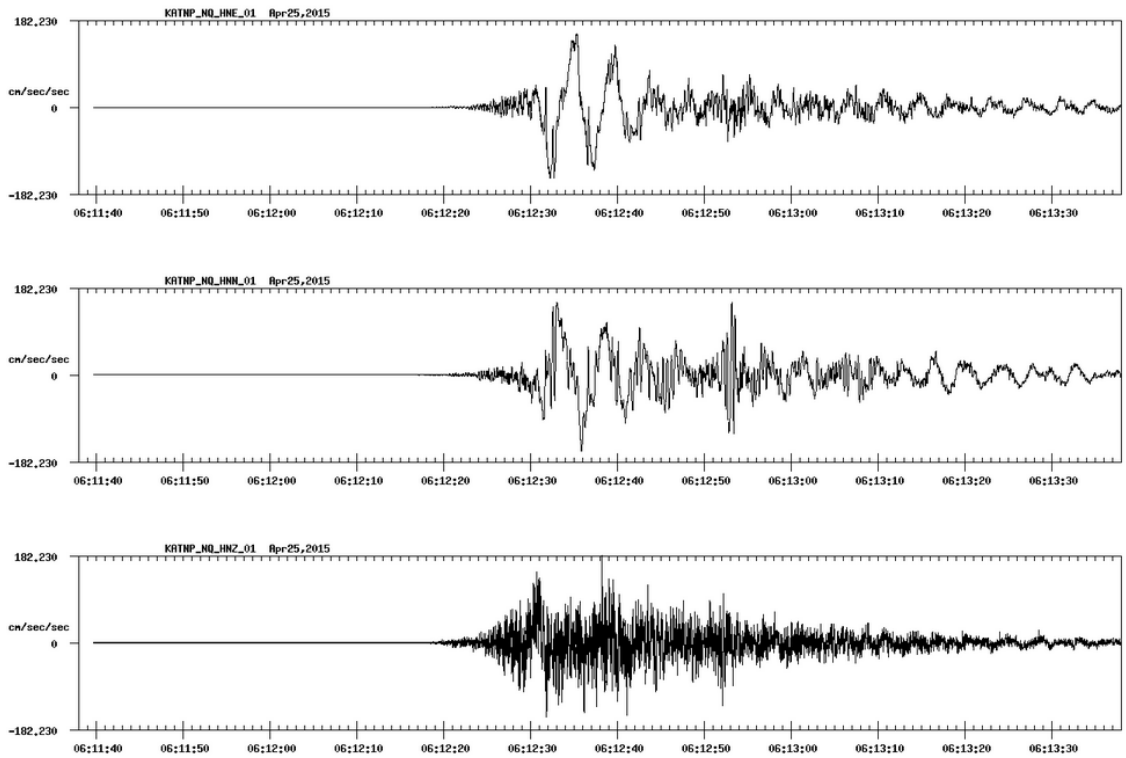


Figure: Long period acceleration ground motions recorded at Kantipath, Kathmandu station. (Source: USGS)

From the ground motion plot, as seen above, the ground vibration is slow in nature in Kathmandu valley Because of this slow nature of the earthquake high rise buildings and flexible mid-rise buildings are expected to suffer maximum damage due to such shaking, while low to stiff mid-rise buildings are expected to suffer least damage.

B. Damaged buildings in Kathmandu Valley

Figure- Ground fissures in Bhaktapur district. There is no damage in the nearby houses seen in the photo *(Photo by Kiran Acharya)*

The land along the marked width has been settled by around 1.5 m. No major cracks in the surrounding houses except tilting and shifting of the affected house. *(Photo by Kiran Acharya)*

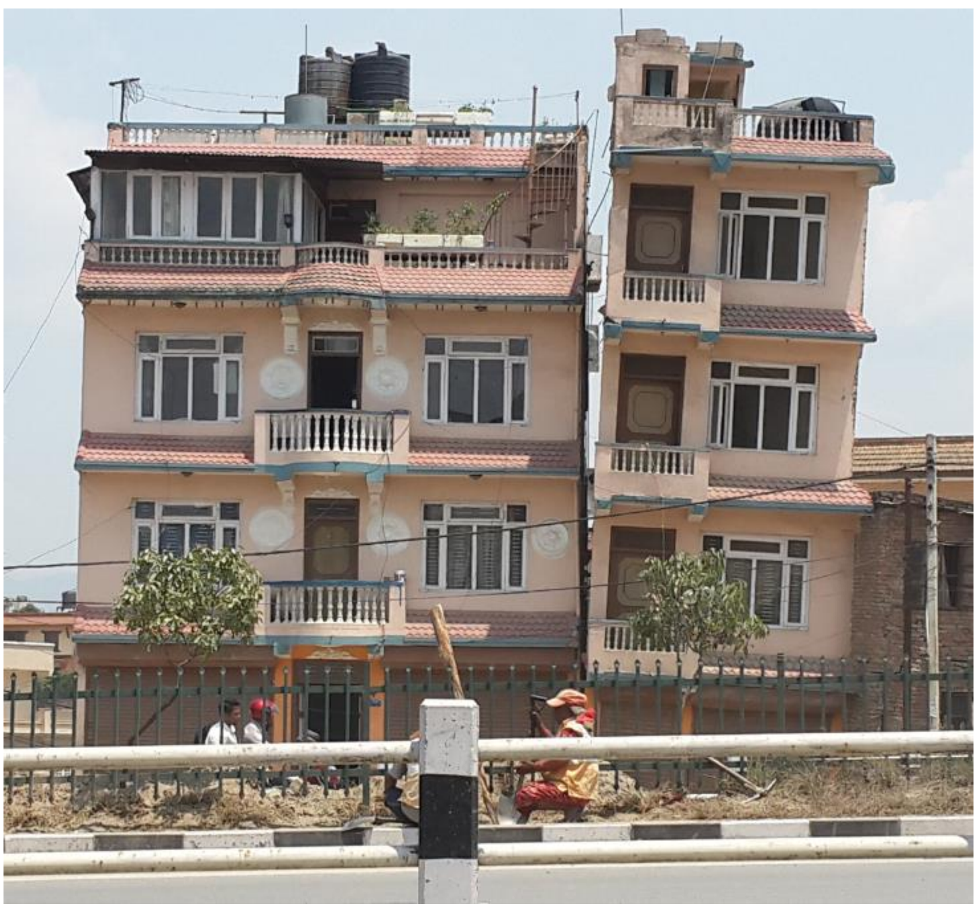
Surface ruptures in the settled part of the land *(Photo by Kiran Acharya)*

Maximum damages on the walls and floors of the green house seen in the previous figure. *(Photo by Kiran Acharya)*

Tilting of the house by around 1 m near the surface cracks *(Photo by Kiran Acharya)*

Tilting of the red house. No structural damage in the white house *(Photo by Kiran)*

Settlement of the front garden of the white house seen in the previous figure by around 1.5 m *(Photo by Kiran)*



Houses near the surface rupture. These are two different houses *(Photo by Kiran)*

Stump of the 9 storey tall Dharahara tower. It felled down towards the marked direction *(Photo by Kiran)*

Kathmandu Durbar Square *(Photo by Kiran)*

An artist depicting the ruined Palace in his canvas *(Photo by Kiran)*

(Photo by Kiran)

Durbar High School *(Photo by Kiran)*

Damage in the roofs of a school in Bhaktapur. There are not even minor cracks at other locations *(Photo by Kiran)*

Pink colored is the retrofitted part of the school while the other had not been retrofitted. *(Photo by Kiran)*

This “Y” Shaped 4 story school building has no cracks on the walls except on the floor of one room on ground floor, shown aside. *(Photo by Kiran)*

Damaged house near to the "Y" shaped school building. *(Photo by Kiran)*

Surprisingly no damage in the marked house, near to the above cracked house. The building on the left corner of the photograph is the retrofitted school building which has no damage at all. *(Photo by Kiran)*

Damaged old houses in the village of Bhaktapur district *(Photo by Kiran)*

Roof of the retrofitted school building is damaged by the adjacent house *(Photo by Kiran)*

Relatively new buildings suffered no damage at all. *(Photo by Kiran)*

Surprisingly no external cracks are visible in such building in Bhaktapur district. *(Photo by Kiran)*

Column shear failure on the ground floor of the house Balaju, Kathmandu *(Photo by Kiran)*

Damaged column of the house in Balaju, Kathmandu area *(Photo by Kiran)*

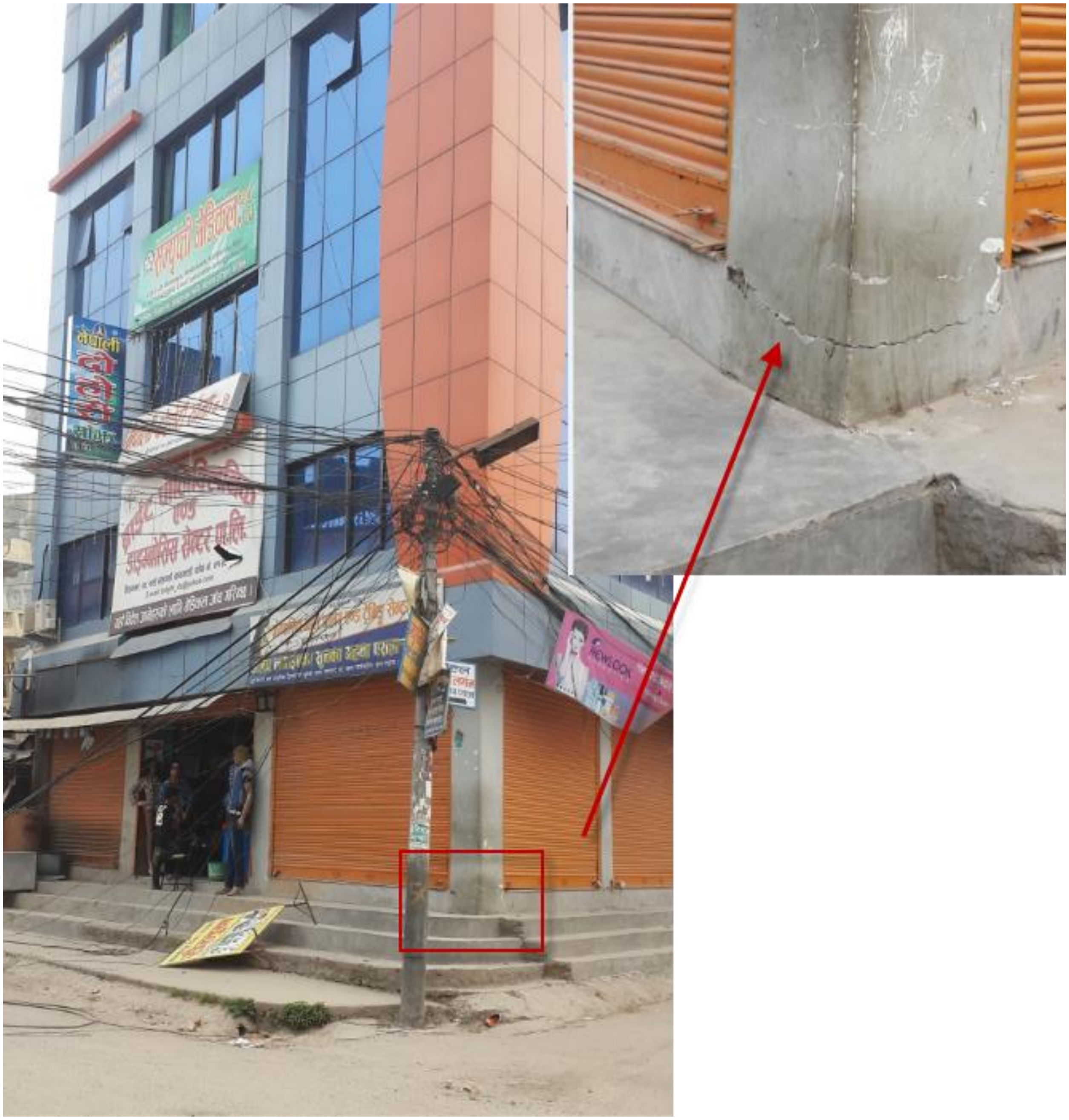
Damages in the interior walls and columns of the house in Balaju, Kathmandu. Longitudinal rebar are buckled after concrete crushing at the soffit of the beam and at column base *(Photo by Kiran)*

Shear failure of the columns on ground story at the soffit of the beam due to short column effect induced by the infill wall in Balaju, Kathmandu *(Photo by Kiran)*

Complete collapse of first two story of a five story house Balaju, Kathmandu, due to soft story effect. There were no infill walls at the periphery of the ground floor. *(Photo by Kiran)*

Close up view of the damaged columns of the previous building. *(Photo by Kiran)*

Shear failure of the column at base of other building in Balaju, Kathmandu. *(Photo by Kiran)*



Critical flexural crack at the column base in the building in Balaju, Kathmandu *(Photo by Kiran)*

More damage in the buildings on right side than on the left side of the road in Balaju, Kathmandu *(Photo by Kiran)*

Horizontal cracks in Swyambhu stupa, Kathmandu *(Photo by Kiran)*

Collapsed buildings due to soft story effect, Sitapaila, Kathmandu *(Photo by Kiran)*

Damaged columns at the marked location of the previous photos *(Photo by Kiran)*

Collapsed building in Sitapaila, Kathmandu. All the rebar were spliced at the same location in the column as marked in the diagram. *(Photo by Kiran)*

Damages in the infill walls and at the corners of the high-rise apartment buildings Kathmandu
(Photo by Kiran)

Soft story collapse of another building in Sitapaila, Kathmandu. No stirrups were provided at the beam column joint location. *(Photo by Kiran)*

Collapsed houses in Sitapaila, Kathmandu *(Photo by Kiran)*

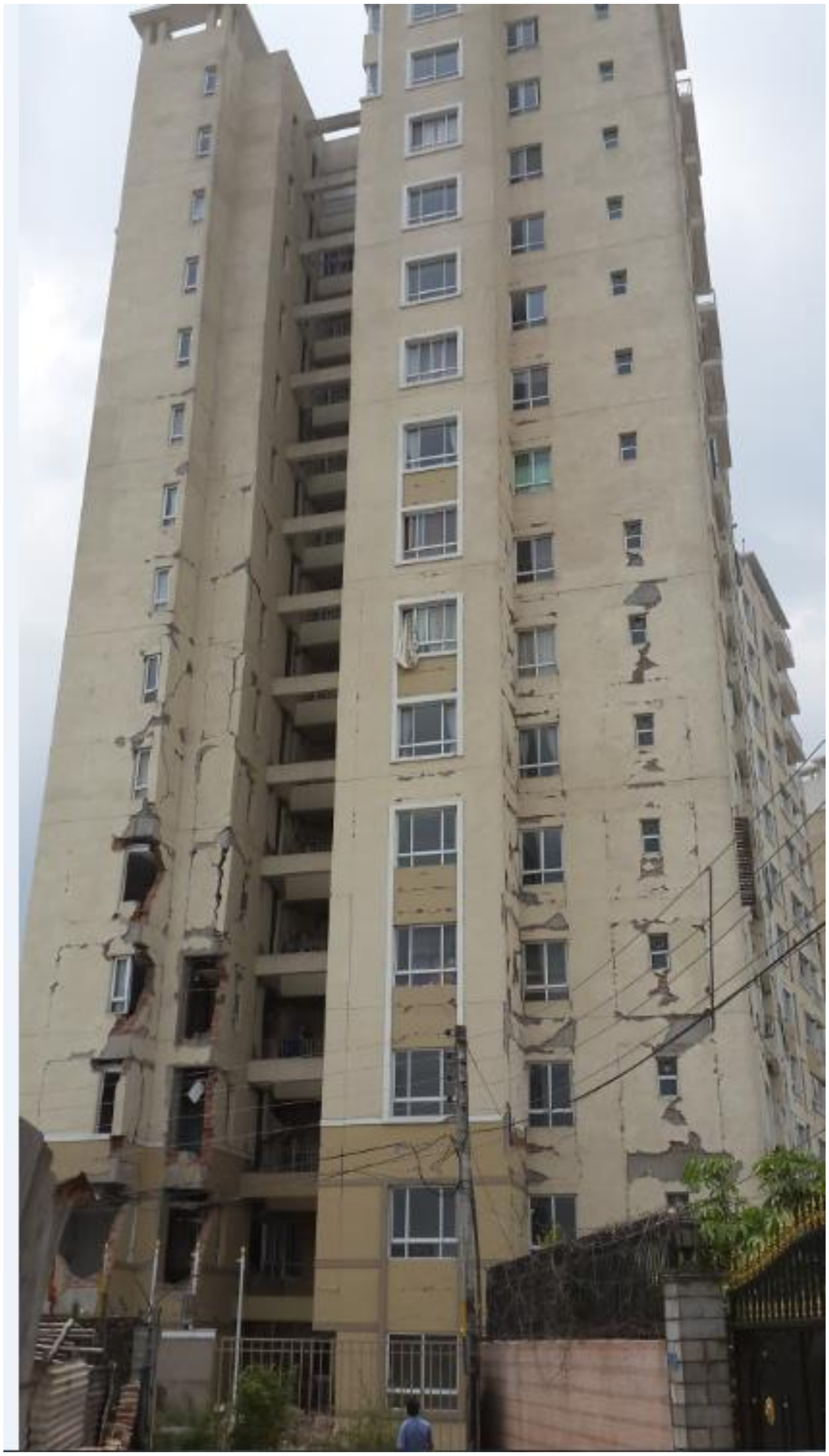
Collapse of a two story frame structure in Sitapaila, Kathmandu. Column bases on the upper story are also damaged. *(Photo by Kiran)*

Damaged column bases on upper story of the previous building *(Photo by Kiran)*

Soft story collapse of a 5 story house in Dhapasi, Kathmandu

Infill wall damage of a 17 storey tall apartment building in Kathmandu (Right face of the building) *(Photo by Kiran)*

Left face of the building. Damage to the middle part of the structure may be attributed to the higher mode participation. *(Photo by Kiran)*



Front face of the building *(Photo by Kiran)*

Damage in Spandrel on left face of the *(Photo by Kiran)*

Overturning of a 7 storey tall building in Kapan area, Kathmandu *(Photo by Surya Raj Acharya)*

Longitudinal reinforcements were spliced at same location in the column and building overturned by lap splice failure at tension location *(Photo by Surya Raj Acharya)*

Another view of the 7 story tall building *(Photo by Surya Raj Acharya)*

Repaired diagonal shear cracks in a school building in Imadol area, Lalitpur *(Photo by Kiran)*

Horizontal crack at the beam interface in a wall that was constructed after constructing the frame in Lalitpur. No other cracks are seen in this 4 story RC frame building except similar vertical cracks at column interface. *(Photo by Kiran)*

No damage at all in such buildings in Bhaktapur. *(Photo by Kiran)*

C. Observations and Conclusions

Following observations are made in Kathmandu valley after the earthquake

1. Long period ground acceleration resulted in the damage of relatively flexible structure where as stiff structures suffered less damage in Kathmandu valley.
2. Buildings where infill walls were constructed after constructing the frames suffered more cracks at beam and column interface, while, the buildings where infill walls and frames were constructed together suffered no such damages.
3. Most of the buildings with complete infill walls on ground floors and buildings without infill walls on ground floor but with larger column dimensions 12”x12”, suffer minor to no damage.
4. Most of the columns are failed by crushing of the concrete at the soffit of the beam or at column base leading to the subsequent buckling of the longitudinal bars.
5. In some buildings it is observed that the building could not resist the overturning moment due to lap splice failure on the tension side. It was observed that all the longitudinal rebar were spliced at same location in such buildings.
6. Complete collapse of the ground floor and in some cases up to 2nd floor of mid-rise buildings (4 to 6 story tall) due to soft story mechanism. This kind of buildings did not have infill walls on the periphery grid on ground floor for commercial purpose and the column sizes were 9”x9”.
7. No major damage in the components of the building near to surface fissures. However they suffer excessive tilting and settlement
8. Collapse of the cultural heritages dated back up to 5th century.
9. Complete collapse of the over aged masonry buildings.
10. Partial collapse of the wooden roofs of relatively new load bearing masonry buildings. Other part of the building remain intact with no critical damage
11. High rise buildings and mid-rise flexible buildings are at more risk than the low to mid-rise stiff buildings in Kathmandu valley.
12. Damage pattern of the High-rise building like Park View Horizon apartment may be attributed to the excitement of higher modes of vibration.
13. Strong beam-weak columns are observed in the collapsed RC frame buildings in Kathmandu.
14. A low rise house in Sindhupalchowk and Gorkha would experience more than double seismic force than the same house in Kathmandu would have experienced. This is primarily due to almost double value of Peak Ground Acceleration (PGA) in Sindhupalchowk and Gorkha (1.32g) than the PGA in Kathmandu (0.73g) and also due to the stiff nature of soil in Gorkha and Sindhupalchowk.