OBSERVATOIN OF BUILDING DAMAGE PATTERNS IN KATHMANDU DUE TO EARTHQUAKE- DRAFT REPORT

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Table of Contents

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].

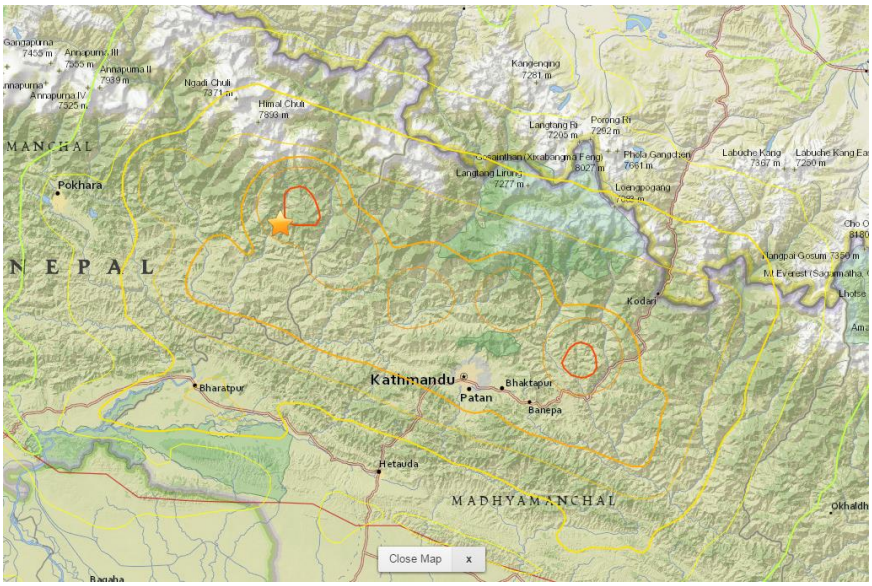


Figure 1: Map showing the location of the epicenter propagation of the rupture towards Kathmandu (Source: USGS)

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.

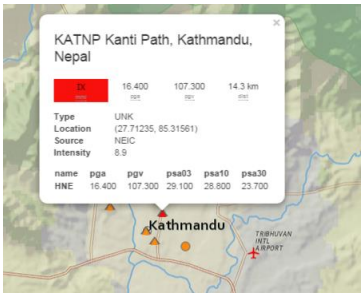


Figure showing the recorded PGA at the station. (Source: USGS)

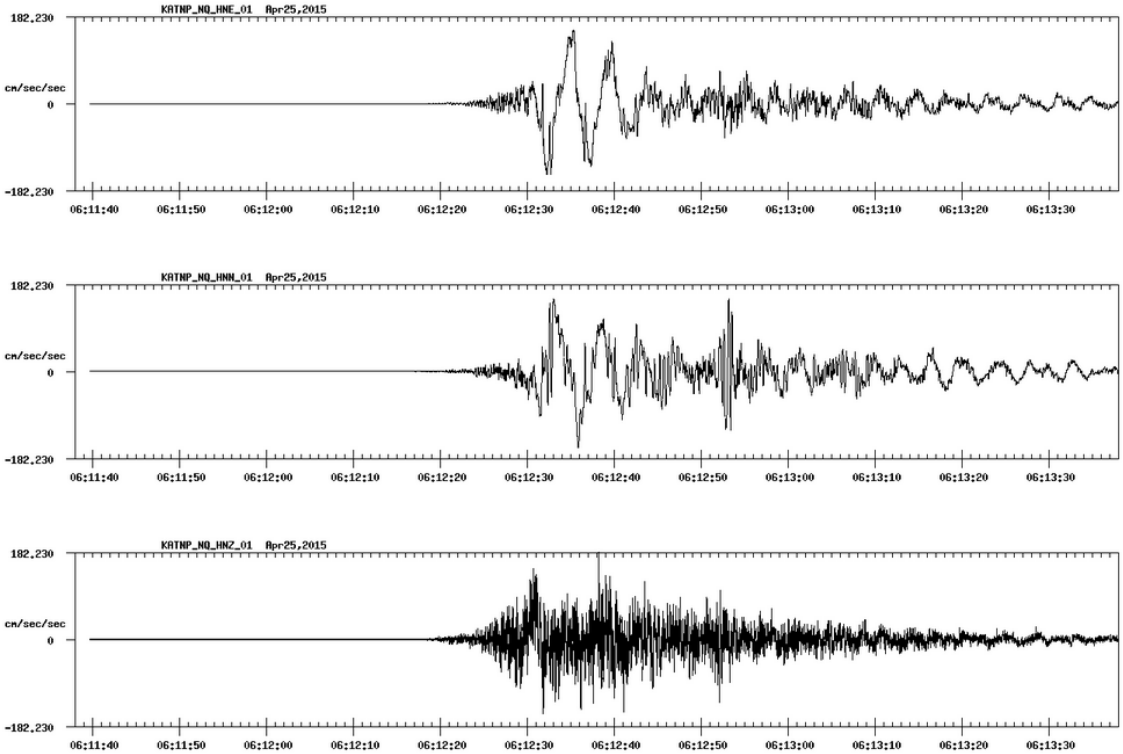


Figure: Long period acceleration ground motions recorded at Kantipath, Kathmandu station. (Source: USGS)

From the ground motion plot, as seen above, the ground vibration is slow in nature in Kathmandu valley. 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.

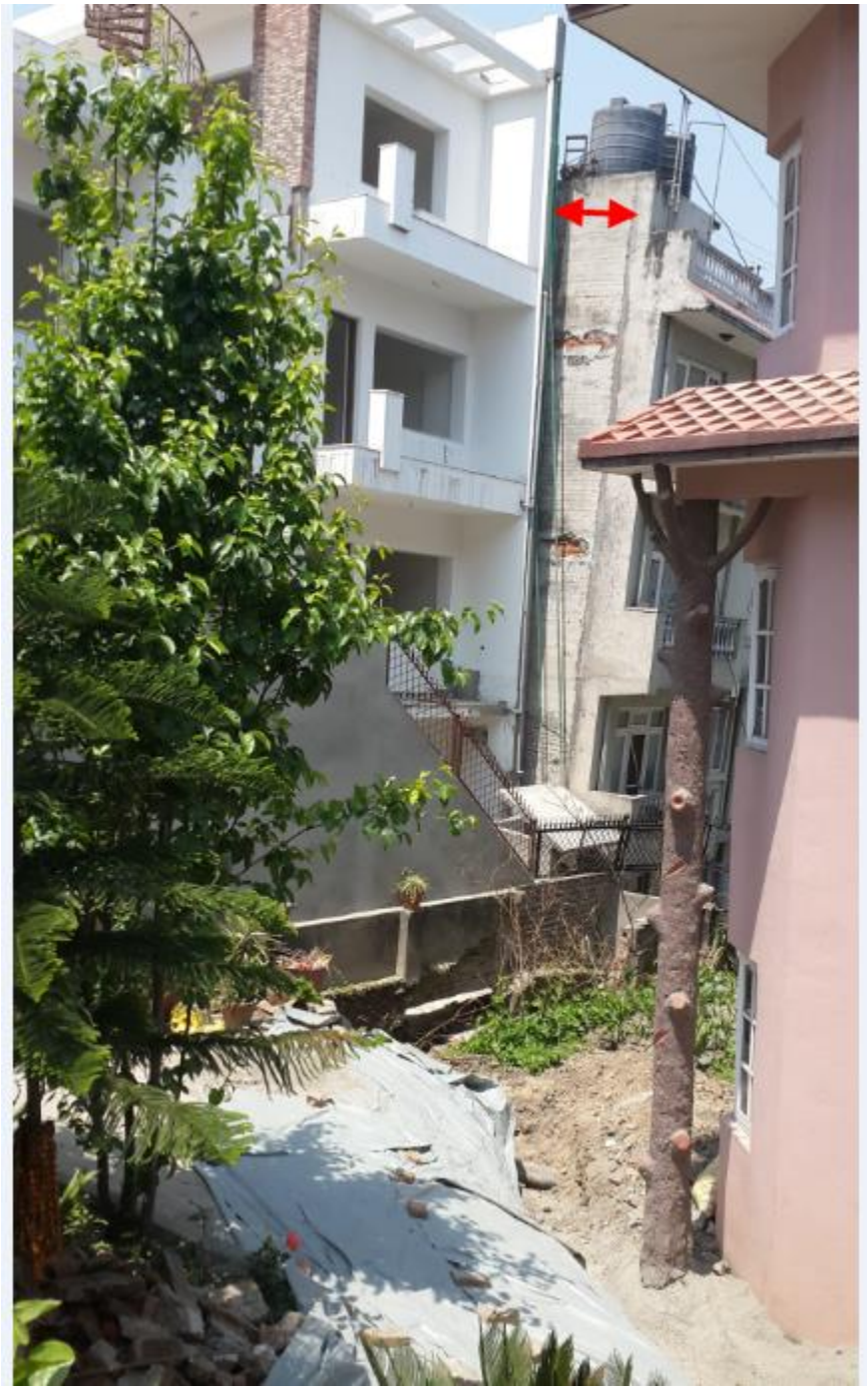
B. Damaged buildings in Kathmandu Valley

Figure- Ground fissures in Bhaktapur district. There is no damage in the nearby houses seen in the photo

The land along the marked width, (approx. 80 m.) has been settled by around 1.5 m. No major cracks in the surrounding houses except tilting and shifting of the affected house.

Surface ruptures in the settled part of the land

Maximum damages on the walls and floors of the green house seen in the previous figure.



Tilting of the house by around 1 mt. near the surface cracks

Tilting of the red house. No structural damage in the white house

Settlement of the front garden of the white house seen in the previous figure by around 1.5 m.

Houses near the surface rupture. These are two different houses.

Stump of the 9 storey tall Dharahara tower. It felled down towards the marked direction.

Kathmandu Durbar Square

An artist depicting the ruined Palace in his canvas

Durbar High School

Damage in the roofs of a school in Bhaktapur. There are not even minor cracks at other locations

Pink colored is the retrofitted part of the school while the other had not been retrofitted.

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.

Damaged house near to the "Y" shaped school building.

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. The retrofitting was done by both side wall jacketing.

Damaged old houses in the village of Bhaktapur district

Roof of the retrofitted school building is damaged by the adjacent house

Relatively new buildings suffered no damage at all.

No external cracks are seen in such building in Bhaktapur district.

Column failure on the ground floor of the house in Kathmandu, Balaju area

Damaged column of the house in Kathmandu, Balaju area

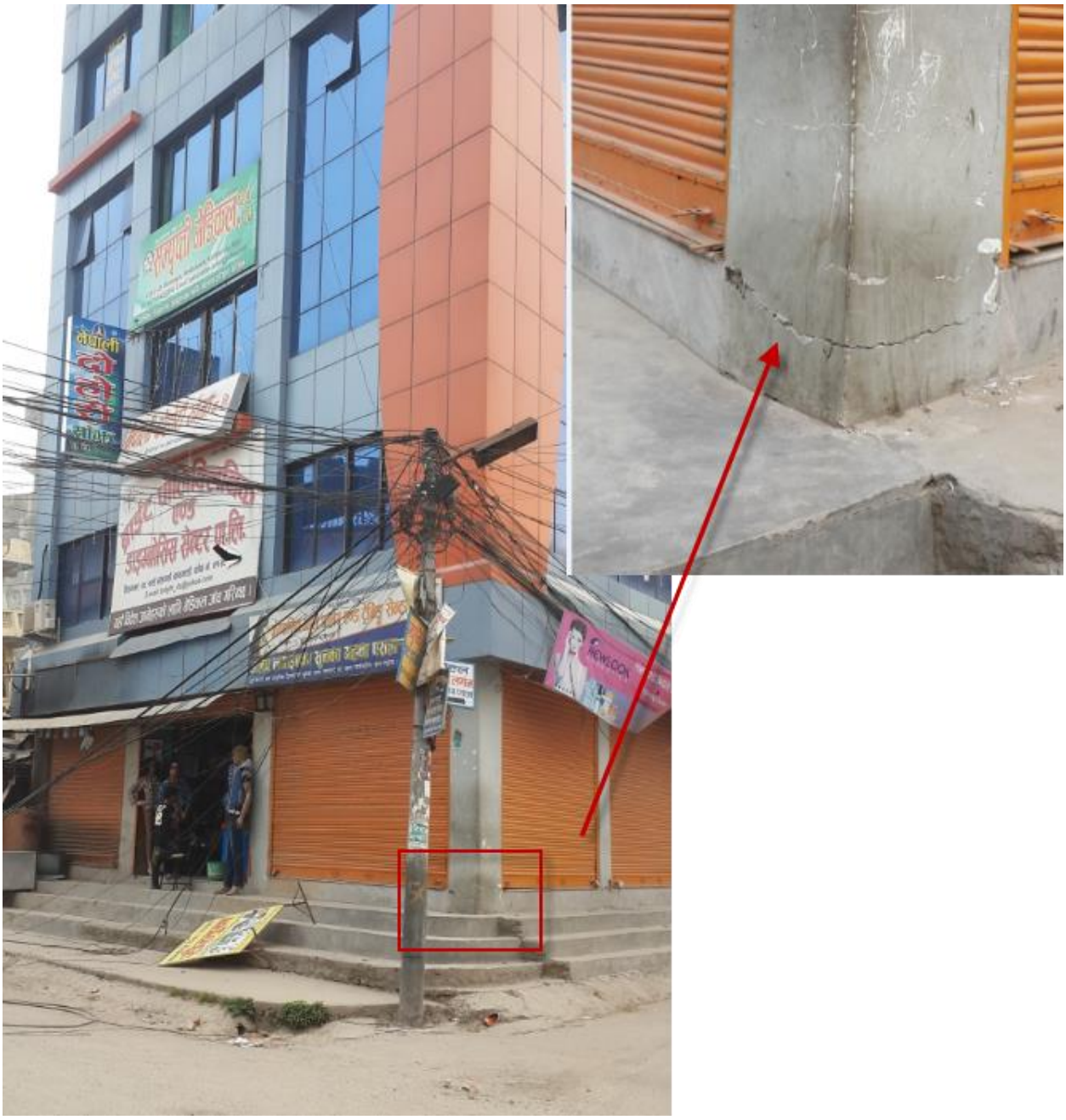
Damages in the interior walls and columns of the house in Kathmandu, Balaju area. Longitudinal rebars are buckled after concrete crushing at the beam column joint and at column base.

Shear failure of the columns on ground story at beam column joint location due to short column effect induced by the infill wall in Kathmandu, Balaju area

Complete collapse of first two story of a five story house in Kathmandu, Balaju area, due to soft storey effect. There were no infill walls on the ground floor.

Close up view of the damaged columns of the previous building

Buckling of longitudinal rebar at column base of other building in Kathmandu, in Balaju area.



Critical flexural crack at the column base in the building in Kathmandu, Balaju area.

More damage in the buildings on right side than on the left side of the road in Kathmandu, in Balaju area

Horizontal cracks in Swyambhu stupa, Kathmandu

Collapsed buildings in Kathmandu due to soft storey effect.

Damaged columns at the marked location of the previous photos.

Collapsed building in Kathmandu, Sitapaila area. All the rebars are spliced at the same location in the column as marked in the diagream.

Damages in the infill walls and at the corners of the high rise apartment buildings in Kathmandu, Sitapaila area

Soft story collapse of a building in Kathmandu, Sitapaila area

Collapsed houses in Sitapaila area, Kathmandu

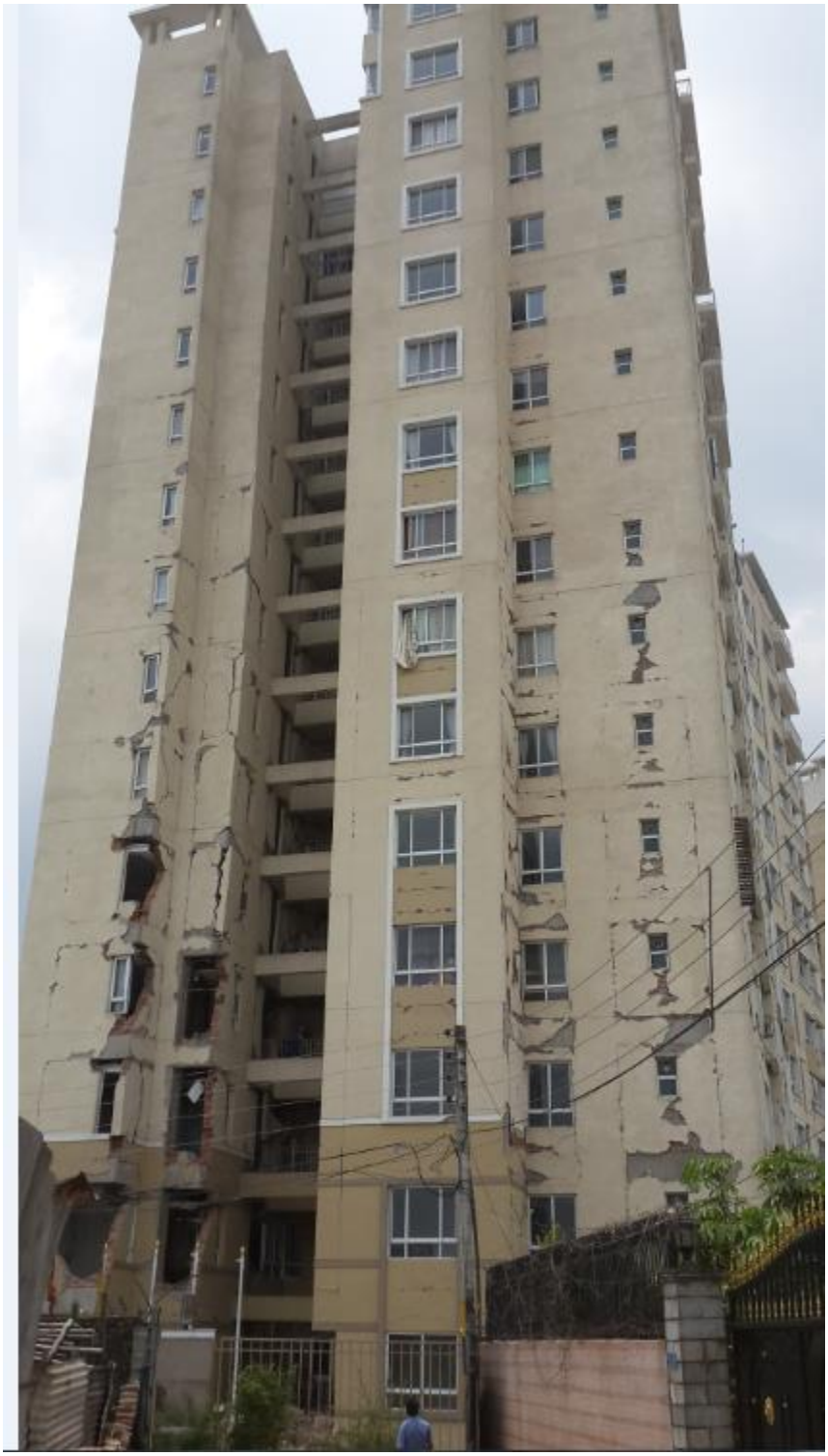
Collapse of a two storey frame structure in Sitapaila area, Kathmandu. Column base on the upper story are also damaged.

Damaged column bases on upper story of the previous building.

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)

Left face of the building



Front face of the building

Damage in beam on left face of the building

Overturning of a 7 storey tall building in Kapan area, Kathmandu

Longitudinal reinforcements were spliced at same location in the column and building overturned by lap splice failure at tension location

Another view of the 7 story tall building

Repaired diagonal shear cracks in a school building in Imadol area, Lalitpur

C. Observations

Following observations are made in Kathmandu valley after the earthquake

a) Collapse of the cultural heritages dated back to 5th century.
b) Complete collapse of the over aged masonry buildings; some were more than 500 years old.
c) Partial collapse of the wooden roofs of relatively new buildings. Other structures remain intact with no critical damage
d) No major damage in the components of the building near to surface fissures. However they suffer excessive tilting and settlement
e) 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”.
f) In some buildings it is observed that the building could not resist the overturning moment due to lap splice failure on the tension side.
g) Most of the columns are failed by crushing of the concrete at below the beam or at column base leading to the subsequent buckling of the longitudinal bars.
h) 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.
i) Buildings where infill walls were constructed after constructing the frames suffered more cracks at beam and column interface, while, buildings where infill walls and frames were constructed together suffered no such damages.
j) Long period ground acceleration resulted in the damage of relatively flexible structure where as stiff structures suffer less damage in Kathmandu valley.

D. References

a) USGS