Mitigation of Seismic Pounding Between Adjacent RC Buildings

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Abstract- *It has been observed from the past earthquake records that major damage to the building takes place due to the pounding between adjacent buildings during an earthquake. Sometimes it results in collapse of the building. Among the all possible structural damage pounding between the structures is commonly observed. Hence, a study on seismic pounding and its mitigation techniques is carried out. The paper contains analysis of seismic pounding between the adjacent buildings using ETABS nonlinear software. Two buildings of story G+10 and G+6 are analyzed with and without shear wall. The results are obtained in the form of storey displacements.*

Keywords- Adjacent Buildings, Mitigation of seismic pounding, Seismic Pounding, Shear wall

I. INTRODUCTION

An earthquake is capable of causing severe damage to structures; especially the earthquake having higher magnitude causes large damage to the structures. In case of the adjacent buildings significant damage is caused due to earthquake vibrations which sometimes result in the seismic pounding. The term seismic pounding is the process of repeated and heavy striking of buildings due to the earthquake vibration. Particularly in India past earthquakes caused large destruction due to the seismic pounding. The annual energy dissipation in India and its surrounding area is identical to an earthquake having the magnitude in between 5.5 to 7.3[1]. Therefore in case if the two buildings are close to each other, it is anticipated that they will result in to seismic pounding. Such types of the cases are easily seen in metropolitan areas where the cost of land is much higher than the other areas of that particular region. If the buildings situated in the metropolitan areas are not properly spaced then there should have safe and economical retrofitting method to mitigate seismic pounding [2-3]. In case of stiff structural systems pounding is critical, especially in case of highly out of phase system [4].

Most of the studies were carried out on structural pounding considering single degree of freedom as a base and lesser work is done on seismic pounding between multistory buildings. Recent study consists of seismic hazard mitigation practices like effect of different separation distances and effect of addition of shear walls are investigated in ETABS nonlinear software [5].

1.1 Seismic pounding mitigation

In general effect of seismic pounding can be mitigated either by providing adequate separation distance or by providing different mitigation techniques such as using shear walls, bracing system, dampers etc [6].

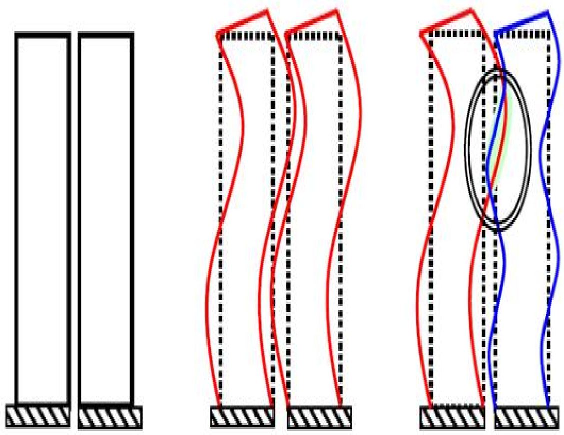
(a) By providing adequate separation distance

According to IS1893:2002(Part 1), the separation distance 'S' should be 'R' times sum of displacements. 'R' may be replaced by 'R/2' if the two buildings are having the same levels where 'R' is response reduction factor [7]. FEMA 273: 1997 mentioned that separation distance between buildings shall be less than 4% of the building height and above to avoid seismic pounding [8]. And also gives the equations for calculating the minimum gap necessary between adjacent buildings.

$$S = U_a + U_b \quad \text{(ABS)} \quad (1)$$

$$S = \sqrt{U_a^2 + U_b^2} \ \text{(SRSS)} \quad (2)$$

Where 'S' is separation distance and U_a and U_b are peak displacement response of adjacent buildings.



(a) Prior to Earthquake (b) Same seismic behavior
(c) Different seismic behavior
Figure1. Behavior of adjacent buildings during an earthquake

Basically seismic pounding takes place due to structural irregularity. Practically it is impossible to make the building having same seismic behavior like another building. In such case [Fig.1 :(b)] there is no need to provide no need to provide minimum separation gap since mode shapes of the buildings are same and in same direction.

(b) By providing different mitigation techniques

Seismic pounding can be reduced to large extent by providing special type of structural system. It includes use of shear wall, bracing, dampers etc. IS 4326:1993 gives an idea for providing the separation necessary in case of special type of structural system which is applicable for the building having storey height below 40m [9]. For the buildings having height more than 40m code suggests to carryout separate dynamic analysis and the gap width should not be less than sum of the dynamic deflection of building at any level.

Table 1. Gap width for different structural systems

Sl. No.	Type of Structural Systems	Gap Width/storey in mm
1	Box systems or frames with shear walls	15.0
2	Moment resistant RC frame	20.0
3	Moment resistant steel frame	30.0

II. METHODOLOGY

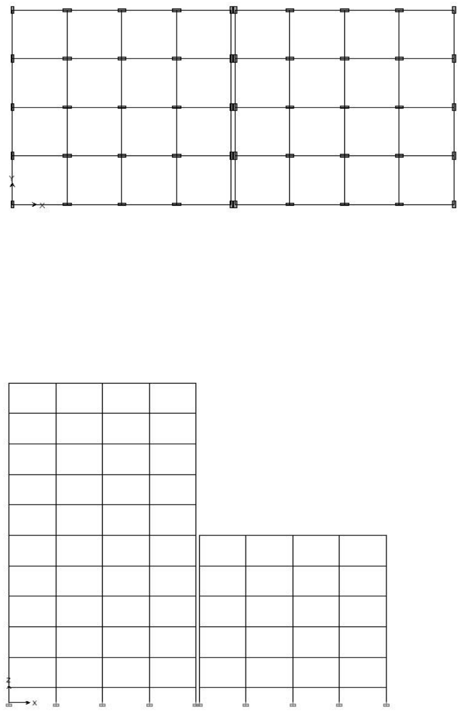
Seismic pounding causes huge destruction to the structure. Thus the present study consists of analysis of RC frame with and without shear wall in ETABS nonlinear software. Seismic pounding response between the adjacent multistory buildings is analyzed considering displacement as main aspect. For linear earthquake building in zone V is considered and a response spectrum analysis is carried out in ETABS. Response spectrum analysis is a method in which a linear dynamic response of the structure is calculated.

In general response spectrum is a plot between peak response (Displacement, velocity, acceleration) of series of oscillator and variable natural frequency. Response spectrum analysis is an important tool for calculating response of the structure subjected to seismic vibrations. Hence, if we calculate the natural frequency of the structure, then we can estimate peak response of the building which can be calculated by reading the value from the ground response spectrum for the particular frequency.

Response spectrum analysis is used for designing the decision making since it relates selected structural type to dynamic performance. In this, the structure having shorter period posses greater acceleration where as those structures of larger period experience greater displacement. It shows effect of damping on the structural response. As per IBC (International Building Code) 5% damping is considered and the modal response can be calculated using CQC, SRSS, and ABS methods.

III. STRUCTURAL MODELING AND ANALYSIS

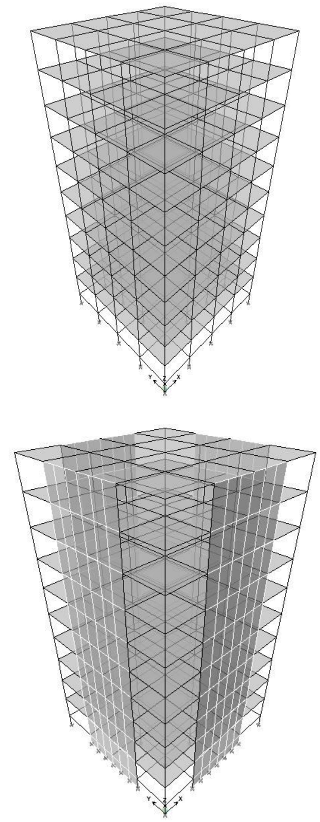
In order to calculate the seismic pounding between adjacent buildings, Two RC buildings (G+10, G+6) are selected. The two buildings are separated by distance 50mm subjected to dead and dynamic loading. Both buildings that is G+10 and G+6 are analyzed in ETABS nonlinear software. Building ‘A’ is of G+10 storey having 4 numbers of bay in X and Y direction. Width of each bay is 4m and height of each storey is 3m.The foundation height is 1.5m, column having size (0.23X0.60)m^2 and beam is of size(0.23X0.45) m^2. The thickness of slab is 120mm. Building ‘B’ is of G+6 storey same loading, material and section properties as that of G+10 storey.M20 grade of concrete is used. Concrete frame design preference is given to IS456:2002,



(a) Plan of building 'A' and 'B' (b) Elevation of building 'A' and 'B'

Figure 2. Plan and Elevation of the building model 'A' and 'B'

3.1 Analysis of Building 'A'



G+10 building without Shear wall

(b) G+10 building with shear wall

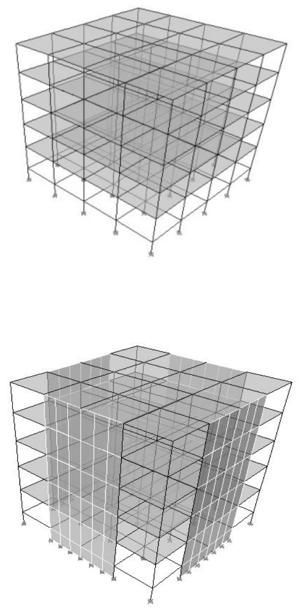
Figure 3. G+10 Building with and without shear wall

Building of type 'A' that is building of G+ 10 story is analyzed in ETABS nonlinear software with tool of response spectrum analysis and effect of seismic pounding is calculated. We get the values of displacements yielding significant pounding. In order to reduce the values of displacement within the storey shear wall is constructed at 2 and 3 bay in X and Y direction. And it yields much smaller values of displacements as compare to previous one as shown in Table 2.

Table 2. Story displacements of building 'A'

Storey	Displacement in m.(Without shear wall)	Displacement in m.(With shear wall)
11	0.0392	0.0087
10	0.038	0.0077
9	0.036	0.0067
8	0.0333	0.0056
7	0.0299	0.0046
6	0.0259	0.0036
5	0.0214	0.0026
4	0.0165	0.0017
3	0.0111	0.001
2	0.0056	0.0004

3.2 Analysis of Building 'B'

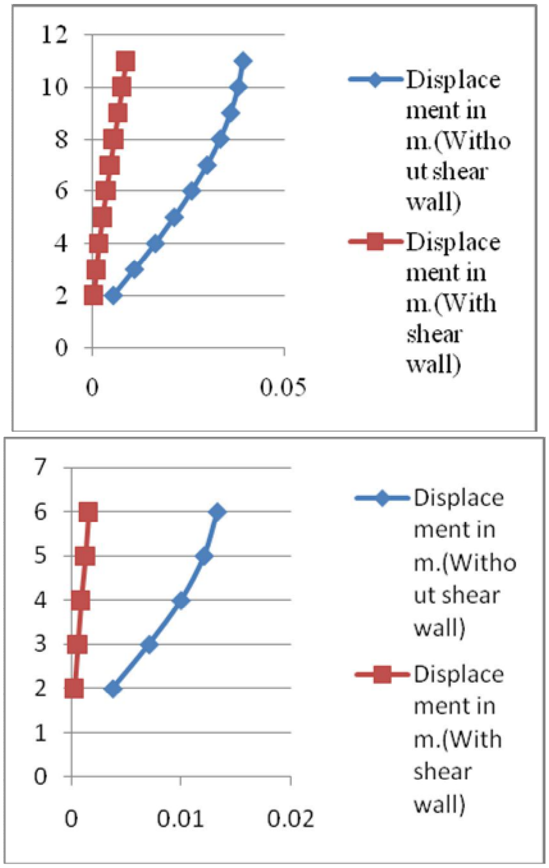


(a) G+6 building without Shear wall
(b) G+6 building with shear wall
Figure 4. G+6 Building with and without shear wall

Building of type 'B' that is building of G+ 6 story is analyzed in ETABS nonlinear software with tool of response spectrum analysis and effect of seismic pounding is calculated. We get the values of displacements yielding significant pounding. In order to reduce the values of displacement within the storey shear wall is constructed at 2 and 3 bay in X and Y direction. And it yields much smaller values of displacements as compare to previous one as shown in Table 3.

Table 3. Story displacements of building 'B'

Story	Displacement in m.(Without shear wall)	Displacement in m.(With shear wall)
6	0.0132	0.0015
5	0.012	0.0012
4	0.0099	0.0008
3	0.007	0.0005
2	0.0037	0.0002



(a) Graph of story displacements of building 'A' (b) Graph of story displacements of building 'B'
Figure 5. Graphical representation of story displacement of building 'A' and 'B' with and without shear wall

Fig.5 shows the graph between storey and displacement for 'G+10' and 'G+6' buildings. The values are calculated by response spectrum analysis. It has been seen that the maximum displacement occurs at the top story and can be mitigated at large extent using shear wall. The top storey displacement for 'G+10'and 'G+6' story is 39.2mm and 13.2mm respectively. After using shear wall it reduces to 8.7mm and 1.5mm.Hence if we are providing the shear wall to the buildings 'A' and 'B', the gap of 50mm distance is sufficient.

IV. CONCLUSIONS

Pounding between the structures is highly nonlinear phenomenon. During the earthquake huge amount of pounding force acts on building, it is impossible to absorb the pounding force completely but we can able to mitigate the pounding force to a large extent. The results obtained in response spectrum analysis are plotted in the form of graph. From that following conclusions are made

(a) As increase in the separation distance decreases pounding force, provision of an adequate separation distance mentioned in the IS codes reduces the possibility of seismic pounding. Among the all codes mentioned earlier FEMA-273 provides larger separation distance between the adjacent buildings since the separation distance is 4% of storey height.

(b) Adjacent buildings having the same seismic behavior need not to provide minimum separation gap as mode shapes are equal and are in same direction.

(c) Response of building is highly affected by the pounding force acting in the longitudinal direction of the building. The story displacement of the building depends on the magnitude of the pounding force in longitudinal direction.

(d) Shear wall resists the longitudinal displacement of the structures which results in mitigation of pounding force in large extent.

(e) It has been seen that, In the process of seismic pounding structure having the shorter time period posses greater acceleration where as the structures having the larger time period experience greater displacement.

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