Prevention of Seismic Pounding between Adjacent Buildings

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ABSTRACT

Seismic pounding between adjacent buildings can cause moderate to severe damages 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 insufficient to accommodate their motions. Buildings are usually separated by expansion joint in many metropolitan cities. It can be prevented by providing safe separation distances, sometimes getting of required safe separations is not possible in such areas due to high land value and limited availability of land. 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. Combined RC wall-bracing and dampers with proper placement are proposed as possible prevention techniques for pounding between adjacent buildings.

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

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 [1] 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 difficulty in using expansion joint and economical loss of land usage [2].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/m^2 and on roof is 1.5kN/m^2. Floor finish on the floor is 1kN/m^2 and weathering course on roof is 1kN/m^2. The seismic weight is calculated conforming to IS 1893-2002(part-I). The unit weights of concrete is taken as 24kN/m^3 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 14.1 version 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 EQ.

Building-1Eight stories have 3 bays in X and Y directions, having corner columns dimension of 0.3x0.6 m^2, whereas all inner columns are of 0.3x0.75 m^2. 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 m^2 in both the direction. Building-2 Five stories 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 m^2, whereas all inner column are of 0.3x0.45 m^2. Beam size is 0.23x0.45 m^2 in both the direction. Pounding is considered in top floor of G+ 5 story i.e. at fifth floor, for observation negative displacement of 5 stories and positive displacement of 8 stories is considered, as we are going for worst condition due to its different dynamic characteristics.

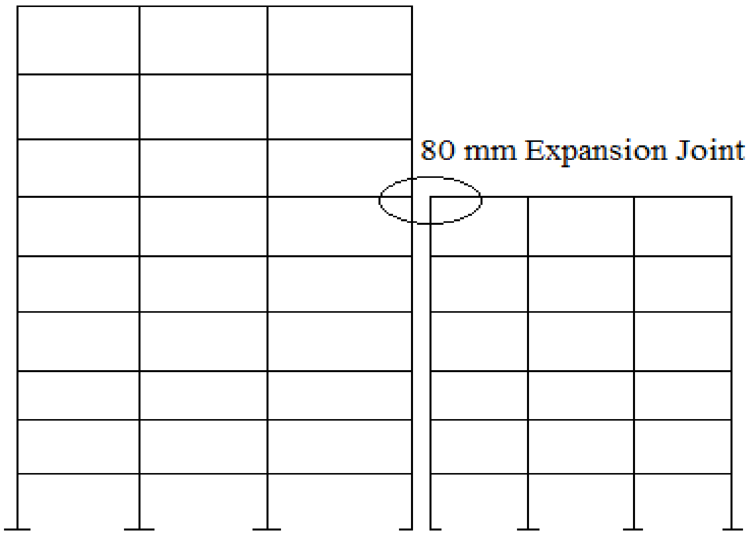

Fig-1: Represent the Position of Adjacent Buildings.

3. PREVENTION MEASURES TO AVOID POUNDING

(1) 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 273-1997(Federal Emergency Management Agency) provides safe separation distances between adjacent buildings.

\$ = $\sqrt{(D_1^2 + D_2^2)}$ is a SRSS (Square Root of the Sum of the Squares) Method

Where,

D_1 = Peak displacement of building -1

D_2 = Peak displacement of building – 2

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

\$=D_1+D_2 is Absolute Method

Where,

D_1= Peak displacement of building-1

D_2= Peak displacement of building-2

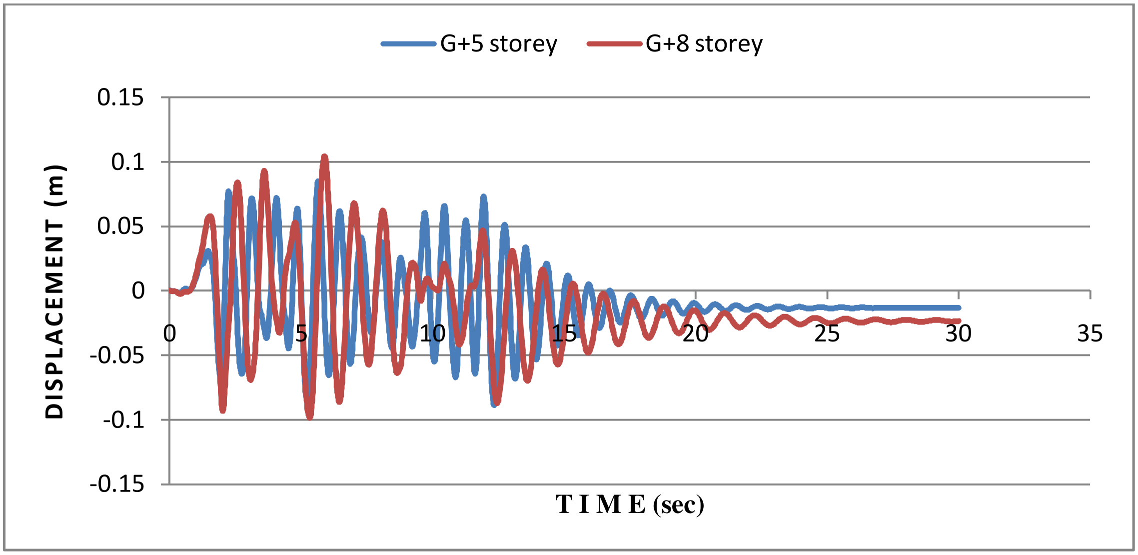

Figure-2: Time vs displacement graph of both buildings at 5th floor level when there is no additional stiffness in buildings.

After analyzing these two buildings in SAP2000 14.1 version under Time History data of Elcentro, is 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 88.52mm at 12.34 sec. The figure also shows that maximum positive displacement for G+8 story building is 104.2 mm at 5.8 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= 109.7mm 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.

(2) Introduction of New RC wall and Bracings to increase stiffness of the Buildings:

Shear/RC 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 (0.23x20x2.6=12 KN/m) and now it is replaced by 0.18m thickness of RC wall, hence the load on beam will be the same (0.18x24x2.6= 12KN/m). RC wall needs to be dowelled with the adjacent beams and columns to transfer lateral force safely to the ground (11. Murthy, C.V.R, 2005).

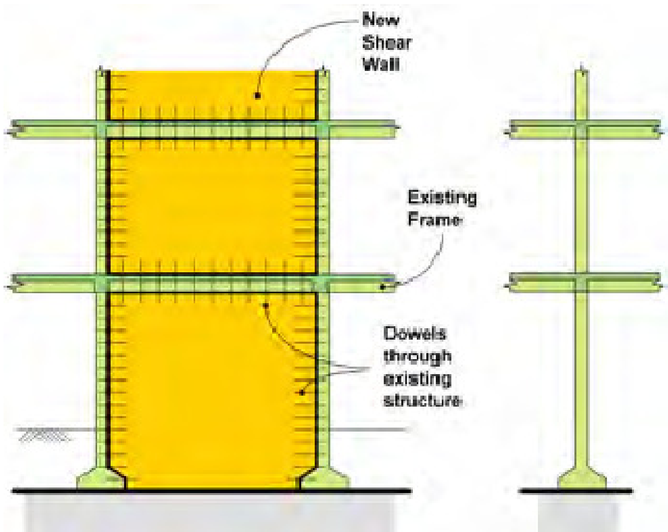

Fig-3: Shows the dowelling of New RC walls through existing structure.

In this both the structures, New RC walls are introduced in the mid exterior panel and cross bracings are provided in inner mid panels of structures to reduce lateral displacement of the buildings. 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. Time History Analysis is carried out by taking Elcentro Earthquake data, to which displacement vs time graph plotted, to observe the displacements of both the buildings at fifth floor level where pounding can occur.

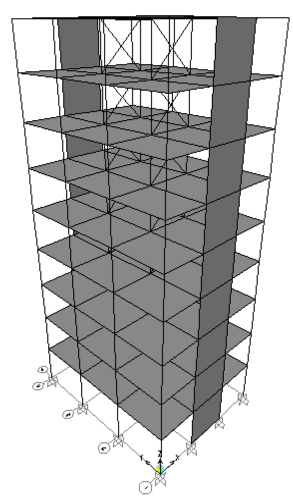

Fig-4: Shows the both RC wall are at exterior mid panel and cross bracing are in interior mid panels.

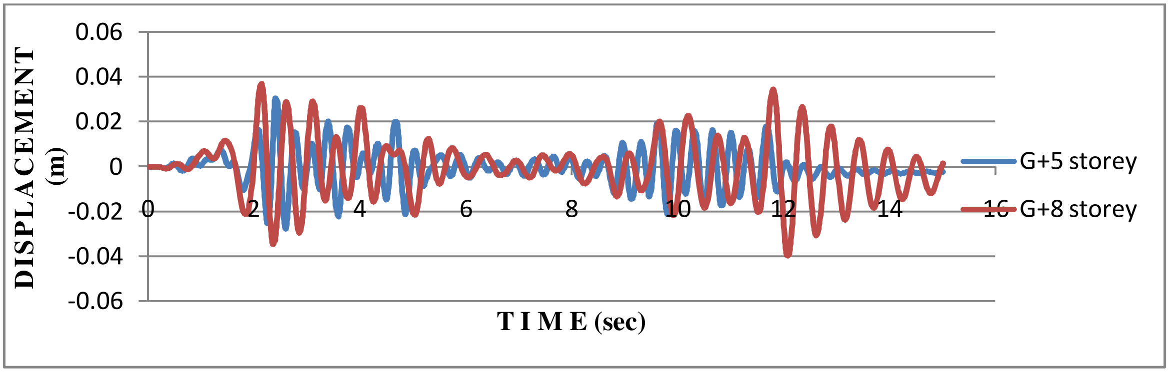

Fig-5: Shows time vs displacement graph for both buildings at 5th floor level when both RC wall and cross bracings provided

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 less than Expansion joint which is 80mm, no chance of pounding at any interval of time.

(3) Introduction of Fluid Viscous Dampers to increase stiffness of the Buildings:

Dampers are provided to improve the seismic response of the buildings. Here dampers are provided at the side panels of both buildings throughout the height, to reduce the lateral displacement. Connection of dampers should be fixed enough to reduce the seismic responses of the buildings.

Effective stiffness (0.2 to 1.2 times the initial stiffness of frame structures) and damping coefficient, Initial elastic stiffness of modeled frame structures is determined from non- linear static analysis (Pushover Curve) and damping coefficient is determined from Eq.4. Damping coefficient is a function of structure mass, stiffness and damping ratio. In this research damping ratio is taken as 5% of the critical value and mass of frame structure is computed by using total gravity dead loads.

Damping Coefficient = □□x 2 √stiffness x mass … Eqn No (1)

No of stories	Weight (KN)	Stiffness (KN/m)	Damping Coefficient (KN-sec/m)
G+5	4378	18333	895
G+8	9143	22000	1418

Table 1 : Weight, Stiffness and Damping coefficients of five and eight story frames obtained from Pushover Analysis.

Initial slope of the pushover curve is used as actual stiffness of the frame. Total Structure stiffness is taken as sum of actual structure stiffness and FVD stiffness.

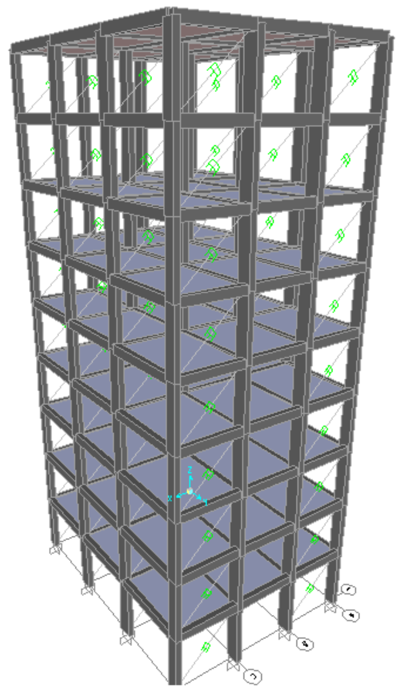

Fig-6: Shows the location of dampers at side panels of both buildings

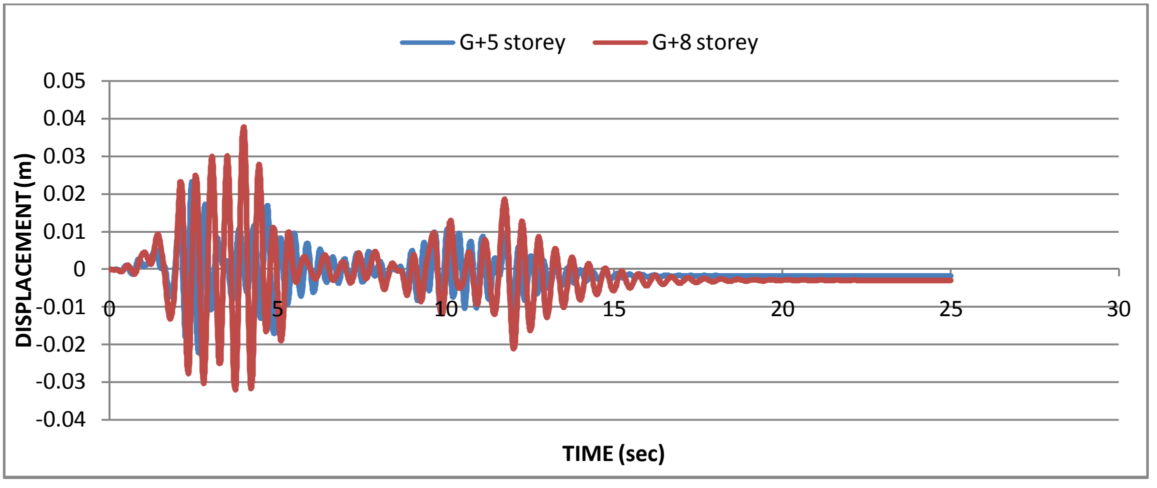

Fig-7: Shows time vs displacement graph of both buildings when dampers are provided at side panels

From figure-7, it can be observed that Maximum Positive displacement of Eight storey at fifth floor is 37.64 mm at 4.0 sec and Maximum negative displacement of G+ 5 storey is 22.14 mm at 2.65 sec. The absolute sum of both is 59.78mm. Hence it is less than Expansion joint, no chance of pounding at any interval of time.

4. CONCLUSIONS

- At the time of design, Design Engineer have to ensure that there will be no pounding possibilities between adjacent buildings.
- Necessary safe separation gap should be provided according to FEMA 273-1997
- If buildings are old and are not in a stage toprovide safe gap, then prevention measure should be taken like this study had undertaken, using of New RC wall, Bracings and Fluid viscous dampers.
- Scope of this study is, replacing FVD with different dampers.
- Prevention methods that are used in this study proved effective to prevent pounding between adjacent buildings.
- It is better to leave set back according to FEMA 273-1997, when the buildings are in planning stage.

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