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Analysis of Seismic Pounding between Adjacent Buildings

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Abstract - *In recent years the pounding of adjacent structures during earthquakes has been receiving considerable attention. Seismic pounding occurs due to collision of two adjacent buildings during earthquake which are having different dynamic characteristics and the buildings vibrate out of phase and the at-rest separation distance is inadequate to accommodate their relative motions. To mitigate the amount of damage from pounding, the most simplest and effective way is to provide minimum separation distance between the buildings. While seismic pounding can be prevented by providing enough separation distances, sometimes getting of required safe separations is not possible in metropolitan areas due to high cost of land, limited availability of land space and the need for centralized facilities under one roof and often ignoring the likelihood of seismic pounding between adjacent buildings during design.*

Key Words: **Seismic pounding, adjacent buildings, Dynamic characteristics, Minimum separation distance, High cost of land etc.**

1. INTRODUCTION

The seismic pounding is known as collision of two buildings which are having different dynamic characteristics and are constructed adjacent to each other. The main reason for this seismic pounding is lack of separation distance between the adjacent buildings. This may happen not only in buildings but also in bridges and towers which are having minimum separation distance between them. Most of the times pounding between the adjacent buildings is commonly observed in the old buildings that were constructed before the earthquake resistant design principles came into the picture. There are many present seismic codes which specifies the minimum seismic gap required between the structures, but still it fails to include all other parameters that leads to the structural deformation. For reducing the damage due to pounding the very simple and effective way is by providing enough space between the adjacent structures, but sometimes it is difficult to be implemented due to high cost of land in metro cities and everyone wants to construct the building up to their property line. The pounding between such closely spaced building structures can become a serious hazard in seismically active regions. By investigating past and recent earthquakes we can observe several pounding damages. During earthquake the adjacent buildings having deferent dynamic characteristics vibrate out of phase and there is insufficient energy dissipation system or separation distance to accommodate the relative motions of adjacent buildings.

Different patterns of adjacent structures which may feel seismic pounding are,

1. Adjacent buildings at same floor levels having different heights.
2. Adjacent buildings with same heights at same floor levels.
3. Adjacent buildings having different total heights with different floor levels.
4. Buildings which are constructed in a rows.
5. Adjacent structural buildings with different dynamic characteristics.
6. Adjacent buildings having unequal heights, pounding may occur in columns.
7. Adjacent buildings having unequal distribution of mass and stiffness.

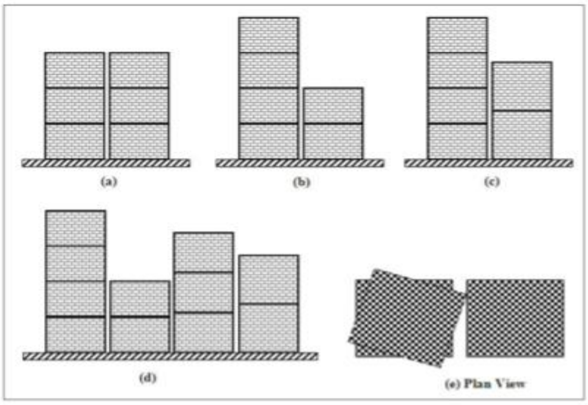

Fig -1: **Representation of different cases where seismic pounding occurs**.

Required Seismic Separation Distance to Avoid Pounding: Bureau of Indian Standards clearly gives in its code IS 4326 that a Separation distance is to be provided between adjacent buildings to avoid collision during an earthquake.

Table -1: The design seismic coefficient to be used shall be in accordance with IS 1893:1984

S.No	Type of Constructions	Gap Width/Storey in mm for Design Seismic Coefficient αh =0.12
1	Box system or frames with shear walls	15
2	Moment resistant reinforced concrete frame	20
3	Moment resistant steel frame	30

NOTE — Minimum total gap shall be 25 mm. For any other value of αh the gap width shall be determined proportionately.

1.1 OBJECTIVES

1. To generate the models of G+15 story and G+10 story buildings for rigid floor diaphragm idealization to carry out dynamic analysis (i.e. response spectrum analysis) using ETABS.
2. Computation of minimum seismic gap required between buildings for rigid floor diaphragm idealizations.
3. To perform linear dynamic analysis of rigid floor diaphragm idealization for medium soil at Zone IV.
4. Analyzing the displacements for different Storey buildings to permit movement, in order to avoid pounding due to earthquake by Linear Dynamic Analysis.
5. To compare the results between different Storey building cases.

2. BUILDING DESCRIPTIONS

For the purpose of analysis, two multistory buildings having 15 storey and 10 stories are considered. Both the buildings are having regular geometry dimensions of 12m X 12m. The dead load is computed assuming the density of concrete 25kN/m^3. Live load is 3kN/m^2 & floor finish is considered as 1kN/m^2. The buildings are assumed to be situated in zoon IV having medium soil. And we considered the 50mm seismic gap between the buildings in all the cases.

2.1 Defining the material properties, structural components and modeling the structure.

Beam, column and slab specifications are as follows:

Column = 750 x 750mm, 650 x 650mm, 400 x 400mm, Beams = 300 x 600 mm, 230 x 450mm, Slab thickness 150mm.

Materials used are:

Grade of concrete is M30 and High strength deformed steel bars with yield strength of 500 N/mm^2 are used.

Assigning loads:

Dead Loads:

The dead loads are calculated on the basis of unit weights of materials given in IS 875 (Part I).The dead loads on the structure include the self weight of beams, columns, slabs, walls and other permanent members. The self weight of beams and columns (frame members) and slabs (area sections) is automatically considered by the program itself. The wall loads have been calculated and assigned as uniformly distributed loads on the beams.

Impose Loads:

Imposed loads are assumed in accordance with IS 875(Part II). The Impose loads have been assigned as uniformly distributed loads on the slab elements. As per IS 1893 (Part I) 2002, 25% of the impose load has been considered.

2.2(G+15) & (G+10) storey adjacent buildings having same floor levels and different storey heights

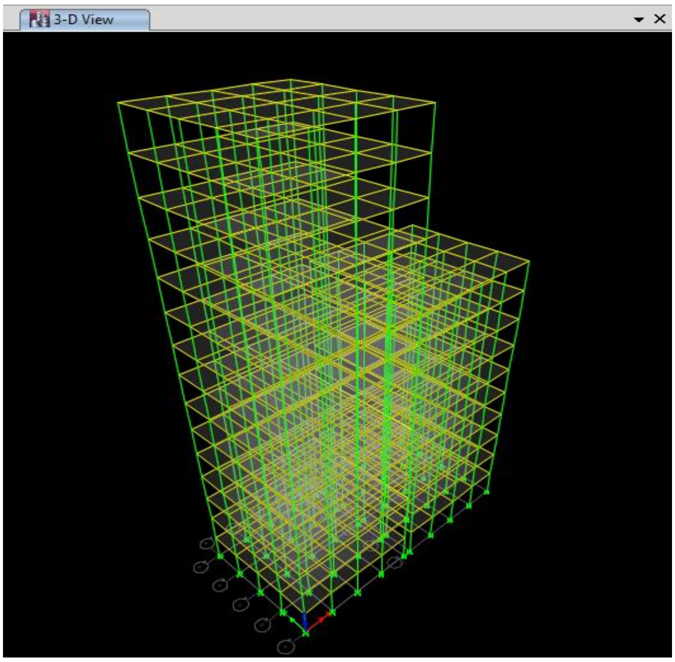

Fig -2: **3D View of (G+15) & (G+10) storey adjacent buildings.**

Analysis of the structure:

To determine the various structural parameters of the models response spectrum analysis procedures have been carried out. Here we are mainly concerned with the behavior of the structure under the effect of Pounding such as earthquakes and the displacement of the structure.

Seismic Analysis Procedures:

The three main techniques currently used for this analysis are -

1. Linear Procedures. · Linear Static Analysis (Seismic Coefficient Analysis). · Linear Dynamic Analysis (Response Spectrum Analysis).

2. Nonlinear Procedures. · Non-Linear Dynamic Analysis (Time History Analysis).

The step by step procedure of Response spectrum analysis in ETABS:-

1. Defining earthquake loads under the load type 'quake' and naming it appropriately.

2. Defining response spectrum function as per IS 1893 (Part I) 2002. The values of Sa/g Vs. T assign in the program.

3. Modifying the quake analysis case with the appropriate analysis case type, applied loads and scale factors.

4. Running the analysis.

2.3(G+10) & (G+10) storey adjacent buildings having same floor levels and same storey heights

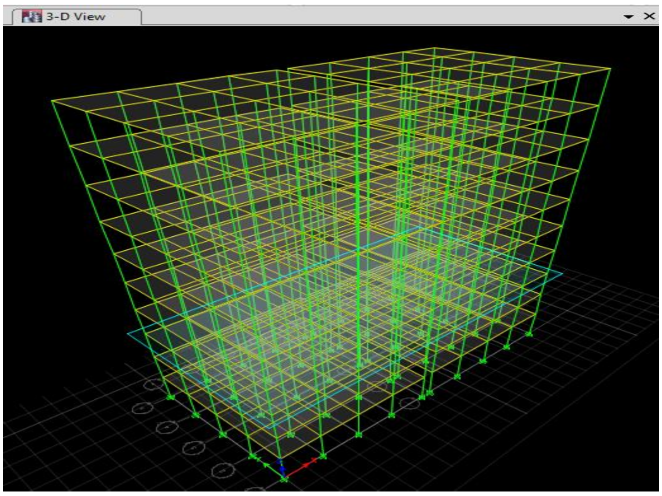

Fig -3: **3D View of (G+10) & (G+10) storey adjacent buildings.**

2.4 G+15) & (G+10) storey adjacent buildings having different floor levels and different storey heights

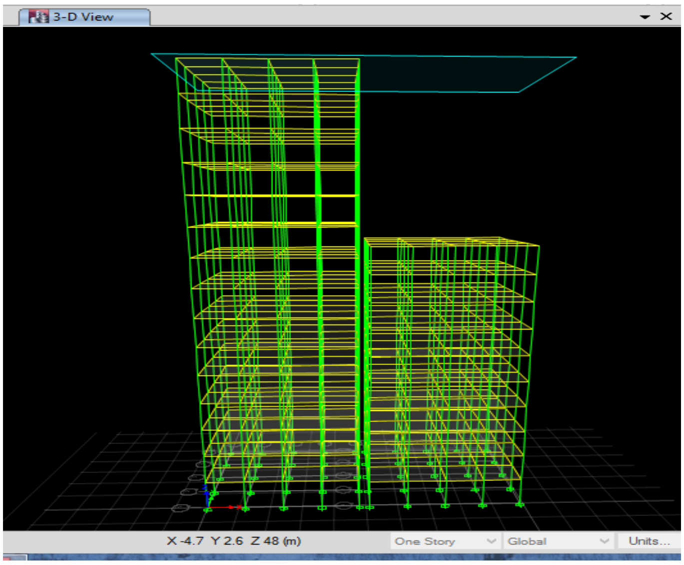

Fig -4: **3D View of (G+15) & (G+10) storey adjacent buildings.**

3. RESULTS AND DISCUSSIONS

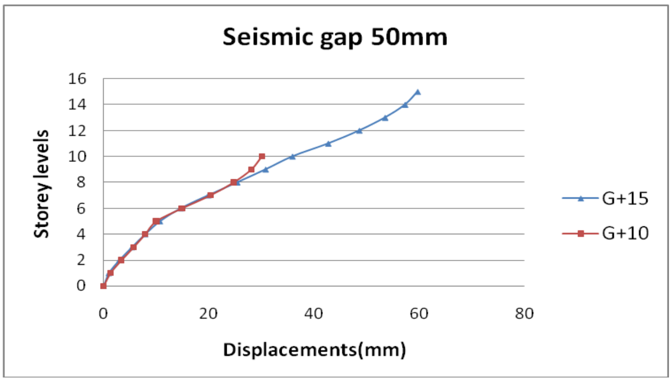

Chart -1: Variation of Horizontal Displacements for Fig.2

In this case G+15 & G+10 storey adjacent buildings having 50mm seismic gap between them are modeled and analyzed and we found max displacement as 59.7mm for G+15 storey building and 30.1mm for G+10 storey building. From the chart 1 it is observed that Horizontal displacements increases with storey heights, and are larger than the seismic gaps provided. So there will be seismic damage between adjacent buildings.

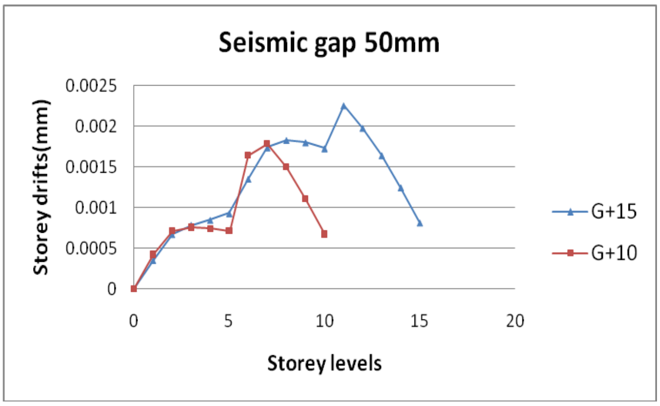

Chart -2: Variation of Storey Drifts for Fig.2

From the chart 2 it is observed that storey drifts for both the buildings are nearly same up to 4th storey. For G+ 15 storey building after 11th storey there is decrease in storey drift and for G+10 storey building after 7th storey there is decrease in storey drifts.

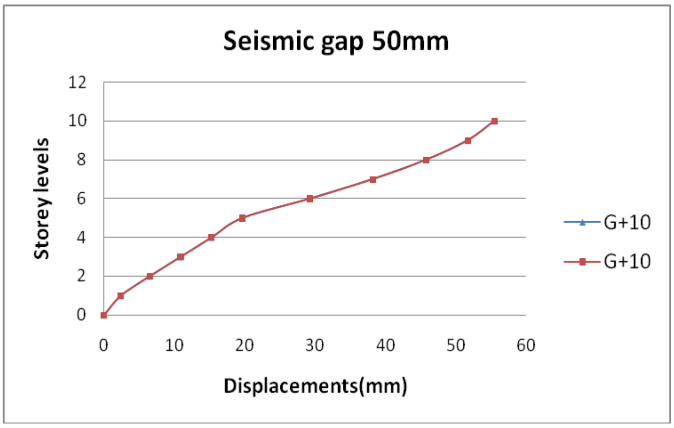

Chart -3: Variation of Horizontal Displacements for Fig. 3

In this case G+10 & G+10 storey adjacent buildings having 50mm seismic gap between them are modeled and analyzed and after analysis we found that both the buildings experiences similar horizontal displacements i.e 55.5mm. From the chart 3 it is clear that adjacent building with same storey heights having same floor levels shows similar behavior and pounding damage is limited to nonstructural components.

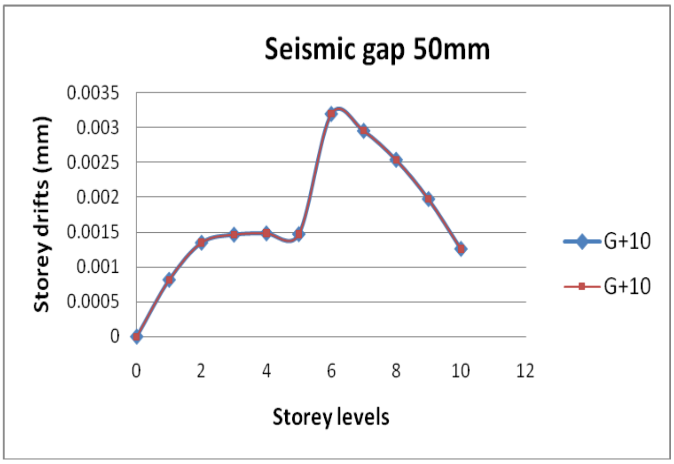

Chart -4: Variation of Storey Drifts for Fig.3

From the chart 4 it is observed that when both the adjacent buildings are at same floor levels having same storey heights the storey drifts for both the buildings are same and they shows similar behavior.

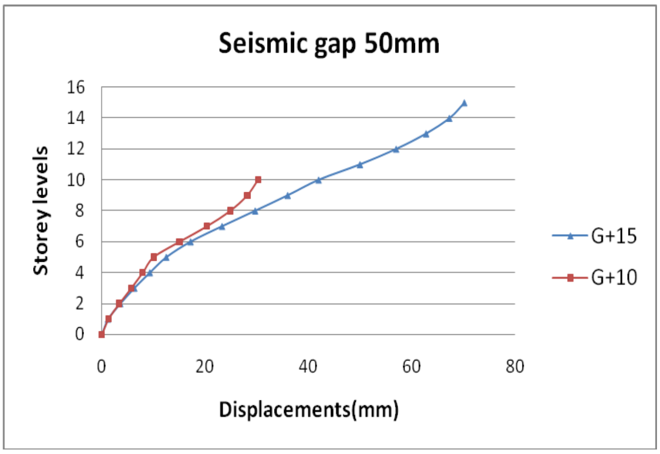

Chart -5: Variation of Horizontal Displacements for Fig. 4

In this case G+15 & G+10 storey adjacent buildings having 50mm seismic gap between them are modeled and analyzed and after analysis it is determined that G+15 storey building experiences max displacement as 70.2mm and G+10 storey building 30.2mm. From the chart 5 it is observed that Horizontal displacements increases with storey heights, and are larger than the seismic gaps provided. So there will be seismic damage between adjacent buildings.

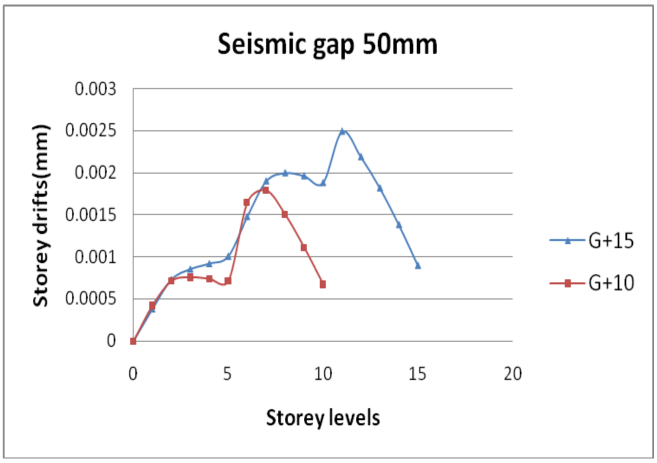

Chart -6: Variation of Storey Drifts for Fig 4

From the chart 6 it is observed that storey drifts for both the buildings are nearly same up to 2th storey. For G+ 15 storeys building after 12th storey there is decrease in storey drift and for G+10 storey building after 7th storey there is decrease in storey drifts.

Table -2: Base shear for all the cases

Case	Base Shear for Building 1 in (kN)	Base Shear for Building 2 in (kN)
Case l 1	4279.36	4435.77
Case 2	8980.95	8980.95
Case 3	4311.59	3972.47

4. CONCLUSIONS

- In all the cases of adjacent buildings, the maximum displacements obtained are greater than seismic gaps provided between them hence there is seismic pounding between adjacent buildings.

- In case of pounding, constructing the buildings by providing safe separation distance between them is the best way of preventing structural pounding. However if adjacent buildings must be constructed for any reason, these structures must be separated with seismic gaps as given in IS 1893 (Part I): 2002.

- Minimum seismic gap of 0.010m (i.e. 10mm) per storey is sufficient in all the cases for no seismic pounding between adjacent buildings.
- The maximum response caused by the impact of two adjacent buildings decreases in the shorter building whereas it increases in the taller one which may lead to critical conditions.
- It is clear that adjacent buildings with same storey heights having same floor levels will show similar behavior and pounding damage will be limited to nonstructural components.
- The effect of seismic pounding does not affect the base shear and storey shear forces.
- The mass of the colliding buildings increases the effect of seismic pounding.
- Stiffness of the buildings can be increased by providing Shear walls, Steel Bracings, combination of both and Dampers.
- At the time of design, design Engineer must take care that there will be no pounding between adjacent buildings in future.

3.1 SCOPE FOR FURTHER STUDIES

There are some suggestions for future research work on modeling of pounding between adjacent structures.

- Extension of this work needs to consider the soil and brick parameters.
- Modeling the structures using expansion joints such as filler or rubber materials etc.

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BIOGRAPHIES

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