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Seismic Pounding Effects in RC Buildings Using SAP2000

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Abstract - *Major seismic events during the past decade have continued to demonstrate the destructive power of earthquakes, with destruction of engineered buildings, bridges, industrial and port facilities as well as giving rise to great economic losses. Among the possible structural damages, seismic induced pounding has gained interest of structural engineers due to their frequent occurance during earthquake. As a result, a parametric study on buildings pounding response as well as proper seismic hazard mitigation practice for adjacent buildings is carried out. Therefore, the needs to improve seismic performance of the built environment through the development of performance-oriented procedures have been developed. This paper aims at studying seismic gap between adjacent buildings by time history analysis in SAP2000. Comparisons of structural response on adjacent symmetrical square building having different layouts with and without base isolations were carried out. Also pounding effect is considered for two different cases ie, floor to floor pounding and floor to mid column pounding. The study showed that seismic gap required for base isolated buildings (LRB) is more compared with fixed base buildings.*

Key Words*: *Seismic Pounding, Separation Distance, Adjacent Buildings, Gap Element, Fixed-Base, Base Isolator, floor to floor pounding, floor to mid column pounding.

1. INTRODUCTION

Pounding is one of the major reasons of structural damages in buildings, constructed very near to each other, when they are subjected to a strong ground motion during an earthquake. In metropolitan cities where buildings have been constructed very near to each other due to high land value and lack of awareness about pounding, pounding mitigation is very necessary for structuralsafety and life safety. Experiences of past and recent earthquake-damages have well established pounding as one of the major causes of structural damages in buildings, constructed very near to each other or without any gap at all. Pounding, which is a collision between adjacent buildings during an earthquake, commonly occurs due to their different dynamic characteristics, adjacent buildings vibrate out of phase and there is insufficient seismic gap between them. This situation can easily be seen in metropolitan cities where buildings have been constructed very near to each other due to very high cost of land and lack of knowledge about pounding and its consequences.

1.1 Gap Elements

Gap element is an element which connects two adjacent nodes to model the contact and is defined as a link element in SAP2000 software, this link element is activated only when the structures come closer and deactivate when they go far away and a collision force will be generated when they come closer. So it is a compression-only element required to assess the pounding force and to simulate the effect of pounding..

1.2 Lead Rubber Bearing (LRB)

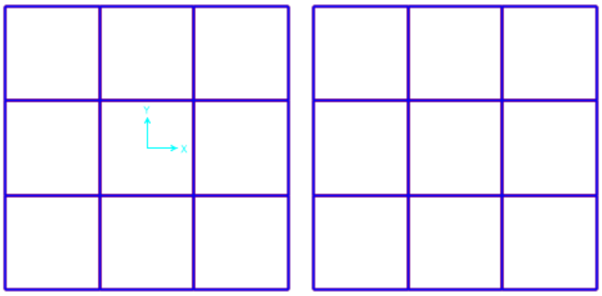
Lead Rubber Bearings (LRB) consists of a laminated rubber and steel bearing with steel flange plates for mounting to the structure. Ninety percent of our isolators have an energy dissipating lead core. The rubber in the isolator acts as a spring. It is very soft laterally but very stiff vertically. The high vertical stiffness is achieved by having thin layers of rubber reinforced by steel shims. These two characteristics allow the isolator to move laterally with relatively low stiffness yet carry significant axial load due to their high vertical stiffness. The lead core provides damping by deforming plastically when the isolator moves laterally in an earthquake.

2. STRUCTURAL MODELLING

The models which have been adopted for study are symmetric six storey (G+5), nine storey (G+8) and twelvestorey (G+11) buildings. The buildings consist of 6 sets of rectangular columns. The inner column dimensions of (G+5), (G+8) and (G+11) are 300mmx450mm, 300 mmx750 mm and 300mmx900 mm and that of corner columns are 230mmx450 mm, 300 mmx600 mm and 300 mmx750 mm respectively. The beam sizes for (G+5), (G+8) and (G+11) are 230 mmx450 mm, 300 mmx450 mm and 300 mmx450 mm respectively and the floor slabs are taken as 120 mm thick. The height of the stories is 3m.The grade of concrete have been taken as M20 for all beams, slabs and M25 for columns. The number of bays in X and Y direction is taken as 3 and width is taken as 3m.

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.

For analytical study, two adjacent reinforced concrete building separated by 0.08 m is considered. Based on pounding location two types of studies are carried out by maintaining storey height same for both buildings (node to node pounding). To assess effect of pounding of floor against column, buildings with different storey heights are also considered in another study. Accordingly, four combinations for the models are considered. first building A has G+5storeys, while the second building B has G+5 stories for model I. G+8 storied building A adjacent to G+5 storied building B is model II. G+11 storied building A adjacent to G+5 building B is model III. G+11 storied building adjacent to G+8 building B is model IV.



Bilding A Building B

Fig.1 Plan of (G+8) and (G+5) Building

2.1 Required Seismic Separation Distance to Avoid Pounding

Seismic codes and regulations worldwide specify minimum separation distances to be provided between adjacent buildings, to preclude pounding, which is obviously equal to the relative displacement demand of the two potentially colliding structural systems. For instance, according to the 2000 edition of the International building code and in many seismic design codes and regulations worldwide, minimum separation distances (Lopez Garcia 2004) are given by ABSolute sum (ABS) or Square Root of Sum of Squares (SRSS) as follow:

- ABSolute Sum (ABS) method
- Square Root of Sum of Squares (SRSS) method

The equation used for ABS method is by equation

$\Delta = U_a + U_b$

According to SRSS method, the minimum seismic gap is given by equation

$\Delta = \sqrt{U_a^2 + U_b^2}$

Where, Δ is separation distance and U_a , U_b are the peak displacement response of adjacent structures A and B, respectively.

3 ANALYTICAL INVESTIGATIONS

3.1 Time History Analysis

Time History analysis has been carried out using the Imperial Valley Earthquake record of May 18, 1940 also known as the Elcentro earthquake for obtaining the various floor responses. The record has a sampling period of 0.02 seconds. Nonlinear Dynamic analysis (Time History) can be done by direct integration of the equations of motion by step by step procedures. Direct integration provides the most powerful and informative analysis for any given earthquake motion. A time dependent forcing function (earthquake accelerogram) is applied and the corresponding response – history of the structure during the earthquake is computed.

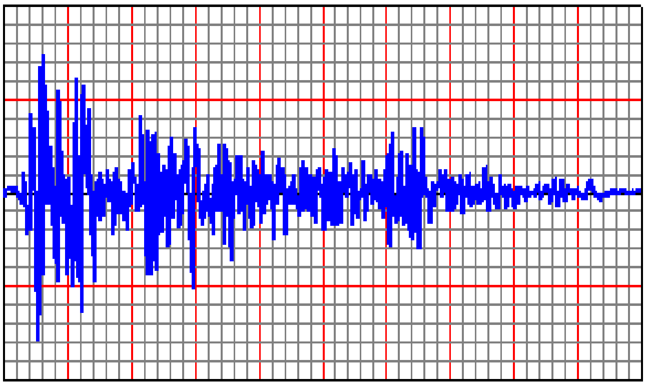


Fig.2 Acceleration Time History of El Centro Imperial Valley 1940 Ground Motion Records

4. RESULTS AND DISCUSSION

4.1 Seismic Gap

Building was analyzed with and without base isolator for an earthquake time history and the results are given below:

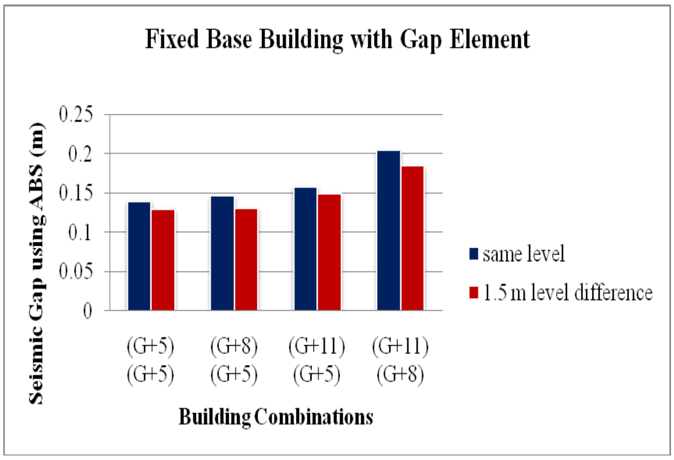


Fig.3 Building Combinations with Gap Element

The minimum seismic gap obtained as per abs method is greater than 0.08 m, pounding has occurred. Location of pounding is one of the important factors to be considered during the pounding effect. Pounding effect is more in floor to floor pounding than in floor to mid column pounding that is seismic gap required for same level building is more compared with 1.5m level difference.

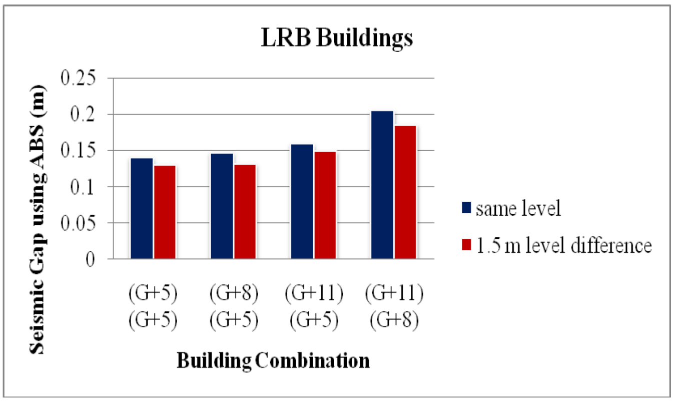


Fig. 4 Building Combinations with Base Isolators

The minimum seismic gap obtained as per ABS method is greater than 0.08 m, pounding has occurred. Location of pounding is one of the important factors to be considered during the pounding effect. Pounding effect is more in floor to floor pounding than in floor to mid column pounding.

4.2 Inter Storey Drift

Inter storey drift of (G+5)(G+5) building combination and (G+8)(G+5) building combination with and without base isolator are given below.

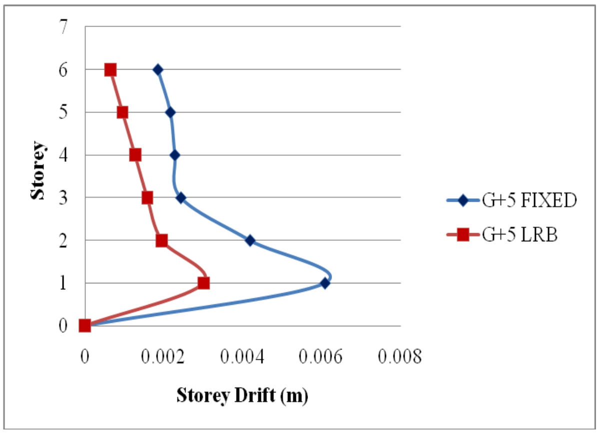
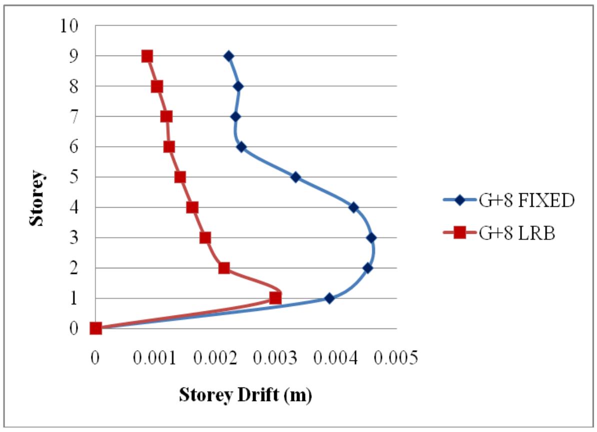
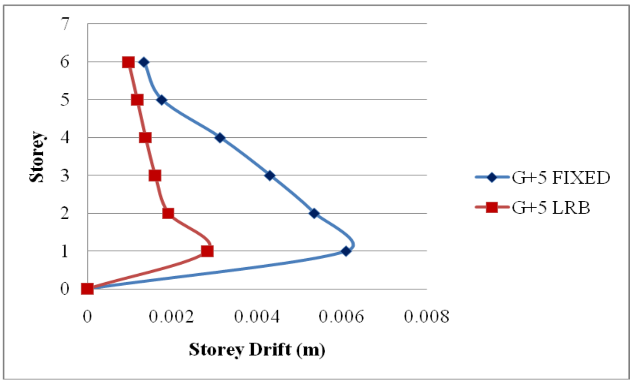


Fig.4 Storey v/s Inter Storey Drift of G+5 &G+5 Buildings



(a)



(b)

Fig.5 Storey v/s Inter Storey Drift f of G+8 &G+5 Buildings

In case of fixed base building, storey drift is higher at the lower floors and it decreases as we move to the top floors. But for base isolated buildings, storey drift is comparatively lower than fixed base buildings at the lower floors and decreases as we move to the top floors. At top floor, storey drift is nearly equal to zero.

4.3 Displacement

The storey displacement at each level for various building model are obtained from the time history analysis methods is shown below.

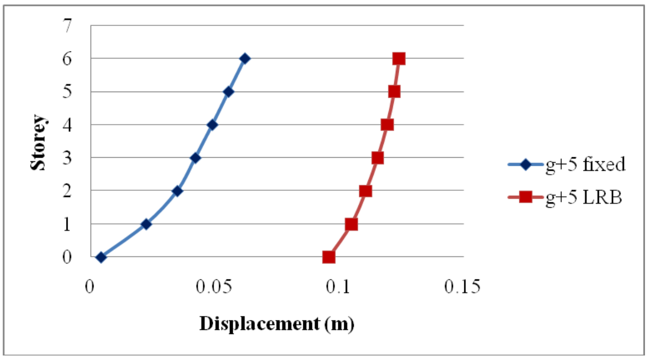
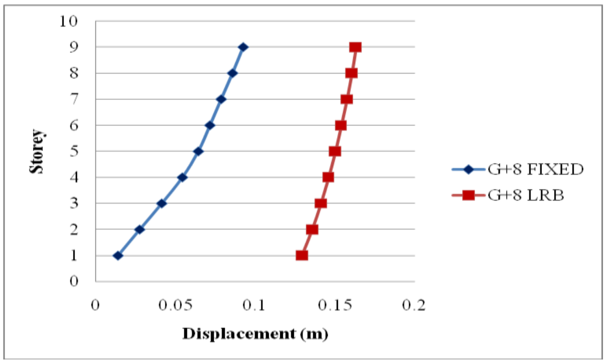
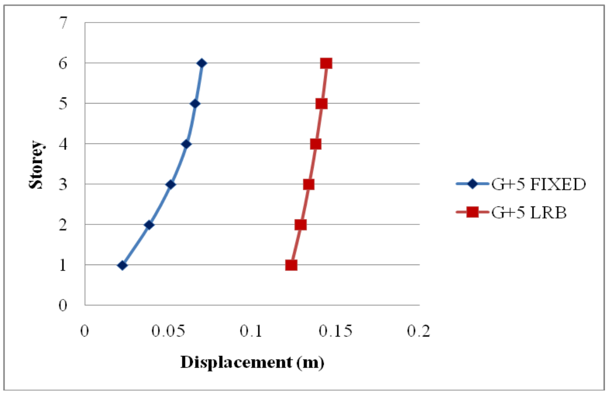


Fig. 6 Storey v/s Displacement for G+5 &G+5 Building Combination



(a)



(b)

Fig. 7 Storey v/s Displacement for G+8 &G+5 Building Combination

In case of fixed base building, displacement is zero at the base and increases as storey height increases. But in case of base isolated building, at the base there is a considerable amount of displacement and increase in the displacement is less as height increases compared to fixed base building.

4.4 Comparisons

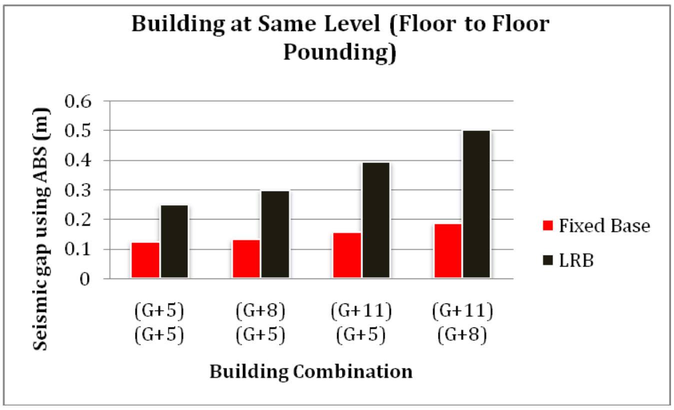


Fig.8 Building Combinations with and without Base Isolator (Floor to Floor Pounding)

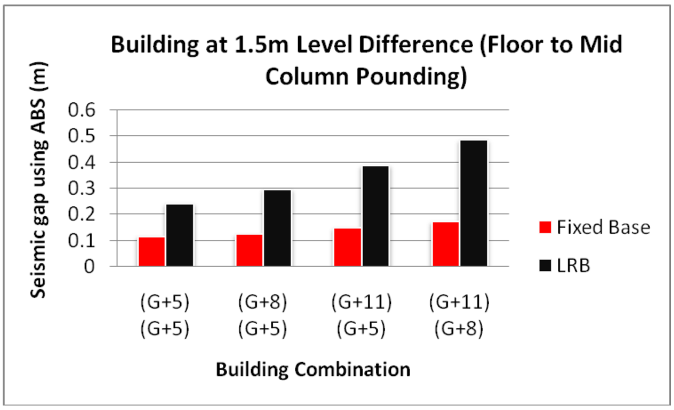


Fig.9 Building Combinations with and without Base Isolator (Floor to Mid Column Pounding)

Seismic gap required for base isolated buildings (LRB) is more compared with fixed base buildings in both floor to floor and floor to mid column pounding as shown in Fig 8 and Fig 9.

5. CONCLUSIONS

Location of pounding is one of the important factors to be considered during the pounding effect. Pounding effect is more in floor to floor pounding than in floor to mid column pounding.

Seismic gap required for base isolated buildings (LRB) is more compared with fixed base buildings.

In case of fixed base building, storey drift is higher at the lower floors and it decreases as we move to the top floors. But for base isolated buildings, storey drift is comparatively lower than fixed base buildings at the lower floors and decreases as we move to the top floors. At top floor, storey drift is nearly equal to zero.

Inter storey drift of base isolated (LRB) buildings are very less compared to fixed base buildings.

In case of fixed base building, displacement is zero at the base and increases as storey height increases. But in case of base isolated building, at the base there is a considerable amount of displacement and increase in the displacement is less as height increases compared to fixed base building.

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