

A STUDY OF SEISMIC POUNDING BETWEEN ADJACENT BUILDINGS

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Abstract

Seismic pounding between adjacent buildings can cause severe damage to the structures under earthquakes, when owing to their different dynamic characteristics. During earthquake, the buildings vibrate out of phase and at rest separation is deficient to accommodate their relative motions. Such buildings are usually separated by expansion joint which is insufficient to provide the lateral movements of the buildings during earthquakes. It can be prevented by providing safe separation distances, sometimes getting of required safe separations is not possible in metropolitan areas due to high land value and limited availability of land space. If building separations is found to be deficient to prevent pounding, then there should be some secure and cost effective methods to prevent structural pounding between adjacent buildings. There are many buildings which are constructed very nearly to one another in Metropolitan cities, because everyone wants to construct up to their property line due to high cost of land. This study covers the prevention techniques of pounding between adjacent buildings due to earthquakes. Constructing new RC walls, cross bracing system and combined RC wall & bracing, with proper placement are proposed as possible prevention techniques for pounding between adjacent buildings.

Keywords: Seismic Pounding, Earthquake, SAP2000, Prevention of structural Pounding, RC wall, Bracings.

1. INTRODUCTION

Investigations of past and recent earthquake damage have illustrated that the building structures are vulnerable to severe damage and collapse during moderate to strong ground motion. Damage has illustrated several instances of pounding damage (3.Sudhir K Jain et.al, 2001) in both building and bridge structures. Pounding damage was observed during the 1985 Mexico earthquake, the 1988 Sequenay earthquake in Canada, the 1992 Cairo earthquake, the 1994 Northridge earthquake, the 1995 Kobe earthquake and 1944 Elcentro earthquake. Significant pounding was observed at sites over 50 km from the epicenter, thus indicating the possible catastrophic damage that may occur during future earthquakes having closer epicenters. Pounding of adjacent buildings could have worse damage as adjacent buildings with different dynamic characteristics which vibrate out of phase and there is insufficient separation distance (1.Abdel and Shehata, 2006). Past seismic codes did not give definite guidelines to preclude pounding, due to economic considerations including maximum land usage requirements, especially in the high density populated areas of cities, there are many buildings worldwide which are already built in contact or extremely close to another, that could suffer pounding damage in future earthquakes. A large separation is controversial from both technical [difficulty in using expansion joint and economical loss of land usage] views (2. A Hameed et.al, 2012).The highly congested building system in many metropolitan cities

constitutes a major concern for seismic pounding damage. The most simplest and effective way for pounding mitigation and reducing damage due to pounding is to provide enough separation, but it is sometimes difficult to be implemented due to high cost of land. An alternative to the seismic separation gap provision in the structure design is to minimize the effect of pounding through decreasing lateral motion. The main objective and scope is to evaluate the effects of structural pounding on the global response of building structures, to determine the minimum seismic gap between buildings and provide engineers with practical analytical tools for predicting pounding response and damage.

2. METHODOLOGY

To observe pounding, a three dimensional reinforced concrete moment resisting frame buildings with open ground floor is taken and analyzed in SAP2000. The two buildings consist of eight stories (G+8) and five stories (G+5). All columns in all models are to be fixed at the base. The height of all floors is 3.2m. Slab of eight stories and five stories is modeled as rigid diaphragm element of 140mm and 130mm thickness respectively, for all stories considered. Live load on floor is taken as 3kN/m² and on roof is 1.5kN/m². Floor finish on the floor is 1kN/m² and weathering course on roof is 1kN/m². The seismic weight is calculated conforming to IS 1893-2002(part-I). The unit weights of concrete is taken as 24kN/m³ The grade of concrete for column is M-25 and for

beam and slab is M-20. The building is special moment resisting frame considered to be situated in seismic zone IV having medium soil and intended for residential use. These buildings are separated by expansion joint of 80mm. Both buildings are analyzed in SAP2000 and are designed as per IS 456-2000. Both buildings are subjected to gravity and dynamic loads. To observe pounding, Time History Analysis is carried out taking data of Elcentro.

Building-1 (G+8) has 3 bays in X and Y directions, having corner columns dimension of 0.3x0.6 m², whereas all inner columns are of 0.3x0.75 m². Width of each bay in X direction is 3.5m, and that of in Y direction is 4.5m, while the beam size is 0.3x0.45 m² in both the direction. Building-2 (G+5) has 3 bays in X and Y directions, width of each bay in X direction are 3m, in Y direction it is 4.5m, having outer column dimension of 0.23x0.45 m², whereas all inner column are of 0.3x0.45 m². Beam size is 0.23x0.45 m² in both the direction. Pounding is considered in top floor of G+ 5 story i.e. at fifth floor, for observation Positive displacement of eight stories and negative displacement of five stories is considered, as we are going for worst condition due to its different dynamic characteristics

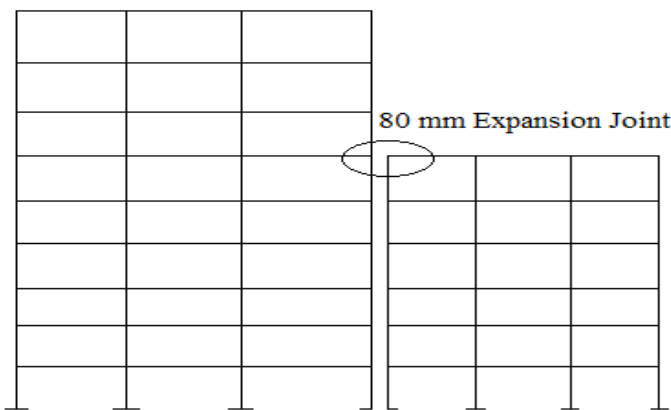


Fig-1: Represent the Position of Adjacent Buildings.

3. PREVENTION MEASURES TO AVOID POUNDING:

3.2 Providing Proper Separation Gap:

As pounding is observed at fifth floor due to positive displacement of eight story and negative displacement of five story buildings To prevent this, FEMA-273(Federal Emergency Management Agency) provides safe separation distances between adjacent buildings.

$\$ = \sqrt{(Q_1^2 + Q_2^2)}$ is a SRSS (Square Root of the Sum of the Squares) Method

Where,

Q_1 = highest displacement of building -1

Q_2 = highest displacement of building – 2

$\$$ should not be greater than the distance between adjacent buildings.

$\$ = Q_1 + Q_2$ is Absolute Method

Where,

Q_1 = highest displacement of building-1

Q_2 = highest displacement of building-2

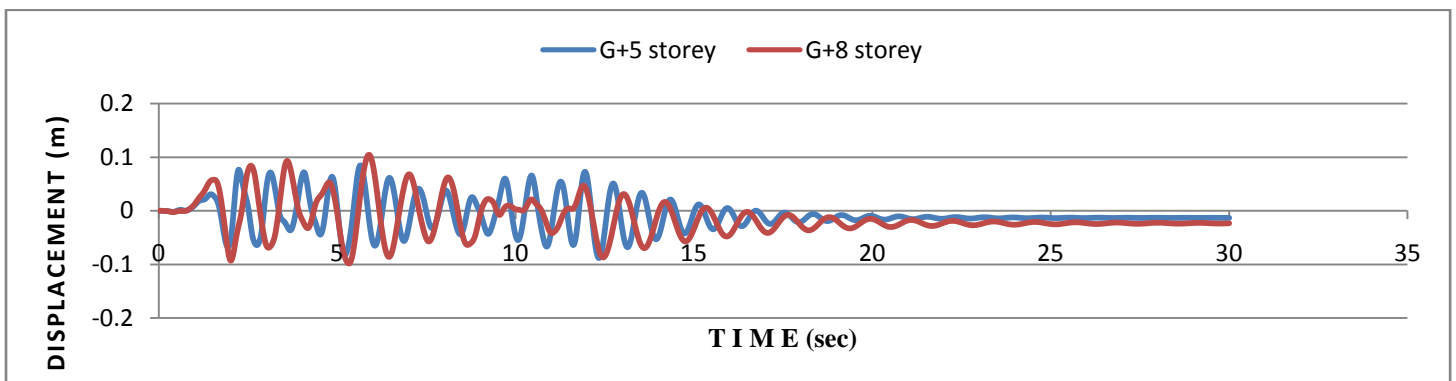


Fig-2: Time vs displacement graph of both buildings at 5th floor level when there is no additional stiffness in buildings.

After analyzing these two buildings in SAP2000 under Time History data of Elcentro which is to be known as above average earthquake, the buildings were observed displacement with respect to time. For pounding observance we are considering worst condition by taking positive displacement of G+ 8 story and Negative displacement of G+ 5 story due to different dynamic characteristics. This figure shows that maximum negative displacement of G+5 story building at fifth floor level is 88.52 mm at 12.34 sec. The figure also shows that maximum positive displacement for G+8 story building is 104.2 mm at 5.88 sec. From figure it is noticed that maximum out of phase movement of both building at 5.8 sec is $(104.2+85.5)-80= 109.7\text{mm}$ which is greater than expansion joint, hence the separation joint between the buildings is 80 mm which is unable to accommodate this out of phase movement, and adjacent buildings will strike or collide at this time for about 29.7mm.

3.2 Provide Cross Bracings to Increase Stiffness:

Since gap between the buildings cannot be increased to accommodate the relative movement of both the buildings, we can reduce the relative displacement by providing additional stiffness i.e. by bracings, shear wall and by combined action, to accommodate out of phase movement under provided gap. Cross Bracings are provided at the end panels of the both buildings to reduce the relative displacements. The connection of steel cross braces with concrete frame structure

requires a very special consideration and the strong connection should be there to transfer the load from concrete frame to cross braces safely.

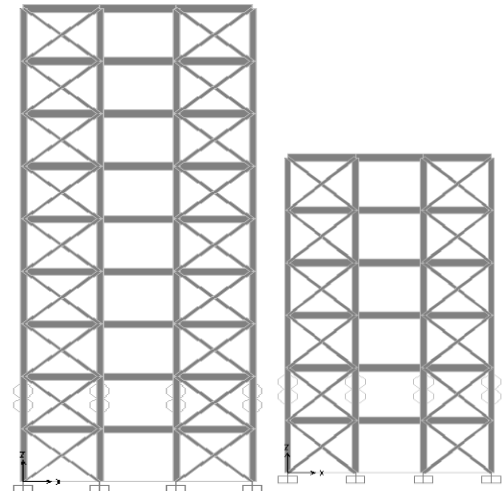


Fig-3: Shows the cross bracing of Eight story and Five story buildings

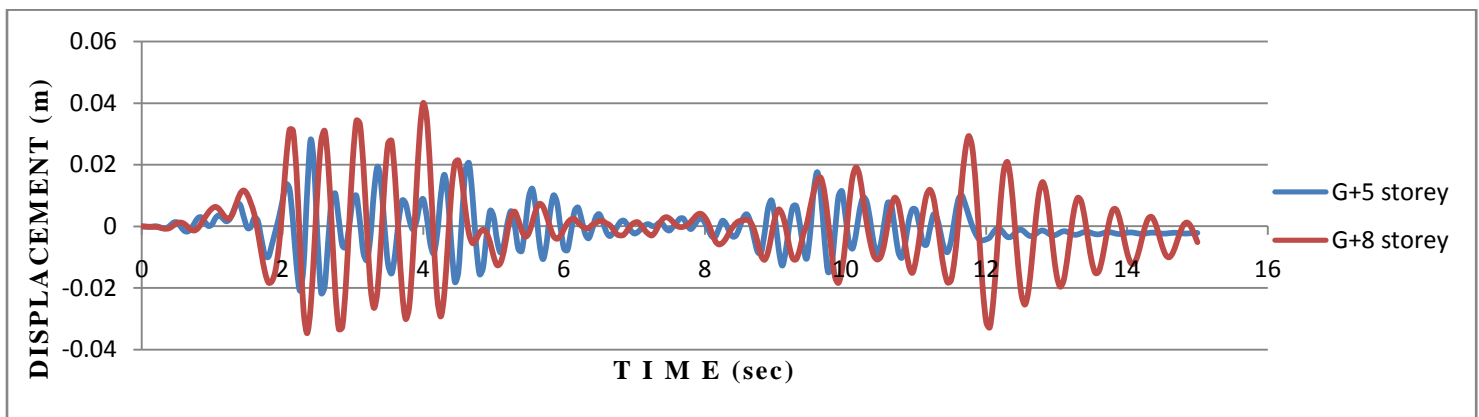


Fig 4: Displacement vs Time graph of both buildings at 5th floor level when cross bracings are introduced in buildings.

Above figure-4, shows time vs displacement graph at 5th floor level, in this Maximum Positive displacement of G+ 8 story at fifth floor is 40mm at 4.00 sec and Maximum Negative displacement of G+ 5 story is 21.56mm at 2.55 sec. It shows that Maximum out of phase movement is $40+21.56= 61.56\text{mm}$ which is lesser than the expansion joint i.e. 80mm, hence No chance of pounding at any interval, when these kinds of additional stiffness is provided.

3.3 Introducing New RC wall to Increase Stiffness:

Shear walls are provided to reduce the lateral displacements in the buildings, here we are replacing masonry wall with RC wall.

Initially beams are designed for $(0.23 \times 20 \times 2.6 = 12 \text{ KN/m})$ and now it is replaced by 0.18m thickness of RC wall, hence the load on beam will be the same $(0.18 \times 24 \times 2.6 = 11.2 \text{ KN/m})$. RC wall needs to be dowelled with the adjacent beams and

columns to transfer lateral force safely to the ground.

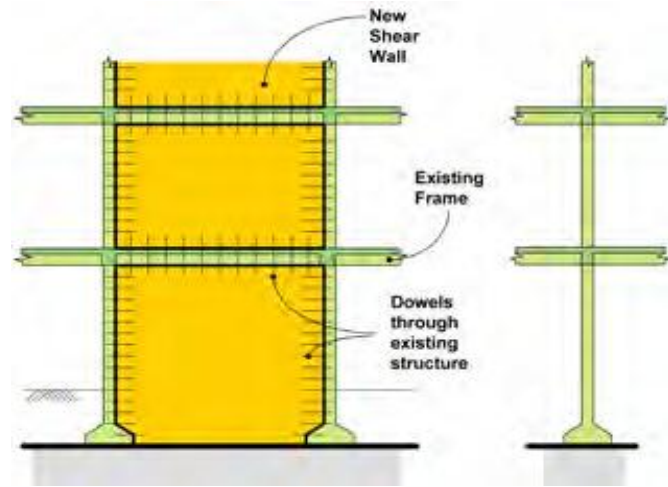


Fig-5: Shows the dowelling of New RC walls through existing structure.

Here in this both the buildings, New RC walls are introduced in the mid panel of buildings to reduce lateral displacement of the buildings (11. Murthy, C.V.R, 2005). In G+ 8storey building, wall is of 3.5 m in X direction and in G+ 5 storey building, wall is of 3.0m length in X direction. As we are interested to reduce the the lateral displacement in X direction were pounding can occur. Time History Analysis is done by taking Elcentro Earthquake data, to which time vs displacement graph plotted, to observe the displacements of both the buildings at fifth floor level.

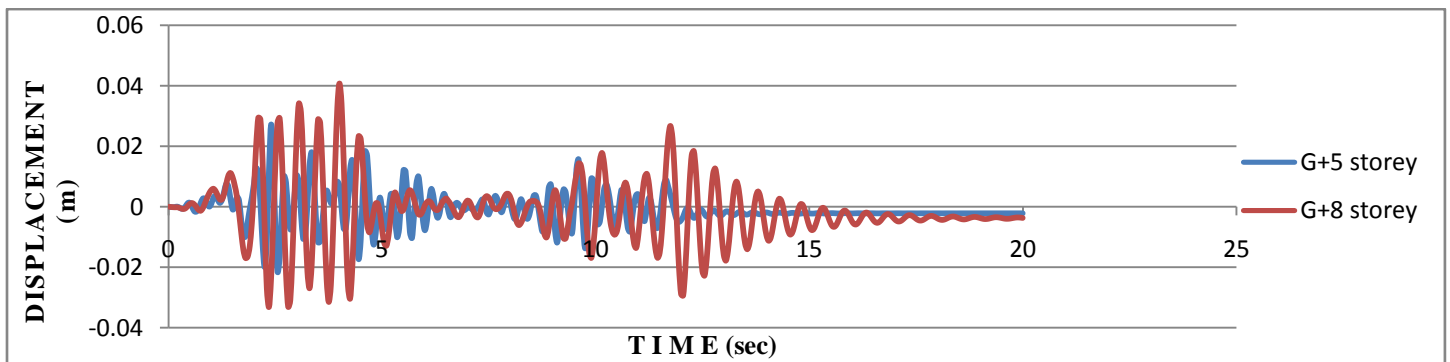


Fig-6:Shows the time vs displacement graph of both buildings at 5th floor when shear wall is constructed.

From figure-6, it is noted that Maximum Positive displacement of Eight storey building is 40.76mm at 4.00 sec and Maximum Negative displacement of Five storey is 21.48 mm at 2.55 sec. Maximum out of phase movement is $40.76+21.48= 62.24$ mm, it is less than expansion joint hence, no chance of pounding at any interval of time .

3.4 Increasing the Stiffness by Combined Shear Wall and Bracing System:

RC walls are provided at exterior mid panels and inner panels are placed by cross bracings in x direction for both the buildings, in order to prevent pounding between adjacent buildings.

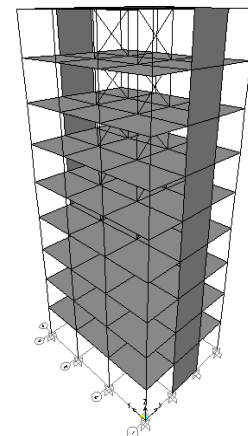


Fig-7: Shows the both RC wall are at exterior mid panel and cross bracing are in interior mid panels.

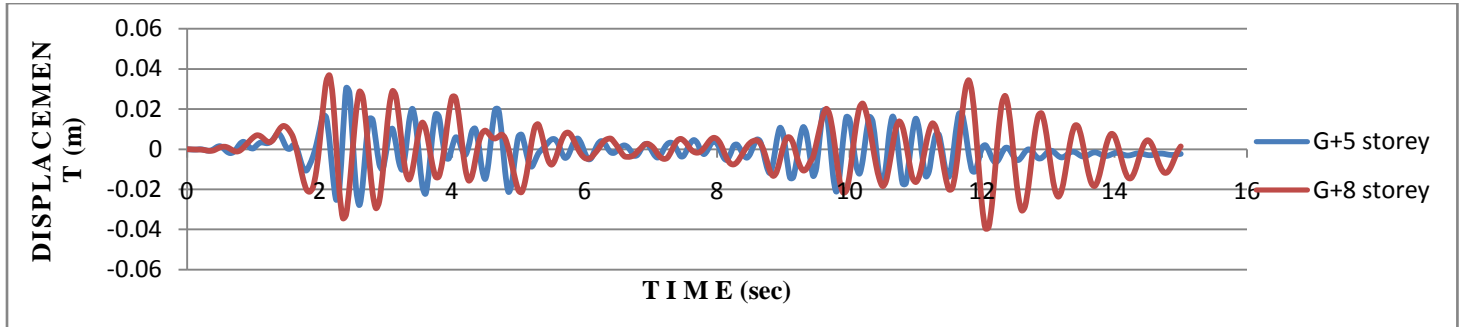


Fig-8: Shows time vs displacement graph for both buildings at 5th floor level when both RC wall and cross bracings provided

From figure-8, it can be observed that Maximum Positive displacement of Eight storey at fifth floor is 36.7 mm at 2.15 sec and Maximum negative displacement of G+ 5 storey is 27.84mm at 2.6 sec. The absolute sum of both is 64.54mm. Hence it is also less than Expansion joint which is 80mm, no chance of pounding at any interval of time.

4. CONCLUSIONS

- At the time of design, designer have to ensure that there will be no pounding between adjacent buildings.
- Necessary safe separation gap should be provided according to FEMA-273.
- If buildings are old and are not in a stage to provide safe gap, then prevention measure should be taken like this study had undertaken, using of New RC wall, cross bracing and combined system of both.
- Scope of this study is , replacing bracings with different dampers.
- All the prevention methods that are used in this study proved effective to prevent pounding between adjacent buildings.
- It is better to leave set back/safe separation gap according to FEMA-273, when the buildings are in early stage.

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