Effect of Earthquake Induced Pounding between Equal Heights Buildings

Digvijay M. Patil [1], V. S. Patil [2]

[1]Student of P.G., M.E. Civil,-Structure Sanjay Ghodawat Institutions, Atigre, Shivaji University, Kolhapur, India
[2]Associate Professor, Civil Engg. Department, Sanjay Ghodawat Institution, Atigre, Shivaji University, Kolhapur, India

---***---

Abstract- *Pounding refers to collision of structures that occurs during earthquake when structures have different dynamic characteristics. The pounding forces can be several times greater than the seismic action effects anticipated by building codes. It can be more dangerous than the effect of earthquake. The main objective of this study to develop Earthquake-induced pounding model of buildings with nonlinear Time history analysis in SAP 2000 software. Also, to study the effect of pounding on seismic performance of buildings with substantially different dynamic properties with addition of shear walls and dampers. Two building having same height (G+7) with different dynamic properties is considered. One building is old building where as second building is new building. With respect to old building, two cases are considered that is building with and without shear wall and dampers. Time history analysis performed on both cases separately. After performing time history on both cases yield pattern, pounding forces, displacement are compared.*

It is observed that in case of building without shear wall and dampers damages, pounding forces, displacement are more than the building with shear wall and dampers. However, in this work the effectiveness of shear walls and dampers as a pounding mitigation measures have been investigated thoroughly

Key Words*: *Pounding, response spectrum analysis, time history analysis, gap element ,shear wall, dampers.

1. INTRODUCTION

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. 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. A 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. 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.

2. SEISMIC INDUCED POUNDING-CASE STUDY ONE

In case of earthquake induced pounding model without shear wall and dampers, two buildings having equal height(G+7). These two buildings have plan dimensions of 16 m × 16 m and bay width of 4 m as shown. Gap between two building is 700 mm Old building is designed for gravity loading. New building is designed by seismic loading. There are many variables in the pounding phenomenon but the two most important parameters namely separation between adjacent buildings and earthquake ground motion time histories have been studied. Table no 1 gives properties of buildings considered for seismic induced pounding for case study one.

Table 1. Properties of buildings considered for Seismic Induced Pounding for case study one

Description	Left Building	Right Building
Building Status	Old	New
Storey Height (m)	3	3
No of stories	8	8
Depth of Footing (m)	2	2
Grade of Concrete	M18.75	M25
Grade of Steel	Fe200	Fe415
Size of Beam(mm)	B230X375	B230X450
Size of Column(mm)	C300X600	C300X900
Thickness of Slab (mm)	150	200
Soil Conditions	Medium	Medium
Response Reduction Factor	5	5
Importance Factor	1	1
Live Load on floors(kn/m2)	2	2
Floor Finish (kn/m2)	1	1
Wall load (kn/m)	11	11
Soft Storey	At Bottom Floor	No
Shear Wall	No	No
Dampers	No	No

2.1 Separation Distance

As per FEMA: 273-1997: Separation distance between adjacent structures shall be less than 4 % height of buildings. Here we provide 700 mm gap between these two buildings.

2.2 Response Spectrum Analysis

The response spectrum analysis is performed for the damping of 5% and IVth seismic zone. The response spectrum analysis is performed to design the sections and then to optimize the design. In response spectrum analysis the structure undergoes to the peak response i.e. maximum response of the structure and the structure is designed to the peak response of the structure. After performing response spectrum analysis, the member optimization has been done and depending upon that column sizes and beam sizes are designed.

After performing response spectrum analysis, the member optimization has been done and depending upon that the designed column sizes and beam sizes with their respective reinforcement in table no. 2 and table no3 respectively for new buildings

Table 2 Column Sizes with their reinforcement

Floor	Column Sizes	Column Reinforcement
1st to 4th	300 mm X 900 MM	12 no of 20 mm Φ
4th t0 6th	300 mm X 900 MM	10 no of 20 mm Φ
6 th to top floor	300 mm X 900 MM	10 no of 16 mm Φ

Table 3 Beam sizes with their reinforcement

	Beam Sizes	Top Reinforcement	Bottom Reinforcement
Beam	230mm X 450 mm	3 no of 12 mm Φ	3 no of 16 mm Φ

2.3 Time History Analysis

The time history analyses (THA) technique represents the most sophisticated method of dynamic analysis for buildings. In this method, the mathematical model of the buildings is subjected to accelerations from earthquake records that represent the expected earthquake at the base of the structure. The method consists of a step-by-step direct integration over a time interval; the equations of motion are solved with the displacements, velocities, and accelerations of the previous step serving as initial functions. Table no 4 gives details of time history consideration for analysis

Table 4 Details of Time History

Load Case Name	Time History
Event	Imperial Valley
Station	El Centro
Year	1979
Analysis Type	Nonlinear
Time History Type	Direct Integration
Geometric Nonlinearity Parameters	None
No of output time steps	7374
Output time step size	0.005
Damping	0.05
Time Integration Parameters method	Hiber –Hughes-Taylor

3 SEISMIC INDUCED POUNDING-CASES STUDY TWO

In case of earthquake induced pounding model without shear wall and dampers, two buildings having equal height(G+7). These two buildings have plan dimensions of 16 m × 16 m and bay width of 4 m. Gap between two building is 700 mm Old building is designed for gravity loading. New building is designed by seismic design Old building is with shear wall and dampers. Shear wall placed at some portion of exterior frame of old building as shown in figure whereas dampers are provided at the top level of old building as shown in figure There are many variables in the pounding phenomenon but the two most important parameters namely separation between adjacent buildings and earthquake ground motion time histories have been studied thoroughly. Figure shows the plan and elevation of buildings considered for case study two. Table no 5 gives properties of buildings considered for seismic induced pounding for case study two.

Table 5 Properties of buildings considered for Seismic Induced Pounding for Case study two

Description	Left Building	Right Building
Building Status	Old	New
Storey Height (m)	3	3
No of stories	8	8
Depth of Footing (m)	2	2
Grade of Concrete	M18.75	M25
Grade of Steel	Fe200	Fe415
Size of Beam(mm)	B230X375	B230X450
Size of Column(mm)	C300X600	C300X900
Thickness of Slab (mm)	150	200
Soil Conditions	Medium	Medium
Response Reduction Factor	5	5
Importance Factor	1	1
Live Load on floors(kn/m2)	2	2
Floor Finish (kn/m2)	1	1
Wall load (kn/m)	11	11
Soft Storey	At Bottom Floor	No
Shear Wall	Yes	No
Dampers	Yes	No

3.1Shear Wall

Shear walls are vertical elements of the horizontal force resisting system. Shear walls should be located on each level of the structure including the crawl space. To form an effective box structure, equal length shear walls should be placed symmetrically on all four exterior walls of the building Shear wall provided to left side of building.

3.2Dampers

Another technique to prevent adjacent structures from interactions during earthquakes is to increase their damping properties through providing supplemental energy dissipation devices Dampers are provided at the top of the building because to avoid functional opening at bottom stories and also avoid minimum damage in the structure. Providing dampers are top of building is more accessible than providing damper at bottom floor. So, it should be provided at top floor of structure

4 RESULT AND DISCUSSION

Time History analysis is performed on earthquake induced pounding model with and without shear wall and dampers in SAP 2000 software. Yield Pattern, pounding forces displacement are obtained.

4.1Yield Pattern

A study of yield pattern of old building frames retrofitted using shear wall and dampers and new building is made. A failure pattern study shows the behaviour of model in inelastic state under the monotonically increased static loads. It is observed that, in case of old building with and without shear wall and dampers, the hinges form in beams firstly and then in columns. When building undergoes time history analysis, it is observed that, in case of building without shear wall and dampers, columns fail earlier than old building with shear wall and dampers. The formation of hinges at performance point are as shown.

4.1.1 At time 5 second (step 1000)

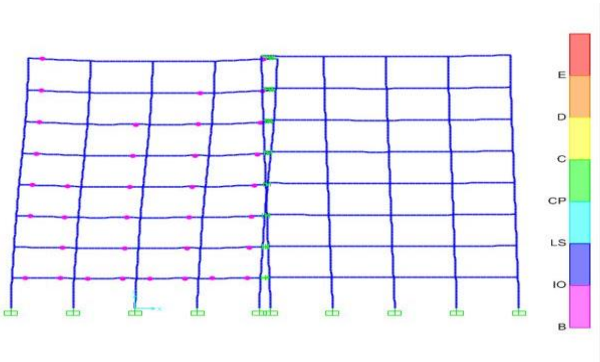

Figure 1 Exterior Frame of pounding model without shear wall and dampers at 5 secs

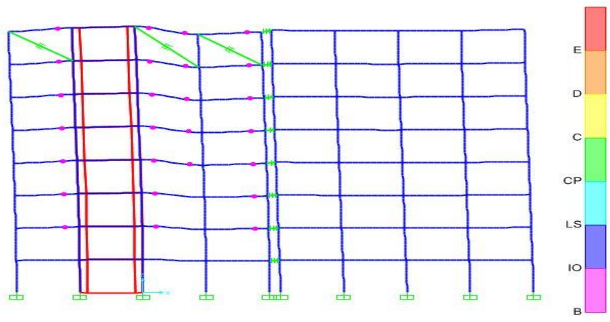

Figure 2 Exterior Frame of pounding model with shear wall and dampers at 5 secs

4.1.2 At time 36.87 second (step 7374)

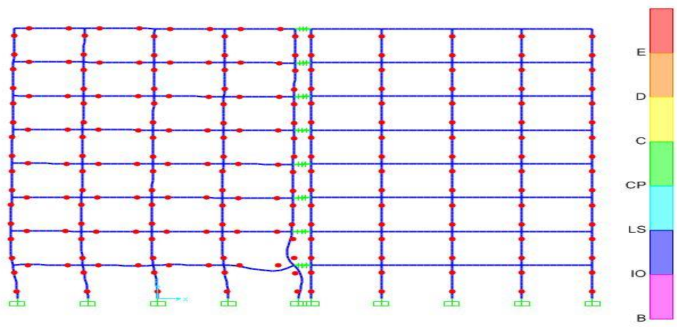

Figure 3 Exterior Frame of pounding model without shear wall and dampers at 36.87 sec

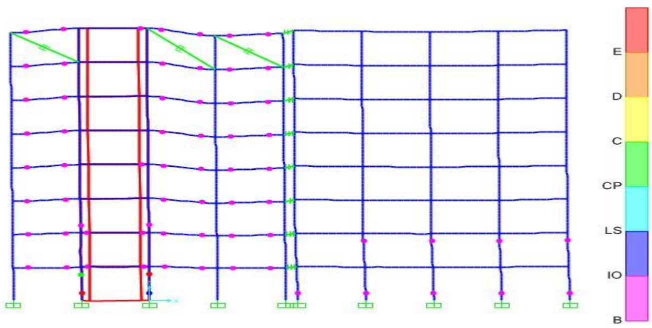

Figure 4 Exterior Frame of pounding model with shear wall and dampers at 36.87 sec

4.2 Pounding Force

In case of pounding forces, it is observed that pounding forces are maximum at top and minimum at bottom in both case that is old building with and without shear wall and dampers. Pounding forces are increases as increase in height of structure in both cases. Pounding forces are maximum at exterior frame of building than interior frame of building and corner frame of building it might be because the effect of impact get distributed among the interior frame.

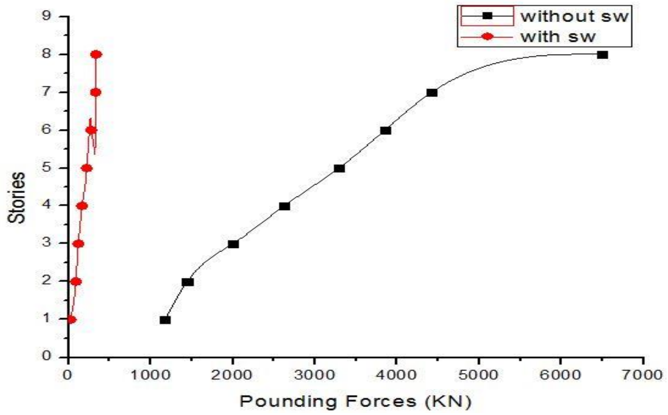

Figure 5 Storiwise Pounding Forces at Exterior Frame of Old Building

4.3 Displacement

In case of displacements it is observed that displacements are maximum at top and minimum at bottom of the columns in both case that is old building with and without shear wall and dampers. Displacements are maximum at exterior frame of building than interior and corner frame of building because as per section pounding forces are maximum at exterior frame of building.

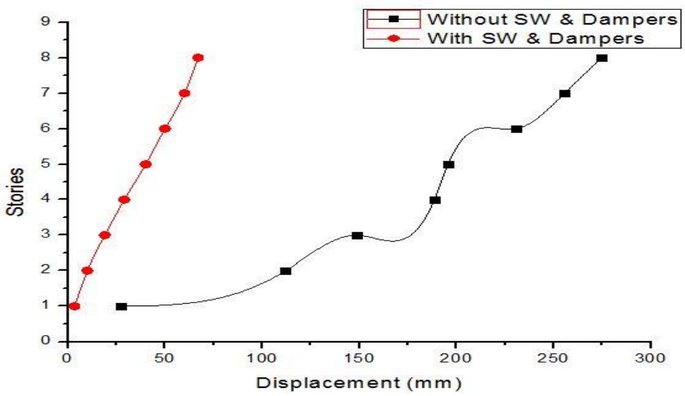

Figure 6 Storiwise Displacement at Exterior Frame of Old Building

5 CONCLUSIONS

A comparative study is made between pounding model with and without shear wall and dampers is studied using SAP 2000 software program.

The following conclusions are made from the parametric study,

1.Damage failure in case of building without shear wall and dampers are more than building with shear wall and dampers.

2. When building undergoes time history analysis, it is observed that, in case of building without shear wall and dampers, columns fail earlier than building with shear wall and dampers.

3. Pounding force in case building without shear wall and dampers are more than building with shear wall and dampers.

5. Displacement in case building without shear wall and dampers are more than building with shear wall and dampers.

6. Pounding forces are increases with increase in height of the structures. Pounding forces is maximum at top floor and minimum at bottom floor in both case that is building with and without shear wall and dampers.

7. Displacements are increases with increase in height of the structures. Displacement is maximum at top floor and minimum at bottom floor in both case that is building with and without shear wall and dampers

8. The shear wall and damper as a pounding mitigation measure avoid pounding altogether by reducing the maximum separation gap beyond which no pounding would occur

9. The Indian code recommended separation gap and separation gap by Absolute Sum Method will avoid pounding between structures to occur.

REFERENCE

1) Agarwal V.K., Niedzwecki J.M., van de Lindtb J.W. (2007) ,"Earthquake induced pounding in friction varying base isolated technique " , Engineering Structures 29(2007) 2825 -2832 .
2) Bharti S.D., Dumne S.M., Shrimali M.K. (2010)," Seismic response analysis of adjacent buildings connected with MR dampers", Engineering Structures 32 (2010) 2122_2133
3) Chitte Chetan J., Jadhav Anand S., Kumavat Hemraj R. (2014), " Seismic pounding between adjacent building structures subjected to near field ground motion " , IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308

4) Jankowski Robert (2008) , " Non-linear Modelling of Earthquake Induced Pounding of Buildings ", ICTAM, 15-21 August 2004, Warsaw, Poland .

5) Khaja Afroz Jamal., Vidyadhara H.S (2014),"Seismic Pounding Of Multistoreyed Buildings " , IJRET : International Journal Of Research in engineering and technology.

6) Madani B. Behnamfar F., Riahi H. Tajmair (2015) , "Dynamic response of structures subjected to pounding

and structure–soil structure interaction" , soil Dynamic sand Earthquake Engineering 78(2015)46–60.

7) Dogan Mizam., Gunaydin Ayten (2009),"POUNDING OF ADJACENT RC BUILDINGS DURING SEISMIC LOADS " , Journal of Engineering and Architecture Faculty of Eskişehir Osmangazi University, Vol: XXII, No:1, 2009

8) Polycarpou Panayiotis C ., Komodromos Petros (2010) , "Earthquake-induced poundings of a seismically isolated building with adjacent structures " , Engineering Structures 32 (2010) 1937_1951.

9) Raheem. Shehata E.Abdel (2006) ,"Seismic Pounding between Adjacent Building Structures " , Electronic Journal of Structural Engineering, 6 (2006) .

10) Shrestha Bipin (2013) , " Effects of separation distance and nonlinearity on pounding response of adjacent structures", Engineering international journal of civil and structural engineering vol 3.

11) Tapashetti Amruta Sadanand., Vijaya S., Swamy B.Shivkumara (2014), "Seismic pounding effect in building ", International Journal of Research in Engineering technology management and applied science .

12) FEMA 440 (2005), "Improvement of nonlinear static seismic analysis procedures", Federal Emergency Management Agency, Washington, DC.

13) FEMA 356 (2000), "Prestandard and commentary for the seismic rehabilitation of buildings", Federal Emergency Management Agency, Washington, DC.

14) IS1893 (Part 1):2002, Indian Standard Criteria for Earthquake Resistant Design of Structures", Part 1: General Provisions and Buildings, Bureau of Indian Standards.

15) Dr. Hosur V., "Earthquake-Resistant Design of Building Structures", Wiley Publications.

16) Nazzal S. Armouti, "Earthquake Engineering Theory and Implementation", International Code Counsil

17) Casarotti C. and Pinho R. (2006), "Seismic response of continuous span bridges through fiber-based finite element analysis", Journal of Earthquake Engineering and Engineering Vibration, 5:1, 119-131.

18) Izzuddin B.(2001), "Conceptual issues in geometrically nonlinear analysis of 3d framed structures",Computer methods in applied mechanics and engineering, vol: 191, pages: 1029-1053, issn: 0045-7825.

19) Papaioannou I. (2005), "Inelastic analysis of Framed Structures Using the Fiber Approach", Proceedings of the 5th GRACM International Congress of Computational Mechanics, Limassol, Cyprus