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Pre Analysis of Seismic Pounding Effect in RCC Building

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ABSTRACT: Major seismic events during the past decade such as those that have occurred in Northridge, Imperial Valley (May 18, 1940), California (1994), Kobe, Japan (1995), Turkey (1999), Taiwan (1999) and Bhuj, Central Western India (2001) 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 been commonly observed in several earthquakes. 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 entitled “Pre Analysis of Seismic Pounding Effect in RCC Building” aims at studying seismic gap between adjacent buildings by dynamic analysis in ETABS. A parametric study is conducted to investigate the minimum seismic pounding gap between two adjacent structures by response Spectrum analysis for medium soil for input in the dynamic analysis on different models.

KEYWORDS: Seismic pounding, Response spectrum analysis, ETABS

I. INTRODUCTION

Investigations of past and recent earthquakes damage have illustrated several instances of pounding damage (Astaneh-Asl et al. 1994, Northridge Reconnaissance Team 1996, Kasai & Maison 1991) in both building and bridge structures. Pounding damage was observed during the 1985 Mexico earthquake, the 1988 Sequoyia earthquake in Canada, the 1992 Cairo earthquake, the 1994 Northridge earthquake, the 1995 Kobe earthquake and 1999 Kocaeli earthquake. Significant pounding was observed at sites over 90 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 or energy dissipation system to accommodate the relative motions of adjacent buildings. Past seismic codes did not give definite guidelines to preclude pounding, because of this and 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. The highly congested building system in many metropolitan cities constitutes a major concern for seismic pounding damage. For these reasons, it has been widely accepted that pounding is an undesirable phenomenon that

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 detailing problem and 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 (Kasai et al. 1996, Abdullah et al. 2001, Jankowski et al. 2000, Ruangrassamee & Kawashima 2003, Kawashima & Shoji 2000), which can be achieved by joining adjacent structures at critical locations so that their motion could be in-phase with one another or by increasing the pounding buildings damping capacity by means of passive structural control of energy dissipation system or by seismic retrofitting.

1.1 Seismic Pounding Effect between Buildings:

Pounding is one of the main causes of severe building damages in earthquake. The non-structural damage involves pounding or movement across separation joints between adjacent structures. Seismic pounding between two adjacent buildings occur

- during an earthquake
- different dynamic characteristics
- adjacent buildings vibrate out of phase
- at-rest separation is insufficient

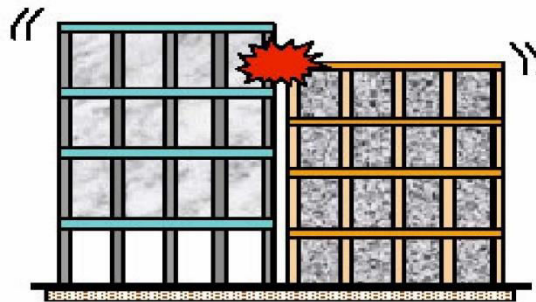


Fig 1.1. Seismic Pounding between Adjacent Buildings.

A separation joint is the distance between two different building structures - often two wings of the same facility - that allows the structures to move independently of one another. Seismic gap is a separation joint provided to accommodate relative lateral movement during an earthquake. In order to provide functional continuity between separate wings, building utilities must often extend across these building separations, and architectural finishes must be detailed to terminate on either side. The separation joint may be only an inch or two in older constructions or as much as a foot in some newer buildings, depending on the expected horizontal movement, or seismic drift. Flashing, piping, fire sprinkler lines, HVAC ducts, partitions, and flooring all have to be detailed to accommodate the seismic movement expected at these locations when the two structures move closer together or further apart. Damage to items crossing seismic gaps is a common type of earthquake damage. If the size of the gap is insufficient, pounding between adjacent buildings may result in damage to structural components the buildings.

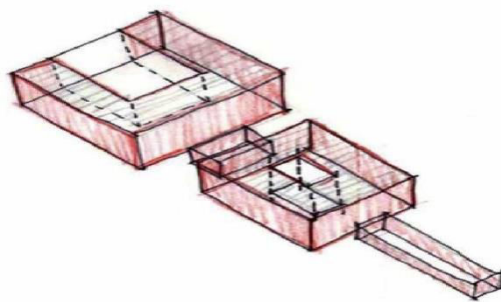


Fig 1.2. A diagram of a Roman house from the first century AD

Bureau of Indian Standards clearly gives in its code IS 4326 that a Separation Section is to be provided between buildings. Separation Section is defined as a gap of specified width between adjacent buildings or parts of the same building, either left uncovered or covered suitably to permit movement in order to avoid hammering due to earthquake. Further it states that For buildings of height greater than 40 meters, it will be desirable to carry out model or dynamic analysis of the structures in order to compute the drift at each storey, and the gap width between the adjoining structures shall not be less than the sum of their dynamic deflections at any level. Thus it is advised to provide adequate gap between two buildings greater than the sum of the expected bending of both the buildings at their top, so that they have enough space to vibrate. Separation of adjoining structures or parts of the same structure is required for. Structures

having different total heights or storey heights and different dynamic characteristics. This is to avoid collision during an earthquake. Minimum width of separation gaps as mentioned in 5.1.1 of IS 1893 : 1984, shall be as specified in Table 1.1 The design seismic coefficient to be used shall be in accordance with IS 1893 : 2016.

Table 1.1: Minimum width of separation gaps as mentioned in 5.1.1 of IS 1893

SR. No.	Type of Constructions	Gap Width/Storey, n mm for Design Seismic Coefficient $a_h = 0.12$
1.	Box system or frames with shear walls	15.0
2.	Moment resistant reinforced concrete frame	20.0
3.	Moment resistant steel frame	30.0

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

II. RELATED WORK

Dr. Mayank Desai and Darshit Jasani (2015) presented application of nonlinear static pushover procedure to the displacement based approach of seismic analysis of g+10 storey building structure for Indian terrain in which they studied seismic analysis for RCC G+10 storey building by application of nonlinear static pushover procedure as a tool to apply Performance Based Design Philosophy to the framed structure using displacement based approach of seismic analysis to determine the performance level of building in Surat city region by considering structural capacity obtained from pushover analysis and earthquake demand obtained from response spectra. Software used for analysis is finite element based software SAP2000. The determination of performance point is based on the Capacity Spectrum Method, which is a method prescribed by ATC Documents. Necessary changes have to be made in order to use this method as the parameters used differ from what are used in IS: 1893. The model used in research is a g+10 storey symmetric (on floor plan) RCC frame. The plan dimensions are 7.5mX7.5m. The location of building has been selected as Surat, Gujarat, India and so various parameters of soil, earthquake and wind have been selected accordingly. The modelling is done in SAP2000. They found that the demand over the structure is estimated by the hazard analysis in terms of maximum displacement or maximum base shear using any of the static or dynamic analyses methods like response spectrum method, static coefficient method or time history analysis etc. and the acceptance criteria prescribed in FEMA documents predict the performance and damage levels of the structure for minor, moderate and severe earthquake event. These levels typically range from immediate occupancy (IO) to collapse prevention.[

Neethu K. N and Saji K. P. (2013) preliminary study was carried out in order to for the building frame to be designed as per IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis and design software SAP 2000 (version 15). To check the seismic performance, an educational building situated in Kerala, India was considered. The main block is a four storey I shaped building and it consist of three portions, a central portion and left and right straight wing portions. The three portions are to be joined by expansion joints. The storey height is 4.05m. The soil type found at the site is hard laterite so isolated square footings are provided for the columns. Design was carried out as per IS 456:2000 and IS13920:1993 for detailing. The structure analyzed is a four-storied unsymmetrical building frame, constructed with moment resisting frame of reinforced concrete with properties as specified below. The concrete floors are modelled as rigid. The floor plan is same for all floors. The concrete slab is 120 mm thick in each floor level. Author has concluded that the existing building frame used for pushover analysis is seismically safe; because of the performance point base shear is greater than design base shear. Since the demand curve intersects the capacity curve near the elastic range, the structure has a good resistance and high safety against collapse .The behaviour of properly detailed reinforced concrete frame building is adequate as indicated by the intersection of the demand and capacity curves.

Sigmund A. Freeman (2004) reviewed the development of the capacity spectrum method. Author concluded that over the years, PBSM procedures have evolved significantly from their humble beginnings; however, there has been a



push to develop increasingly complex, codified PBSE procedures. In the author's opinion, by codifying PBSD, the very essence of PBSD, i.e. the focus on the attributes and behavior of an individual building, is destroyed. Engineers must be given sufficient latitude to arrive at the best estimate of a building's capacity (Freeman et al., 2004). PBSD can be a useful tool for design and to estimate the performance characteristics of buildings subjected to strong earthquake ground motion. There is no "magic bullet" single procedure. It takes a combination of analytical procedures, data evaluation, judgment, experience and peer review to get a credible approximation of how a building works in the inelastic range of lateral motion (Freeman and Paret, 2000). The CSM stands up well when compared to other PBSD procedures and has the added advantage of giving the engineer the opportunity to visualize the relationship between demand and capacity. Differences between the various methodologies have more to do with unknowns in material behavior and quantification of energy dissipation than in the methods of analysis (Freeman, 1998b). Research on PBSD procedures should be encouraged to close the gap between researchers and practicing structural engineers. There should be more interaction between the researchers and practicing structural engineers to resolve controversial issues and to form consensus.

V.Vysakh, Dr. Bindhu and K.R. Rahul Leslie (2013) studied capacity spectrum method of obtaining performance point through performance based analysis. ATC 40 report published by Applied Technology Council identifies three capacity spectrum procedures A, B and C for determination of performance point. Procedure A is the most direct application of the theory while procedure B is based on the simplifying assumption of constant post yield slope. Procedure C is a purely graphical method that is not convenient for programming. The assumption may introduce some error into the procedure B. The conventional software packages like ETABS, SAP2000 are based on procedure B. They developed a program based on procedure A and comparing the outputs of the developed program and conventional software ETABS. From which they observed that a difference is found in the results obtained from ETABS and the program based on procedure A. ETABS is based on procedure B in which a simplifying assumption that post yield stress remains constant is made. This assumption is concluded to be the source of this difference. They also observed that the variation in spectral acceleration value with respect to ETABS is 7.28% and the corresponding variation in spectral displacement value is 6.25%. A difference of 22 mm is found between the design displacement values between the two procedures in the four storied structure. They conclude that the results from procedure A and procedure B shows minor difference in their values. This variation is negligible for actual design purpose. Hence the conventional software packages based on procedure B is found to be performing satisfactorily.

Objectives of investigation:

1. Generation of three dimensional models of buildings for rigid floor diaphragm idealization to analyze with response spectrum method dynamic using ETABS.
2. Analyzing the displacement of buildings for six Storey (G+5) and eleven Storey (G+10) building cases to permit movement, in order to avoid pounding due to earthquake by Linear Dynamic Analysis.
3. Performing linear static analysis for rigid floor diaphragm idealization for lateral load pattern on the models.

III. METHODOLOGY

For present work seismic analysis is carried out for reinforced concrete moment resisting building frame having (G+10) and (G+5) storey to check final displacement in both buildings to avoid seismic poundings using FEM based software ETABS. The building is modeled by using the finite element software ETABS. The analytical model of the building includes all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of the beams, columns, slab, walls, and foundation. The non-structural elements that do not significantly influence the building behavior are not modeled. Also three models has been made to check behaviour of two closed spaced buildings during seismic loading.

Three models have been considered for the purpose of the study:

1. Eleven storey (G+10) adjacent building with equal floor levels (model-1).
2. Eleven storey (G+10) and adjacent six storey (G+5) building with equal floor levels (model-2).
3. Eleven storey (G+10) and adjacent six storey (G+5) building with unequal floor levels (model-3).

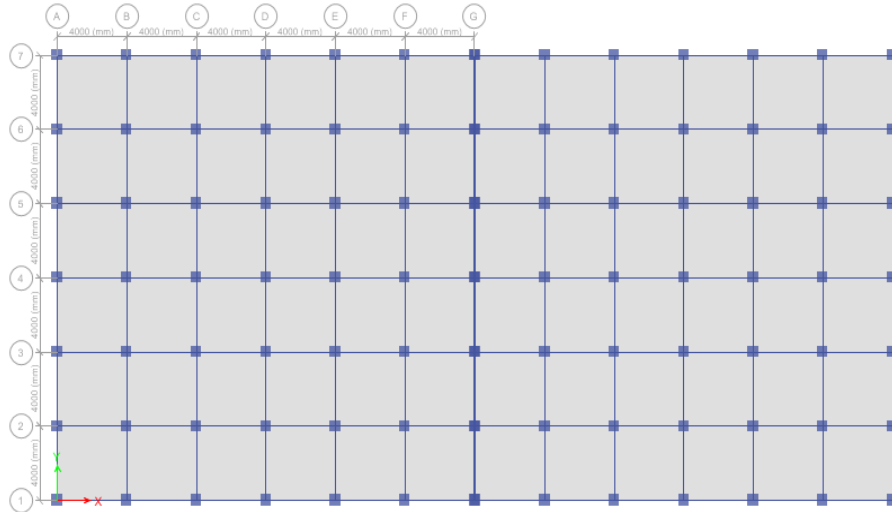


Fig.: -3.1 Plan of the Building in AutoCAD & ETABS

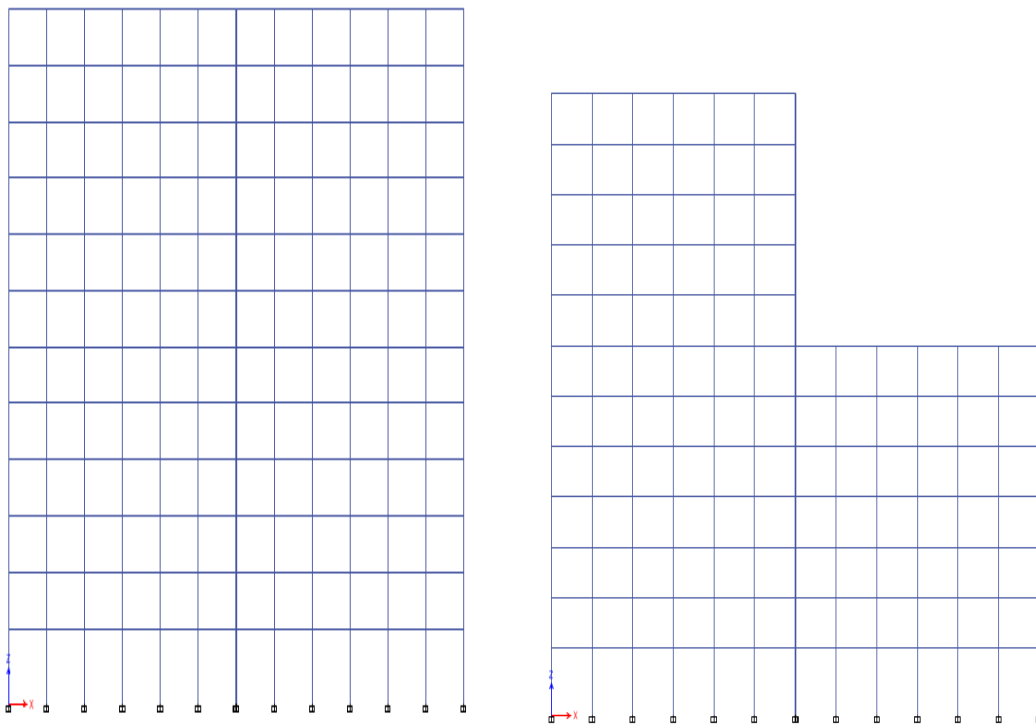


Figure 3.2 Elevation of model-1 considered in ETABS Figure 3.3 Elevation of model-2 considered in ETABS

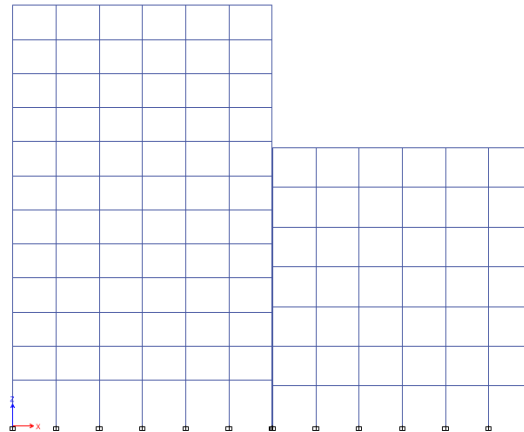


Figure 3.4 Elevation of model-3 considered in ETABS

IV. RESULTS

Seismic performance evaluation is a complex phenomenon as there are several factors affecting the behavior of the building. Response spectrum analysis has been carried in all three models to check lateral displacement of buildings so that length of expansion joint gap can be identified and effect of seismic ponding can be further be calculated.

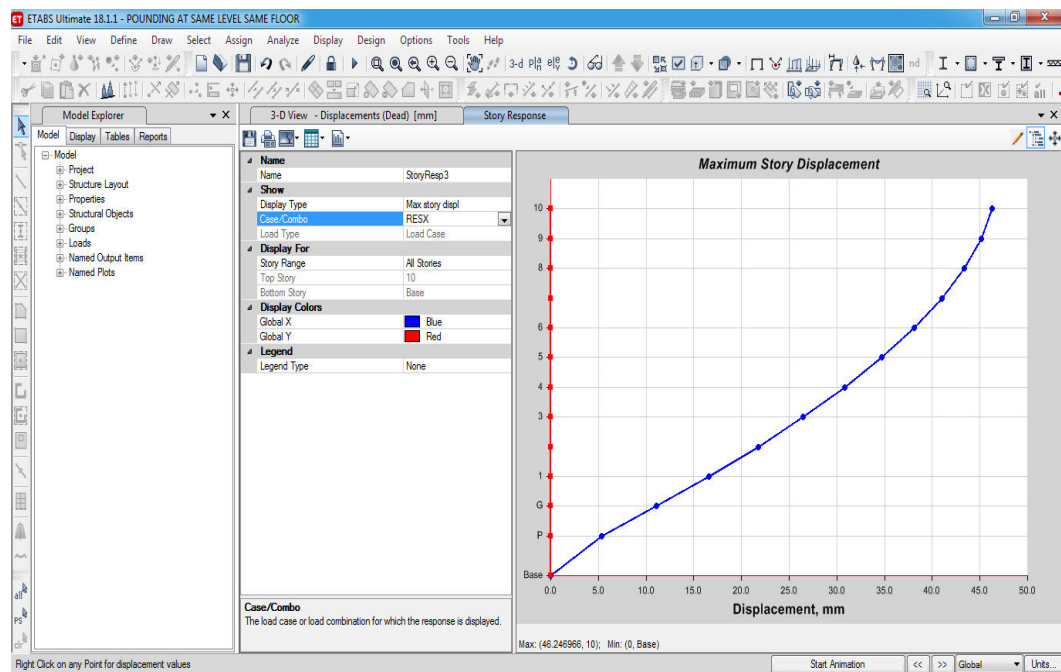


Figure 4.1 Maximum lateral displacement in Model-1 at pounding floors in ETABS

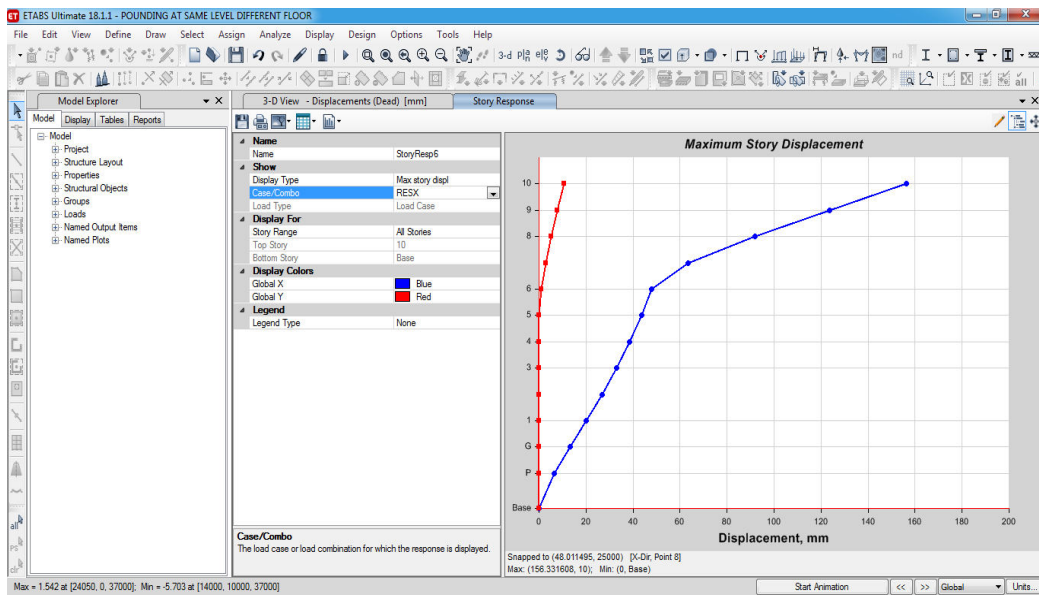


Figure 4.2 Maximum lateral displacement in Model-2 at pounding floors in ETABS

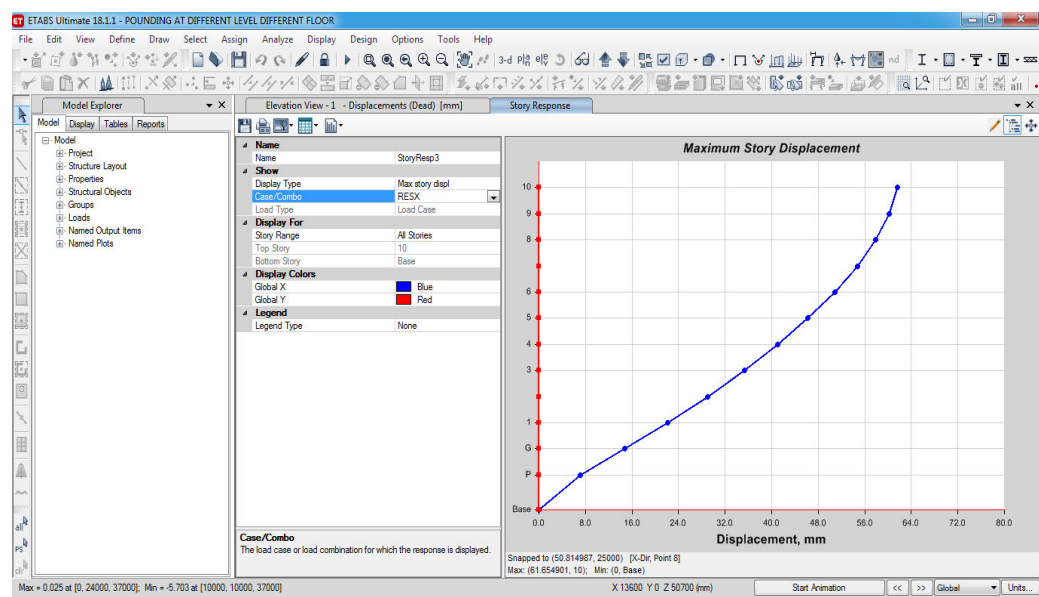


Figure 4.3 Maximum lateral displacement in Model-3 at pounding floors in ETABS

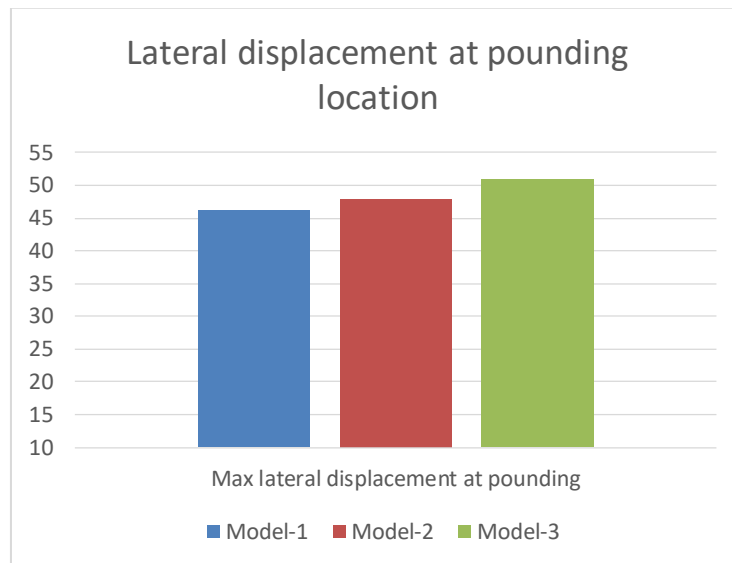


Figure 4.4 Variation of maximum lateral displacement at pounding floors in ETABS

V. CONCLUSION

This paper presents a summary of the present study, for the two closely spaced buildings with varying heights.. On the basis of the results and discussions obtained in this investigation, the following conclusions have been drawn.

1. Response spectrum analysis gives a fair idea about displacements of each floor during the earthquakes.
2. From results, it is found out that the value of story displacement is maximum for model-3 i.e. when heights of building is different as well height of each floor is different.
3. More precautions should be taken when tow building is closely spaced with varying height and varying story height.

VI. FUTURE SCOPE

A lot of research work is taking place in the globe to study the performance of structure due to heavy earthquake loading. Following are the some points for future scope of this study:

1. This study can further be extended for tall buildings.
2. Seismic pounding effect can be studied for varying spacing of buildings.
3. Time history analysis can be applied to study seismic pounding effects.

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