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Pounding Effect on Adjacent Building with Different Plinth Level

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Abstract

The difference in the dynamic properties of adjacent structures results in the pounding.[1] The difference in mass or stiffness leads to the out-of-phase vibration of the building, causing seismic interaction during the time of the earthquake. Though many research has been carried out in the pounding, there are less research that matches the scenario of Nepal, especially the Kathmandu valley where there is a dense population and unplanned urbanization. Although the building code, has provision of seismic gap there is no scenario, where it has been applied. With a proper study on the pounding effect on such buildings, the displacement and force-induced can be studied and helps in the proper construction of buildings. So, there need to be codal provision inclusive of pounding force for the better evaluation of so such adjacent building. The analysis on pounding adjacent buildings using infill was carried out for different building configuration such as when plinth level of adjacent buildings were at different using sap2000. The infill wall were simulated as diagonal struts. [2]The stiffness of the gap element was taken as 100 to 10000 times the stiffness of neighboring linked element. The pounding force are greater at floor to floor pounding rather than floor to column pounding.

Keywords

Pounding, Infill wall, Displacement, pounding force

1. Introduction

1.1 Background

The investigation after the earthquake present that the adjacent buildings with different properties experiences the different displacement. If there is no proper seismic gap between the adjacent buildings, then the pounding effect is induced causing extra stress and load to the adjacent building. Although the code stated to have a seismic gap, due to dense population especially in an urban area the proper seismic gap is not able to maintain, due to unplanned urbanization. In Nepal, urbanization is dominated by few large and medium cities with the excessive population being concentrated in the Kathmandu valley. The past code provision did not have a definite guideline for the pounding. For the more use of land in the densely populated area, the seismic gap are not provided. Still in the present contest of scenario, the building which is constructed adjacent to one another, the analysis or construction of the new building is studied or analyzed isolated. So, the seismic behavior of engineered buildings lacks the level of technical consideration and analysis. [3]The difference in dynamic properties of adjacent structures results in the pounding. The difference in mass or stiffness leads to the out-of-phase vibration of the building, causing seismic interaction during the time of earthquake. One of the worst cases of pounding is when there is floor to column pounding especially through the mid-height of the column. The impact is massive as the pounding of a highly rigid slab will be striking the column at its mid-height.

[4]The pounding interaction between the building and force transmission is calculated using the hertz model. The analysis will be carried to both linear and nonlinear responses of the building.[5]A probabilistic performance-based procedure for determining the critical separation distance (CSD) between adjacent buildings exhibiting linear elastic behavior. With the addition of stiffness of infill there will be reduction of displacement[6].

1.2 Types of Pounding

The types of pounding analyzed in this thesis are:

A. Adjacent building with the same heights another same floor levels
B. Same floor levels but with different heights
C. Different total height and with different floor levels
D. Building having an irregular lateral load resisting system

1.3 Problem and Issue

Because of modernization and increased population density, internal migration, family and property division, and so on, linked buildings are erected throughout time in city areas in search of opportunity and infrastructures. Based on historical data, many analysts anticipate that a large earthquake would strike Nepal once every 75 years. As it has been proven right as such large earthquakes have struck Nepal in 1934 and recently in 2015. As Nepal is in a seismically active location, the performance of adjacent housing in key city areas should be known.

1.4 Need of study

Although many research has been carried out in the pounding, there are less research that matches the scenario of Nepal, especially the Kathmandu valley where there is a dense population and unplanned urbanization although the building code, tells about the seismic gap there is no scenario where it has been applied. With a proper study on the pounding effect on such buildings, the stresses and force-induced can be studied and helps in the proper construction of buildings. So, there need to be codal provision inclusive of pounding force for the better evaluation of so such adjacent building. As no one knows when the next earthquake going to hit the Kathmandu valley which is densely populated. The best way to avoid catastrophic loss in the next upcoming is through the study of the present scenario and provide the best solution to it.

1.5 Research Objectives

i. To determine the induce pounding force in an adjacent building
ii. To find the displacement in each floor level
iii. To find out the effect on building with change in floor level of the adjacent buildings

1.6 Selection of Building

The visual survey of building in the core area of Lalitpur, Kritpur, and Kathmandu was done. Based upon the observation, the building of this size and shape were taken into consideration. The buildings each of 5 stories were considered. The floor height of both buildings was the same. They have different dynamic properties as the one building is 2 bay and the next one is 3- bay buildings.

1.7 Methodology

The following tasks will be carried out to attain the objective.

a) A study of the literature on the seismic pounding impact between buildings, the effect of gap separation, contact elements, modeling, and analysis methods is carried out.
b) Data collection, architectural and structural drawings for building evaluation.
c) Create a three-dimensional model in SAP2000 and calculate the structure's response under linear and nonlinear loading conditions.
d) Preliminary, the linear static analysis was done as per NBC 105:2020 and later time history analysis was carried out
e) The displacement and Pounding forces are studied
f) Displacements and pounding forces curves were plotted.
g) Analysis of the result was done.

1.8 Limitation of Study

i. The current study takes into account only two-building, as the number of buildings in a row can be more than two.
ii. No soil interaction is considered, as soil type may also vary the outcome.
iii. Pounding between RCC buildings is considered. There might be pounding of masonry with RCC or masonry to masonry.

2. Formulation of The Pounding And Mathematical Expression

2.1 Non-Linear analysis

In this method of analysis the building are subject to recorded earthquake motion. In this method of analysis the building is subject to geometry and material non-linearity. For the research purpose at least 3 earthquake needed to be used.for this research paper, Gorkha, Chi-chi and North-ridge earthquake data were used for the evaluation of the building.

2.1.1 Calculation of stiffness of gap element

[7]The stiffness of the gap element is typically accepted as 100 to 10000 times the stiffness of the neighboring linked element. [8] The force-deformation relationship is

$$f=\begin{cases} k(d+gap), \text{if } (d+gap)<0 \\ 0 \quad \text{otherwise.} \end{cases}$$

2.1.2 RC Frame Building with unreinforced masonry infill walls

As per IS 1893:2016, RC building with moment resisting frames and unreinforced masonry infill walls, there is variation in story stiffness and story Strength.

- Ends of diagonal struts shall be considered to be pin-jointed to RC frame;
- For URM infill walls without any opening, the width was of equivalent diagonal strut shall be taken as:

$$w_{ds} = 0.175\alpha_h^{-0.4} L_{ds}$$

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4E_f I_c h}}\right)$$

where Em and Ef are the moduli of elasticity of the materials of the URM

3. Building Description

Table 1: Building Description

General		
Type of Building	Building-A	Building-B
Plinth Area	104.00 Sq. m.	60.00 Sq. m.
Number of Storey	5	5
Total height of structure	15.00 m	15.00 m
Building Dimension in X direction C-C	7.20 m	4.00 m
Building Dimension in Y direction C-C	14.40 m	14.40 m
column Sie	350x350	350x350
Beamsie	230x350	230x350
Slab Thickness	125mm	125mm
Structural System	Special Moment Resisting System	
Design Software	SAP 2000 v20.2.0	
Steel	7850 Kg/m3	7850 Kg/m3
RCC	25.0 KN/m3	25.0 KN/m3
Live load(IS 875 Part 2 is used as refered by103:1994)		
Room	2.0 KN/m2	2.0 KN/m2
Corridor, Staircase, Store	3.0 KN/m2	3.0 KN/m2
Balcony	3.0 KN/m2	3.0 KN/m2
Toilet and Barth room	2.0 KN/m2	2.0 KN/m2
Roof	1.5 KN/m2	1.5 KN/m2
Concrete Used	M20	M20
Reinforcement Used	Fe 500	Fe 500
Design Philosophy	Limit State	Limit State

Table 2: Earthquake input

Earthquake	Mw	PGA(g)	Station
Northridge	6.7	0.33	Sunvalley
Chi-Chi	7.6	0.144	Ch4024
Gorkha	7.8	0.15	Kritipur

3.1 Building Plan

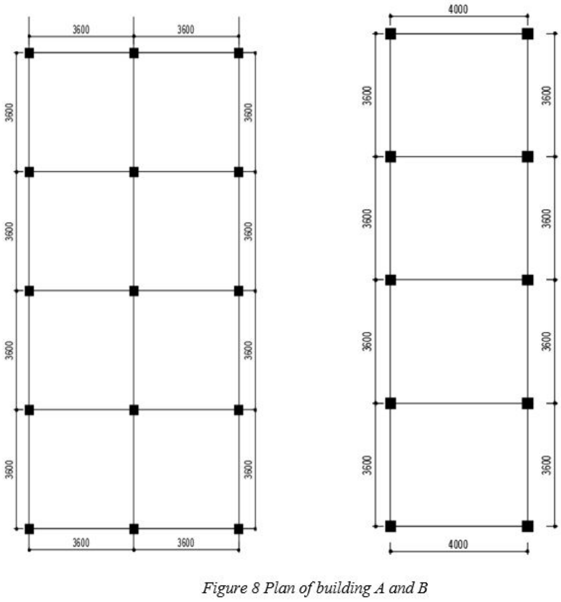

Figure 1: Plan of buildings

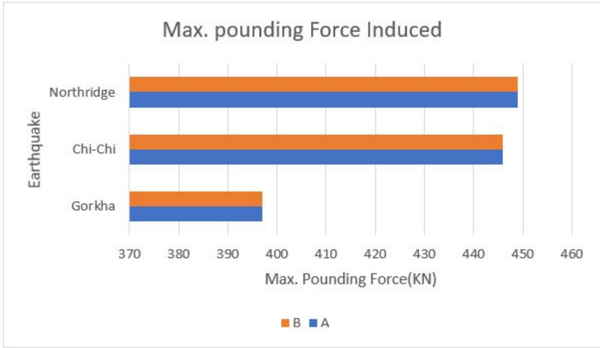

Figure 2: Bar Graph showing the pounding force when Configuration of both buildings are at the same plinth level

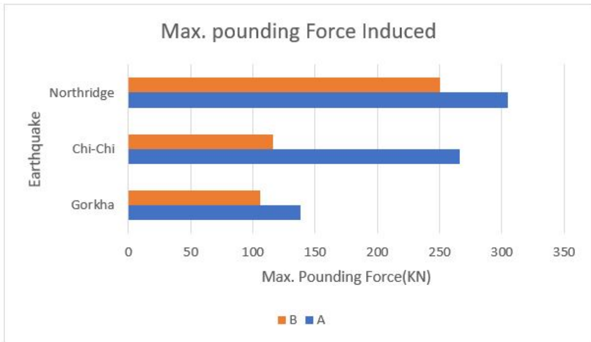

Figure 3: Bar Graph showing the pounding force of configuration when the plinth level of building A is 0.75m below than building B

4. Results and Discussion

As per the above mention procedure and explanation, the analysis of buildings was carried out. After analysis seismic parameters such as pounding force and displacement for five different configurations were taken into account for three different time history analyses.

4.1 Pounding force

From the graphs, the maximum Pounding force was induced for the Northridge earthquake. The maximum pounding force was found when the floor and plinth level of the adjacent building was at the same level. When the plinth level of the building is at a lower level than adjacent buildings, the maximum pounding force was found in the floor level of that building, which make the buildings at higher level more vulnerable to the earthquake.

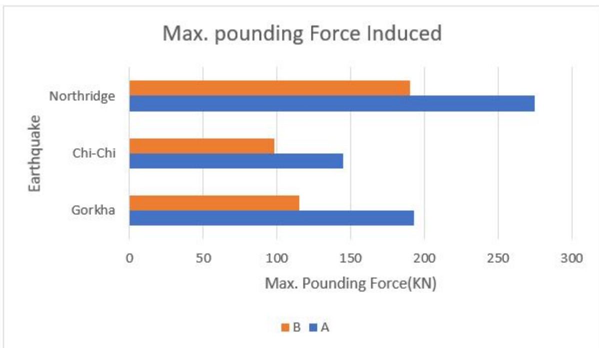

Figure 4: Bar graph showing the pounding force of configuration when the plinth level of building A is 1.5m below than building B

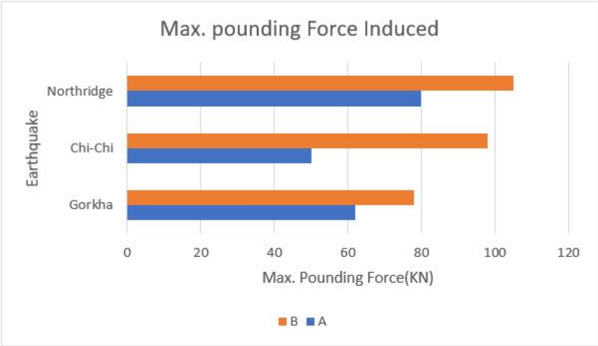

Figure 5: Bar Graph of configuration when the plinth level of building A is 0.75m above building B

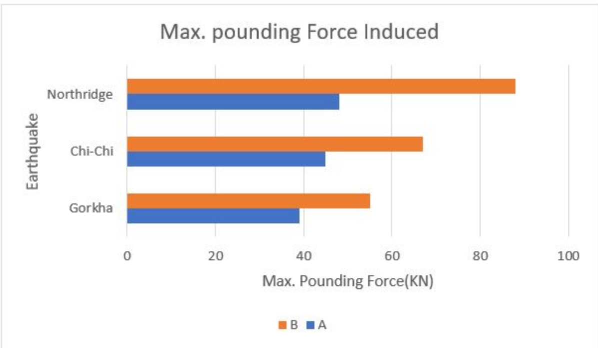

Figure 6: Bar Graph showing the pounding force for configuration when the plinth level of building A is 1.5m above building B

4.2 Max Displacement

From graph, there is maximum displacement for the Northridge Earthquake.There is maximum displacement, when the floor and plinth level of the building is at the same level. There is less displacement of the building for the difference in the floor than building on the same floor level. There is higher Positive displacement for building-B and building-A has higher negative displacement. This is because for building-A there is resistance of building-B in positive direction and for building-B there is resistance of building-A in negative direction.

5. Conclusion

With the difference in plinth levels, the induced pounding force is smaller as compared to the pounding force induced in the same plinth level. Though the pounding force is smaller, it can be more devastating as the shear force induced at the floor level of different plinth level is higher. But for the same plinth level, there is pounding of floor to the floor where the shear force is lower for this configuration.The maximum pounding force was induced in the floor level with lower plinth level, which make the building at higher level more vulnerable to the earthquake. With different plinth levels, there is less peak displacement as compared to the same plinth level, as the floor same plinth level. There is higher Positive displacement for building-B and building-A has higher negative displacement. This is because for building-A there is resistance of building-B in positive direction and for building-B there is resistance of building-A in negative direction.

5.1 Mitigating Measure

The best mitigating for the pounding reduction is to provide the seismic gap as per code. Providing the shear wall helps to reduce the displacement. With the addition of impact-absorbing materials (rubber shock absorbers, polystyrene, and polymers) at the colliding part of the building the pounding force can be reduced. Providing the link element (spring link or viscoelastic link) in the adjacent building for the in-phase vibration also reduce the pounding in the buildings. Furthermore, the dampers can be also installed in the building for reduction of pounding.

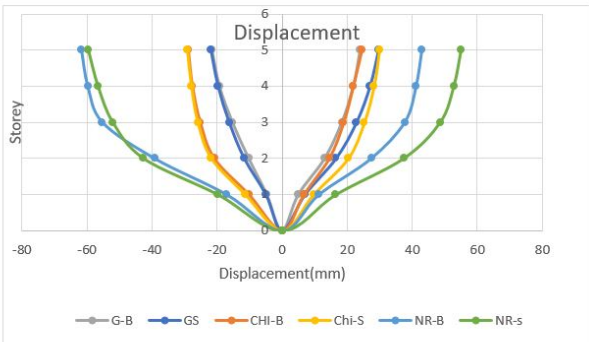

Figure 7: Maximum displacement for configuration when the plinth level of building A is 0.75m below than building B

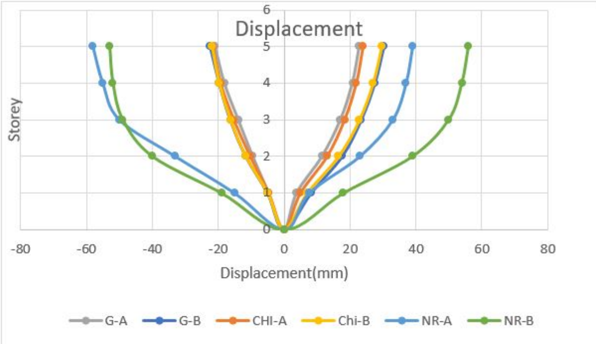

Figure 8: Maximum displacement for configuration when the plinth level of building A is is 1.5m below than building B

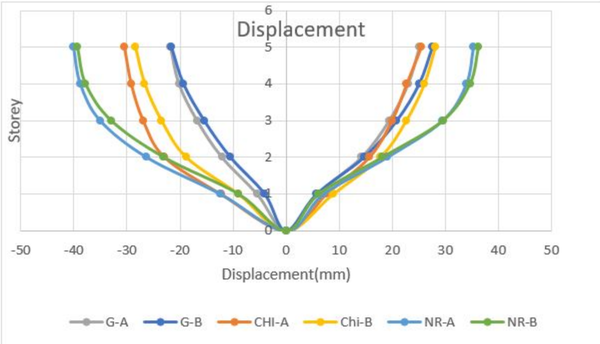

Figure 9: Maximum displacement for configuration when the plinth level of building A is 0.75m above building B

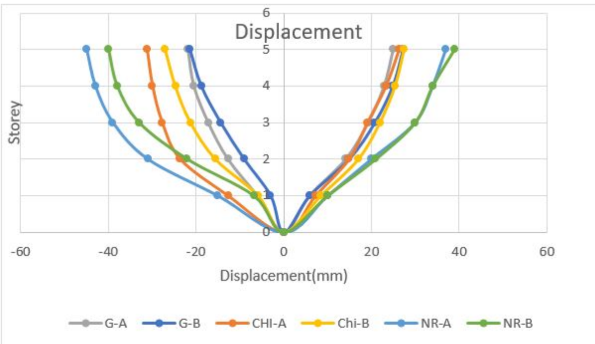

Figure 10: Maximum Displacement for configuration when the plinth level of building A is 1.5m above building B

5.2 Future Scope

- The building consider for this thesis is symmetrical, unsymmetrical buildings or building with different geometry can be considered.
- The soil interaction between the buildings can be also taken into account.
- The pounding between masonry with masonry or masonry with RCC can be done.
- The pounding interaction between more than 2 buildings can be also done.

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