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Seismic Pounding Effect in RCC Building with Varying Height

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ABSTRACT: 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. To estimate the seismic demands, nonlinearities in the structure are to be considered when the structure enters into inelastic range during devastating earthquakes. This paper entitled "Seismic Pounding Effects in Buildings." aims at studying effect of varying seismic gap between adjacent buildings by dynamic analysis in SAP2000. 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. Pounding shear at various story levels that are greater than those obtained from the no pounding case. Also, increasing gap width is likely to be effective when the separation is sufficiently wide practically to eliminate contact.

KEYWORDS: Seismic pounding, dynamic analysis, SAP2000

I. INTRODUCTION

An earthquake is the shaking of the surface of the earth, resulting from the sudden release of energy in the earth's lithosphere that creates seismic waves. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. The seismicity or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. At the earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground. When the epicentre of a large earthquake is located offshore, the seabed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides, and occasionally volcanic activity. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. An earthquake's point of initial rupture is called its focus or hypocentre. The epicentre is the point at ground level directly above the hypocentre. Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools needs to be sharpened for analysing structures under the action of these forces. Adjacent buildings with insufficient separation, having different dynamic characteristics may vibrate out of phase during earthquakes causing pounding between them. The pounding of structures may lead to severe damage and even result in complete collapse.

Interactions between neighbouring, inadequately separated buildings or bridge segments have been repeatedly observed during earthquakes. This phenomenon, often referred to as earthquake-induced structural pounding, may result in substantial damage or even total destruction of colliding structures during severe ground motions. Structural pounding is a complex phenomenon involving plastic deformations at contact points, local cracking or crushing, fracturing due to impact, friction, etc. Forces created by collisions are applied and removed during a short interval of time initiating stress waves, which travel away from the region of contact. The process of energy transfer during impact is highly complicated, which makes the mathematical analysis of this type of problem very difficult. 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 (Kasaiet 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

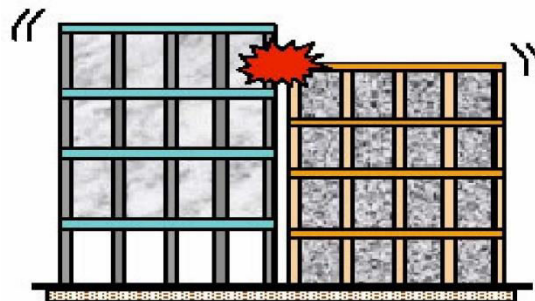


Fig 1.1. Seismic Pounding between Adjacent Buildings.

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.

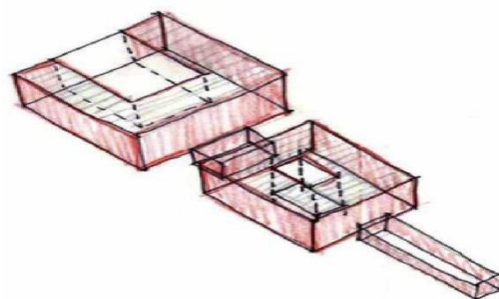


Fig 1.2. A diagram of a Roman house from the first century AD

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

B. K. Raghu Prasad, A. Seetha Ramaiah and A. K. Singh (2004) carried out pushover analysis through capacity spectrum method for structures asymmetric in. They studied the 6 static equations of motion for the two-storey shear building structure is made use of to obtain the column forces. Thus by tracking the yielding of columns, the capacity spectrum is obtained. The capacity spectrum is superimposed on the demand spectra drawn in ADRS format. It is observed that the influence of eccentricity is obtained in the pushover analysis. Thus the formation of hinges based on standard yield criterion for biaxial bending can be tracked, thus leading to capacity diagrams. It was observed that as eccentricity increases the yield level of the whole frame reduces. Such capacity diagrams are juxtaposed on plots of spectral acceleration vs. spectral displacement for various levels of ductility. The points of intersection give the required ductility for the given yield level of the frame, undergoing both rotations and translations.

Dr. S. N. Tande and Reshama M. Karad (2013) studied performance based inelastic seismic analysis of building system. They dealt with detailed discussions on non-linear static analysis methods various structural performance levels of building. Seismic evaluation followed by information about various strengthening techniques for beam and column. The study includes the Pushover Analysis of G+6 storey building located in seismic zone III on a site with medium soil using SAP 2000 with default and user-defined hinges and concluded that model with user-defined hinge properties is more successful for capturing hinging mechanism.

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.



RajkuwarDubal, Gole Neha, Patil G. R, SandipVasanwala and ChetanModhera (2014) studied application of performance based seismic design method to reinforced concrete moment resistant frame with vertical geometric irregularity with soft storey. To study the effect of soft storey we have compared 10 storey frames which was modified into 10 different models by considering soft storey in each storey with conventional and Performance based Seismic design method, we have considered 10 storey models. The basic plan and elevation for all 10 models is kept same. Frames are considered of 12mx12m area. Height of building is 32m.. Basic Dimensions for the frames and general design parameters were taken commonly as. Type of frame: Moment Resistant frame, Size of Column = 500 x 500mm, Size of Beam = 300 x 600 mm, Thickness of Slab = 120mm thick Wall thickness = 150mm, Floor Finish = 1 KN/m², Live load at all floor levels = 2 KN/m², Zone IV, Medium type of soil. From conducting above analysis, they found that Performance point in PBSB and I.S 1893 2002 is near same for all 10 cases .For Soft story to ninth floor varies maximum with 72.08 % increment , Displacement in first model is 0.012m less than conventional model so this elates performance point , Spectral acceleration is greater only in 9th case is increased up to 50% (0.06) in PBSB method and (0.04) in conventional method , Base shear in both methods does not show much difference except in last case .The difference is 600KN, Storey drift for model with ninth floor soft storey is less 0.04mm and largest for storey for which value is 0.4mm for first floor , Roof drift ratio (PBSB: I.S method) for ninth storey is maximum i.e.1 and least for model having soft storey at third floor i.e. 0.857. From the above discussion, they concluded that Performance Based Seismic Design involves distribution of lateral forces according to new distribution factor which is defined on basis of real ground motion. Initial design process includes utilization of optimum sections which sustain the earthquake loads hence iterative trials are avoided and this method proves to be practical than current practice of designing earthquake resistant structures

Shehata E. Abdel Raheem (2006) presented an effort to understand Performance Based Design Approach In this, a five storey symmetrical building is designed using STAAD.Pro and the performance based seismic design is performed by N2 method using a simple computer-based pushover analysis technique using SAP2000, a product of Computers and Structures International. A 3-D model of five storey RCC building has been created using finite element package SAP 2000 to undertake the nonlinear analysis. Beams and columns are modeled as nonlinear frame elements with lumped plasticity at the start and the end of each element. SAP 2000 provides default-hinge properties and recommends PMM hinges for columns and M3 hinges for beams as described in FEMA-356. The procedure compares the capacity of the structure (in the form of a pushover curve) of a MDOF system with the demands on the structure (in the form of inelastic response spectra of a single degree freedom system). The method is formulated in acceleration displacement format. The graphical intersection of the two curves approximates the performance point of the structure. The proposed method is illustrated by finding the seismic performance point for a five storey reinforced concrete framed building located in Zone-IV, symmetrical in plan (designed according to IS 456:2002) subjected to three different PGA levels as input ground motion 0.1g, 0.3g and 0.4g are used as per IS Code 1893: 2002. The elastic response spectra are changed to inelastic response spectra which are taken as seismic input. He also concluded that roof displacements increase as the frame is pushed forward for different PGA levels of earthquake and ductility demand increases as the frame is pushed towards plastic range and ultimately at ∞ demand the structure collapses due to plastic mechanism for different PGA levels.

Objectives of investigation:

1. Generation of three dimensional models of buildings for rigid floor diaphragm idealization to analyze with dynamical analysis using SAP2000.
2. Analysing the impact forces on both buildings for six Storey (G+5) and eleven Storey (G+10) building cases due to pounding effect due to earthquake by.
3. Finalising the methods to reduce pounding effect in closely spaced buildings.

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).

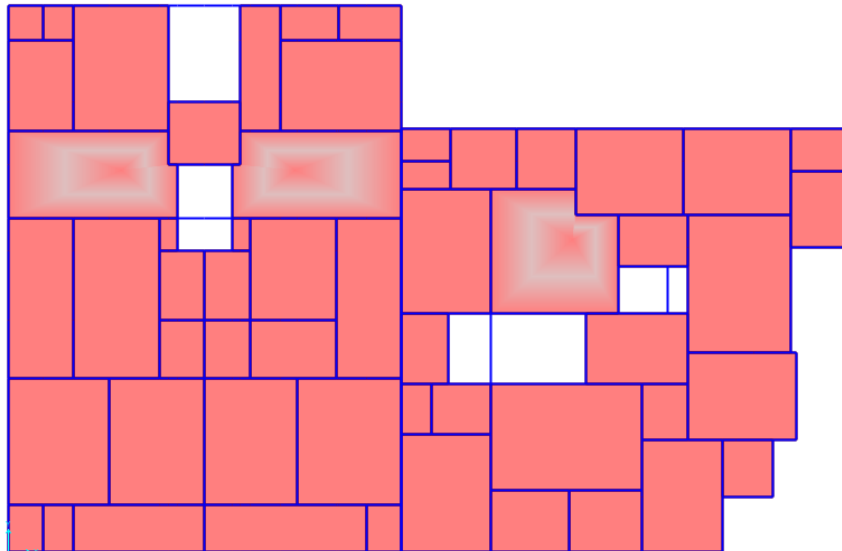


Fig.:-3.1 Plan of the Building inAutoCAD &SAP2000

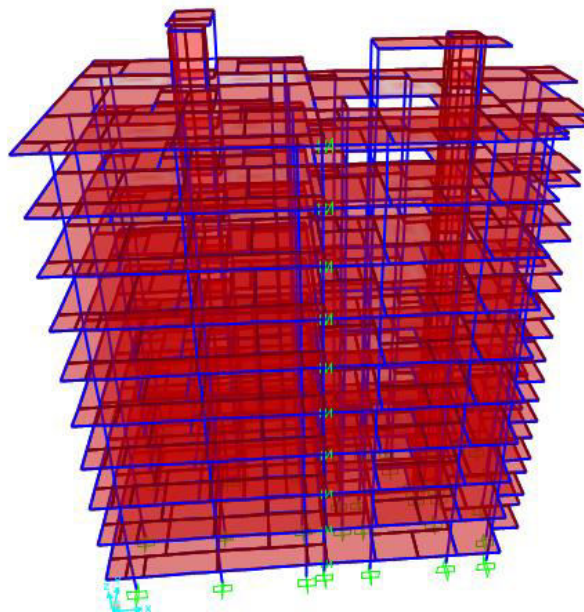


Figure 3.2 3D View of model-1 considered in SAP2000

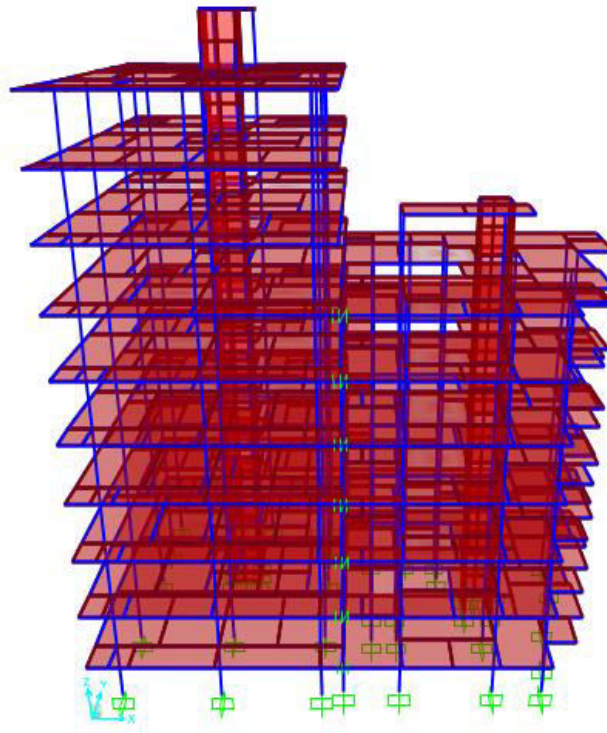


Figure 3.33D View of model-2 considered in SAP2000

IV. RESULTS

Seismic pounding is a complex phenomenon as there are several factors affecting the behavior of the building during pounding. Dynamic analysis has been carried in both models to check lateral impact forces on both buildings so that effect of pounding can be estimated during earthquake.

Table4.1 Maximum Impact forces (in kN) in buildings with change in gap distance between two buildings

	10mm	20mm	30mm	40mm	50mm
Same no of floors	1687	1590	1328	1147	1005
Varying no of floors	1043	885	671	580	463

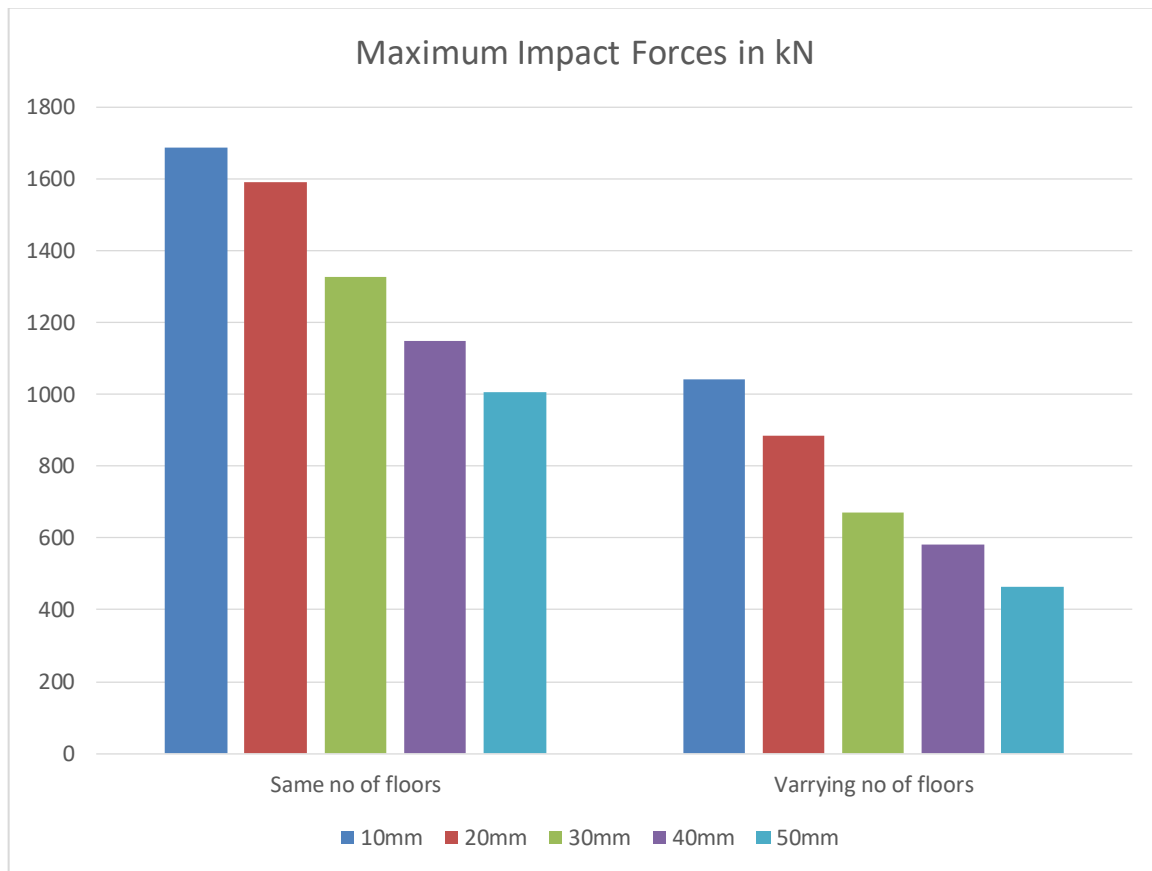


Figure 4.1 Variation of impact forces for change in gap distance between two buildings

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. Gap element analysis in SAP2000 gives a better picture of behaviour of buildings for seismic poundings.
2. From results, it is found out that the value of impact forces reduces with increase in gap distance between two buildings.
3. For two closely spaced buildings with different no of stories impact forces is much more as compared to two closely spaced buildings with same no of floors.

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. Study can be done for performance base design i.e. pushover analysis.
3. Time history analysis can be applied to study seismic pounding effects.

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