IJIRMET ISSN (Online): 2456-0448
International Journal of Innovative Research In Management, Engineering And Technology
Vol. 4, Issue 12, December 2019

STUDY OF SEISMIC POUNDING EFFECT ON TALL BUILDINGS

[1] SWATHY S G NATHAN, [2] BINCY S
[1] M-Tech, Dept. of Civil Engineering, KTU, SJCET, Palai, India.
[2]Asst. Professor, Dept. of Civil Engineering, SJCET, Palai, India.

Abstract : The building structures are vulnerable to severe damages due to strong ground motion. Among the various structural damages, pounding damage is the most serious one. This is the most serious seismic hazard usually occur in highly populated areas during earthquake. Pounding is mainly observed when there is insufficient gap between the adjacent buildings. This scenario mainly is in urban areas where multi-storey buildings are closely occupied due to non-availability of sufficient land or may due to high land value. Hence, it is necessary to study of the effect of pounding on buildings. Here, the dynamic analysis of the effect of pounding on building is studied using the software SAP 2000. Two adjacent RC frame structures are considered for the analysis. Non-linear time history method of dynamic analysis has been used in this study. The effect of pounding on adjacent RC frame structures are studied. Later the effect of shear walls and damper on seismic pounding is studied. The parameters considered for the study are storey displacement, storey drift and shear. The minimum separation distance required is also determined.

Keywords - Pounding, Adjacent building, Mitigation, Seismic gap, SAP2000

I. INTRODUCTION

From the past record, it was found that the greatest source of devastation to mankind is earthquake. It is also found that the building structures have been subjected to greater destructions under strong earthquake excitation. In the present scenario, the main problem faced in urban areas is the lack of sufficient land and also the high value of available land. As a result, sufficient distance cannot be provided between the adjacent buildings, thereby the buildings are closed spaced. These buildings may collide each other under strong earthquake motion causing damages to the structure. This collision of adjacent buildings under the impact of lateral force, mainly earthquake, is called seismic pounding. The simplest method to prevent pounding is to provide minimum separation distance. Two types of pounding damage can occur, which are: (a) Local damage at the point of impact caused by the collision force while, (b) global damage depends on the dynamic properties of both buildings at the time of collision. There are different types of pounding namely, node to node pounding and floor to column pounding. Of these, the latter is found to be more destructive. Hence, it is necessary to accept an efficient structural design to reduce the damages. Pounding is the result of irregular response of the adjacent building of different heights and of different dynamic characteristics. It can also occur when buildings are of same floor level, but the intensity of damage is very less compared to buildings with different floor level.

II. LITERATURE REVIEW

During earthquake, the building sway laterally out of phase, which causes collision of the structure to the adjacent one. This collision between adjacent building structure under seismic load is named as seismic pounding [1]. For conventional design, we usually ignore the effect of pounding. This causes greater damages to the building structure considering the effect of pounding will help in developing more conventional and safe de-sign work in the future.

In order to study the behavior and response of pounding, various studies were conducted. These helps in getting a good perspective about the nature of pounding. Usually pounding is considered to be a non-linear problem. The building of interest will be modelled either as single degree of freedom system (SDOF) or multi degree of freedom system (MDOF) based on the structure type. The pounding effects are simulated using spring dash pot model [3], depending on SDOF or MDOF.

The pounding study is conducted to investigate various parameters. To obtain best results on pounding, detailed parametric studies have been conducted. For which the parameters considered were storey drift, displacement, acceleration, base shear etc. The behavior of pounding can be studied analytically or by experimental set up.

A. Experimental Studies

Experimental studies were also conducted to determine the required separation distance between adjacent building. The study was done using 9 artificial and 6 actual earthquake records. The elastic and inelastic study were conducted using parameters like damping, building height etc. Spectral difference method based on DDC rule was used to determine the separation distance [2]. This method based on response spectrum found to be more accurate than any other methods like ABS or SRSS rule. From this experimental study the significance of damping on pounding effect was determined. It was found that damping

reduces the relative displacement of the structure and also it promotes in phase motion of the building.
Various survey was carried out to determine the intensity of damages incurred on buildings under severe earthquake. One such survey was taken to determine the damage caused under 1989 Loma Prieta earthquake [4]. The damages caused will be classified to four types. From the study, they found that the pounding mainly occurred severely on old buildings without steel or lateral system. Example study was also conducted to determine the intensity on damages caused. They found that the building with the latest design were less damaged.

B. Analytical Studies

From past analytical studies, the dynamic studies were similar by lumped mass system. The torsional effects were ignored for the analysis. Also assumptions were made that the floor levels are same so that the effect of pounding will concentrate on the lumped mass level of the structure. It was found that adjacent buildings with different materials exhibit different hysteretic behavior [6]. Thus, for better simulations of the actual probability of pounding of adjacent structure with different material, different hysteretic loop is being used. The effect of seismic interaction on RC frame structure strengthened with cable elements were estimated using numerical approach. Double discretization with FEM and in time by direct incremental approach [10] is used for the study. From this they concluded that the cable strengthening method is very much effective in reducing the pounding response. Thus, this method can be used for seismic upgrading of the buildings.

III. MODEL STUDY

The main objective of this study is to analyze the effect of pounding on adjacent building under earthquake. Two RC frame structures, one of 16 storey and other of 20 storey have been considered for the study. The gap provided between two building is 85 mm. Gap element of sufficient stiff-ness was used to connect the buildings. Nonlinear time history analysis is carried out in SAP 2000. The base of the structure is assumed to be fixed in order to neglect the soil structure interaction. The geometric properties are given in table below (Table I).

All units are in mm.
TABLE I
GEOMETRIC PROPERTIES OF THE BUILDING MODELS

MODEL	OUTER COLUMN	INNER COLUMN	BEAMS	SLAB
G +15	300 x 500	300 x 650	300 x450	150
G +19	300 x 600	300 x 700	300 x450	160

The stiffness of the link element is assumed to be greater than the stiffness of the buildings. The stiffness of the non-linear gap element used is obtained as 64x106 kN/m, which is calculated using the general equation

The software model of the two buildings drawn in SAP 2000 are represented below (Fig.1).

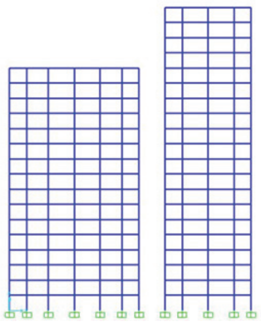


Fig. 1 Model A

The displacement of both buildings at pounding level of model A (Fig.2) are plotted against time scale. In case of model A, the graph is unstable which shows that pounding will cause drastic changes in the behavior of the buildings. The first collision between the two build-

IJIRMET ISSN (Online): 2456-0448
International Journal of Innovative Research In Management, Engineering And Technology
Vol. 4, Issue 12, December 2019

ings at the pounding level occurs at a time of 3.1 sec where the out of phase movement = 89 + 93 = 182 mm > 85 mm. The maximum positive displacement and negative displacement of the buildings at pounding level is at 6.6s and 5.7s respectively.

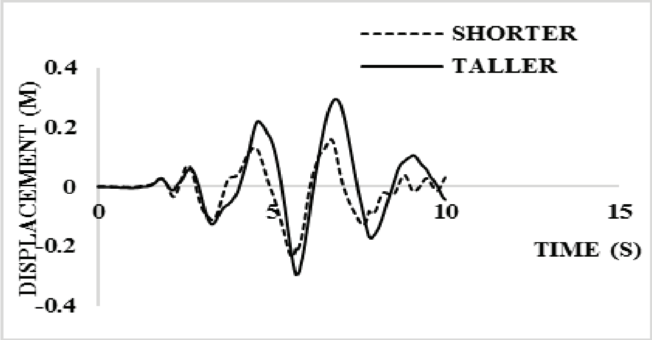


Fig. 2 Displacement – time graph at the pounding level

The pounding force will be the compressive force acting on the gap element, which determines the collision force between the buildings. Here, a force of 21430 kN (Fig.3) is obtained at time of 5.7s where the negative displacement is maximum. The pounding force reveals the intensity of collision. Greater the force, greater will be damages occurring. It is thus necessary to reduce the pounding force to reduce the damages. This has been validated with an adjacent seven and four storey building (Saiful.I, et al., 2012).

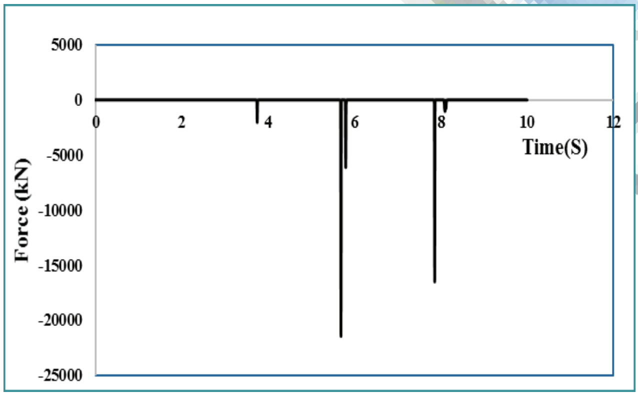


Fig.3 Pounding force at the 16 th storey of model A

A. Minimum Separation Distance

In order to prevent the pounding between the adjacent structures, the simplest method is to provide minimum separation distance between them as per the standard code. Different methods are being used to find the gap distance namely Square Root Sum Square (SRSS) Rule or Absolute Sum (ABS) Rule.

(SRSS)

δ = (ABS)

The Indian Seismic Code IS 1893:2016 gives criteria for providing the sufficient gap. Thereby for adjacent buildings of different floor level, the minimum distance to be provided is given by:

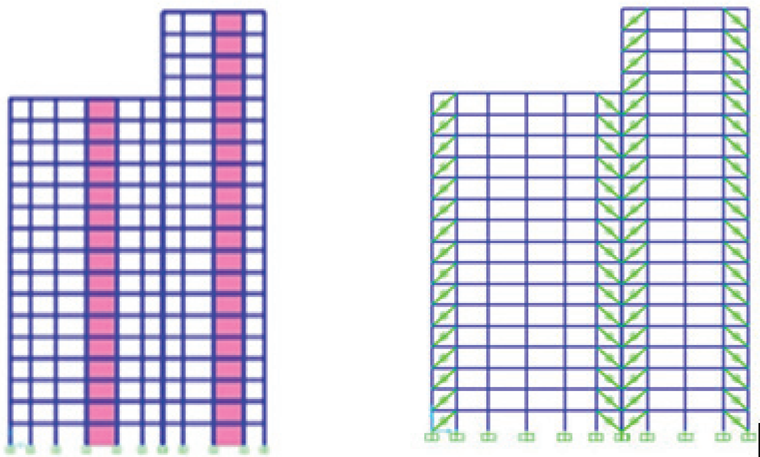
where δ is the separation distance; and are the displacements of the two buildings and R is the response reduction factor.

In this case, the displacement of both the buildings are obtained as 157 mm and 348 mm. Hence, by Indian Code the separation distance to be provided is 2 m. But from SRSS Rule, we get a gap distance of 381 mm which is less than 0.04 times the height of the building. But even when providing a distance of 381 mm between them, there is chance of pounding. Thus in order to prevent the collision or pounding between them and to keep the building safe, we need to provide a safe distance of 2m between the buildings.

IJIRMET ISSN (Online): 2456-0448
International Journal of Innovative Research In Management, Engineering And Technology
Vol. 4, Issue 12, December 2019

B. Effect of Shear wall and Damper

In case of unavailability of sufficient land especially in urban areas, we cannot provide this safe distance of 2m between the building. In that case, other methods can be used to reduce the pounding. To reduce the damages under pounding, the building model have been incorporated with dampers and shear wall as shown in figures below to study its effects on pounding damages. This will improve the stiffness of the whole system, thereby reduces the displacement of the system under pounding. Shear wall of 200 mm thick (Fig.4.a) is provided at the inner core of the adjacent building by keeping the symmetricity of them. Non-linear FVD (Fluid Viscous Damper) (Fig.4.b) is provided as diagonal braces along the edges of the building.



(a) Model B (b) Model C

Fig. 4 Model of building with (a) shear wall (b) damper

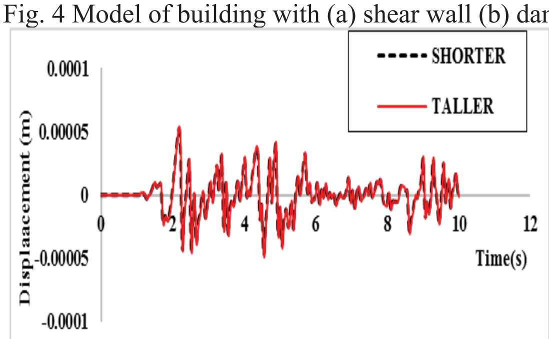


Fig. 5 Displacement graph at the pounding level of model B

The out of phase movement (Fig.5) when provided with shear wall is obtained as 0.106 mm which is less than 85 mm. So, there is no the chance of pounding. The provision of shear wall is effective only when it is provided at the inner core of the buildings. If they are provided at edges or at any other location, there is chance of pounding.

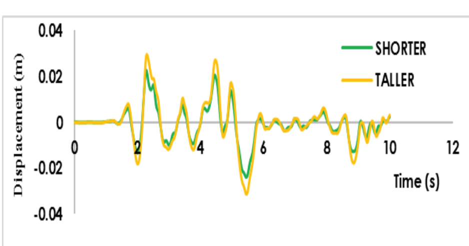


Fig. 6 Displacement graph at the pounding level of model C

The stiffness and damping coefficient of FVD is calculated using the equation , where k and m are the stiffness and mass of the damper, is the damping coefficient. When FVD are provided along the end portion of the two buildings, the out of phase movement (Fig.6) will be obtained 53.9 mm less than 85 mm. These FVD helps in increasing the stiffness of the building and also enhance the energy dissipation property.

IV COMPARISON STUDY

In order to understand the effectiveness of each method proposed above, parameters like displacement, drift and storey shear are used.

TABLE II

DISPLACEMENT AT POUNDING LEVEL

MODEL	DISPLACEMENT (mm)	
	SHORTER	TALLER
A	157	293
B	0.053	0.042
C	16.39	19.59

The displacement of both taller and shorter building are given in Table II. It is clear than the displacement at pounding level has been reduced considerably by using dampers and shear wall. The building become more stiff which helps in preventing the bouncing movement between them. The overall displacement of building is reduced since the shorter building will prevent the further movement of taller building after pounding and also the stiffness of the system increases when the buildings comes in contact.

TABLE III

STOREY DRIFT AT POUNDING LEVEL

MODEL	STOREY DRIFT	
	SHORTER	TALLER
A	0.0051	0.00627
B	0.0000257	0.0000186
C	0.000573	0.000654

Storey drift is the ratio of the difference in displacement of adjacent floor to the storey height. Drift (Table III) also decreases to a large extent. Drift at pounding level is high compared to floors below them. This is due to the fact that the storey shear will be less at that level. Usually drift is less at the bottom storey and increases to the pounding level. Drift shows the relative displacement between the floors. Thus the lesser the drift the building is less displaced and thus it become more safe.

TABLE IV

STOREY SHEAR AT POUNDING LEVEL

MODEL STOREY SHEAR (kN)	SHORTER	TALLER
A	24.5	20.2
B	5.21	4.75
C	8.26	7.75

Storey shear (Table IV) also reduces when providing the braces, dampers and shear wall. This is due to the increase in stiffness of the buildings that makes them less vulnerable to damages. The storey shear is very less when shear wall is provided compared to when FVD is provided. Shear wall become effective only when it is provided at the inner core of the building.

V. CONCLUSIONS

This paper mainly focused on studying the effect of pounding on adjacent buildings and to determine the effect of dampers and shear wall on pounding. It was found that adjacent building will collide with each other when not provided sufficient gap between them. The simplest way to reduce the pounding is to provide sufficient gap between the buildings. In case of unavailability of sufficient land, dampers and shear wall can be used. It shows a massive reduction in displacement under pounding when shear wall and dampers are provided. This reduction in displacement is mainly due to the fact that there will be increase in stiffness of the buildings in addition to the stiffness of the system when it comes in contact under earthquake excitation. Use of shear wall helps in reducing the displacement to 90 percent compared to that of dampers. Shear wall will be effective only when provided at the inner core of both buildings while dampers are provided at the edges to make them effective in reducing the damages. The combination of damper and shear wall at different location can be also used to reduce the pounding effect. The extent with which they reduce the damages can also be studied.

VI. ACKNOWLEGEMENT

The author wishes to express her deepest gratitude to Dr. Fr. Bennet Kuriakose, Asst. Professor, KTU, for giving all his valuable advices and guidance. The author would like to thank Asst. Professor Bincy S, KTU, for all her support and guidance through the whole period of this work and also for the thorough proof reading of this paper. The author also takes this opportunity to thank all her colleagues for their great help for this study

VII. REFERENCES

1. B. Maison, and K. Kasai, Analysis for Type of Structural Pounding, Journal of Structural Engineering,1990.
2. V. Jeng. K. Kasai and A. Jagiasi, The Separation to Avoid Seismic Pounding, Earthquake Engineering,1992.
3. H. Hao, X. Liu, and J. Shen, Pounding Response of Adjacent Buildings Subjected to Spatial Earthquake Ground Ex-citation, Advances in Structural Engineering, 2000.
4. R. Jankowski, Non-linear FEM analysis of earthquake induced pounding between the main building and the stairway tower of Olive View Hospital, Engineering Structures, 2008.
5. P. Komodromos, Simulation of the earthquake-induced pounding of seismically isolated building, Computers and Structures 2009.
6. M. Abdel, and M. Ghouneim, Modelling and analysis of factors affecting seismic pounding of adjacent multi storey building", Earthquake Resistant Engineering Structures, 2009.
7. Y. Huo, and J. Zhang, Effects of Pounding and Skew-ness on Seismic Responses of Typical Multispan Highway Bridges Using the Fragility Function Method, Journal of Bridge Engineering, 2013.
8. M. Licari, S. Sorace, and G. Terenzi, Nonlinear Modeling and Mitigation of Seismic Pounding between RC Frame Buildings, Journal of Earthquake Engineering,2014.
9. F. Rojas, and J. Anderson, Pounding of an 18-Story Building during Recorded Earthquake, Journal of Structural Engineering, ASCE, 2015.
10. M. Abdel, and N. Ahmed, Pounding Mitigation in Buildings using Localized Interconnections, Advances in Structural Engineering and Mechanics, 2017.
11. B. Shrestha, Building Pounding Damages Observed during the 2015 Gorkha Earthquake, Journal of Performance of Constructed Facilities, 2017.