MID-COLUMN POUNDING EFFECTS ON ADJACENT TALL BUILDINGS AND ITS MITIGATION USING VISCOUS DAMPERS

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Abstract - *Seismologists have shown that, during earthquake, the building structures are vulnerable to severe damages. Among the possible structural damages the seismic induced pounding has been commonly observed phenomenon. Seismic pounding is the phenomenon of collision of two building which are of different dynamic characteristics .It may be much more critical if floors of one building hit at the mid height of columns in the other building (Mid-column pounding). Among the different innovative techniques, which allow to control and modify the seismic response of structures, an important role have assumed for the passive control techniques such as use of Non-Linear Fluid Viscous Dampers(FVD).In this paper, systematic studies regarding the mid-column pounding of regular RC buildings without FVD and with FVD at different locations of the buildings are investigated in ETABS V.16. For performing analysis, nonlinear dynamic time history analysis has applied to structure under El Centro Earthquakes.*

Key Words: *Seismic pounding, Mid-column pounding, Seismic gap, Gap element, Non-linear time history analysis*

1. INTRODUCTION

Adjacent buildings with insufficient separation distance and 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 of the structure. Seismic pounding damage was found between adjacent buildings during the 1985 Mexico, 1994 Northridge, 1995 Kobe, 1999 Kocaeli and 2008 Sichuan earthquakes. Pounding building scenarios can be generally categorized as floor-to-floor and floor to column pounding (mid-column) as shown in Fig.1. Seismic pounding in buildings may lead to increased floor accelerations and concentrated local damages. It could lead to plastic deformation, column shear failure, infill wall damage, local crushing and sometimes the entire collapse of the structure. Adjacent structures with different floor levels are more vulnerable when subjected to seismic pounding due to additional shear forces on the columns . The most effective and simplest way for pounding mitigation is to provide safe separation gap. But in metropolitan cities it is not possible to provide enough separation gaps due to high land value and limited availability of the land. The current research is focusing to evaluate the effects of structural pounding and to determine proper seismic hazard mitigation practice for already existing buildings as well as new buildings. Introduction of stiffeners like RC walls, bracings, dampers etc, is an alternative to the seismic separation gap provision in the structure design.

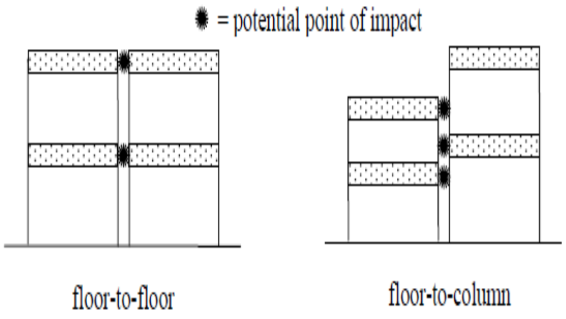


Fig -1: pounding categorization (source: G.L Cole (2010), Ref [15])

2. MITIGATION USING NON-LINEAR FLUID VISCOUS DAMPERS

The current study focuses on fluid viscous dampers shown in Fig. 2.When the fluid viscous damper is subjected to external loads, the piston rod with piston will make reciprocating motion in the cylinder to force the silicone oil filled in it to move back and forth between the two cavities separated by the piston. When the fluid viscous damper strokes in compression, fluid flows from Chamber 2 to Chamber 1. When the fluid viscous damper strokes in tension, fluid flows from Chamber 1 to Chamber 2. The high pressure drop across the annular orifice produces a pressure differential across the piston head, which creates the damping force.

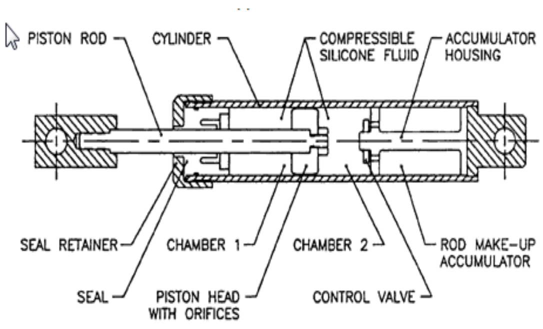


Fig -2: Fluid Viscous Damper

It develops a force which is a function of the relative velocity between its ends. The force/velocity relationship for this kind of damper, can be characterized as

$$F=CV^{\alpha}$$

α is the damping exponent and C is the damping coefficient. For non-linear viscous dampers, α is less than 1.

3. NON-LINEAR TIME HISTORY ANALYSIS

For performing analysis, a set of nonlinear dynamic time history analysis has applied to structure under the ground excitation data of El Centro earthquake. Damping of 5 % is taken for earthquake ground motion. The graph of the El Centro ground motion function is divided into 6000 points of acceleration data equally spaced at 0.002 sec. The accelerograms for ground motions selected for analysis are shown in Fig-3.

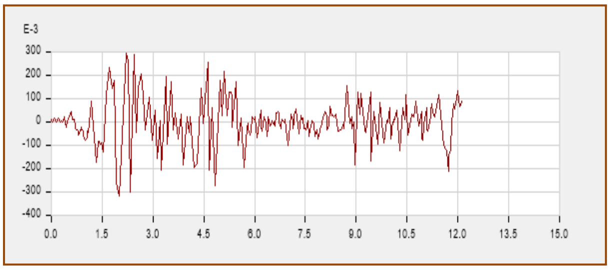


Fig -3: Elcentro EQ Data

4. METHODOLOGY

The selected (G+9) and (G+6) buildings are assumed to be special moment resisting frame located in zone IV in medium soil having a separation gap of 80 mm between bottom four storeys and 115 mm between remaining storeys.It is intended for residential use. Both buildings are analyzed using ETABS v.16 and designed as per IS: 456:2000 [6] .Hertz non-linear spring gap element is used having stiffness of 4.77 x 10^5 KN/m [18] .They are subjected to gravity and dynamic loading. 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. The seismic weight is calculated conforming to IS 1893-2002(part-I) [3]. The unit weight of concrete is taken as 24kN/m^3. The weight of the masonry infill wall of 230 mm thickness is considered as UDL on the beam and also for seismic mass calculation. All columns in the models are assumed to be fixed at the base for simplicity. The height of ground floor for ten storey building is 4.5m and all the upper storey are 3m.The height of ground floor and upper floor of seven storey building is 3m.Slab of ten stories and seven stories are modeled as rigid diaphragm element of 0.14m and 0.13m thickness respectively, for all stories considered. The grade of concrete for column is M-25 and for beam and slab M-20.

Building-1 (G+9) has 3 bays in X and Y directions having width 3.5m and 4.5m respectively. Bottom four storeys of building has column dimension of 300 mm x 750 mm, whereas remaining columns of top six storeys are of 300 mm x 750 mm. The beam size is 300 mm x 475 mm in both the direction. Building-2 (G+6) has 3 bays in X and Y directions having width 3.5m and 4.5m respectively. Bottom four storeys of building has column dimension of 300 mm x 450 mm, whereas remaining top three storeys are of 230 x 450 mm. Beam size is 230 mm x 475 mm in both the direction.

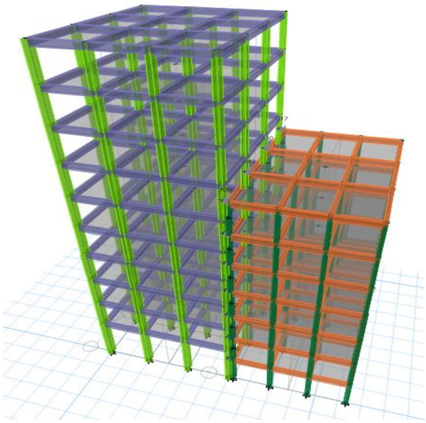


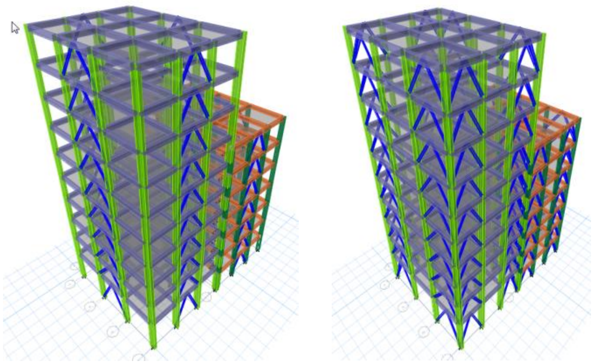
Fig -4: 3D view of G+9 and G+6 storey buildings with gap element

4.1 Introducing Non-Linear Fluid Viscous dampers

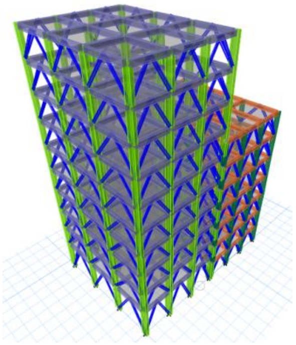
In ETABS v.16, Viscous damper of type Damper-exponential is assigned to the structure in the form of chevron bracings of ISMC 225 throughout the height of the structure in both X and Y direction. They are provided at mid bays, end bays and all outer bays of the buildings. A panel zone is defined at the midpoint of the beam with non-linear link property. The chevron will intersect to the mid-point of the beam where the panel zone is assigned. In the panel zone, the beam-brace connectivity is selected with non-linear behavior in U2 direction for assigning the damper in X direction and U3 for assigning dampers in Y direction.

Properties of viscous damper	G+6 along X direction	G+6 along Y direction	G+9 along X direction	G+9 along Y direction
Direction	U2	U3	U2	U3
Stiffness (KN/m)	350000	350000	250000	250000
Damping (KN*s/m)	750	750	750	750
Damping exponent	0.5	0.5	0.5	0.5

Table -1: Properties of viscous damper along the X and Y direction of both the building



(a) Mid bays (b) End bays



(c)All bays

Fig -5: Viscous dampers at different location of the buildings

5. RESULTS AND DISCUSSION

5.1 Time period

Modal analysis using Ritz method is carried out to obtain the mode shapes and fundamental time period of buildings with and without dampers.

Table -2: Fundamental time period of building

Cases	Fundamental time period in sec
Without dampers	1.902
With FVD at mid bay	1.9
With FVD at end bays	1.897
With FVD at all bays	1.896

Placing VD in the building does not significantly alter its natural period, but it increases the damping effect in buildings.

5.2 Displacement and pounding force

Displacement of both G+9 and G+6 buildings and pounding force generated in link element at pounding level without dampers and with dampers at different locations of the buildings are shown in figures given below

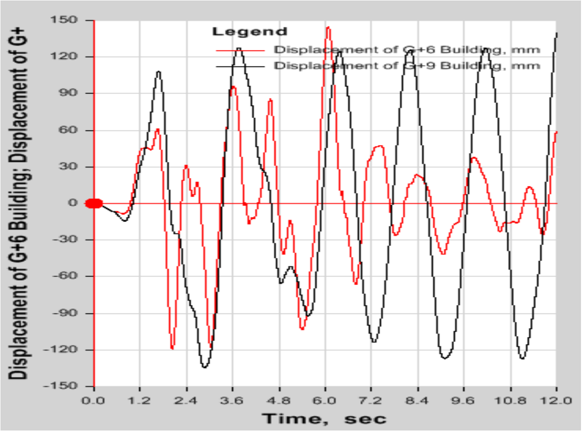


Fig -6: Displacement of buildings without dampers

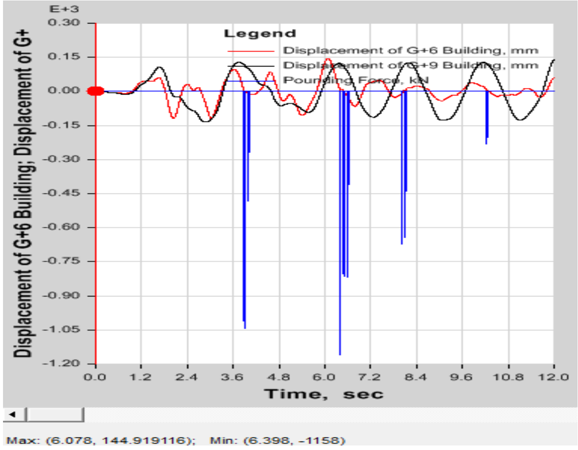


Fig -7: Pounding force without providing dampers

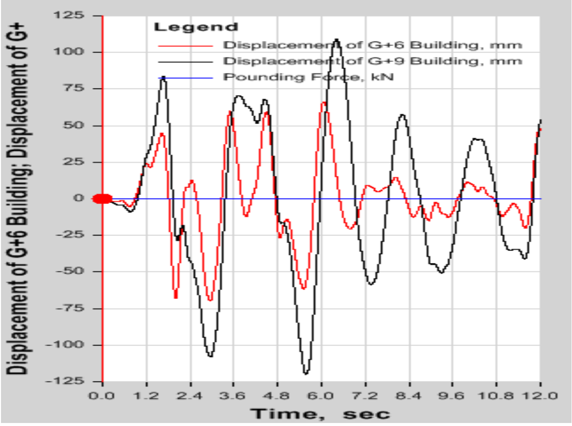


Fig -8: Displacement time history and pounding force of buildings with FVD at outer mid bays

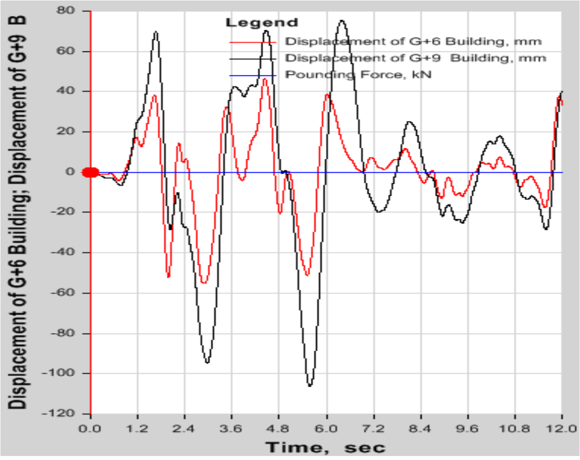


Fig -9: Displacement time history and pounding force of buildings with FVD at outer end bays

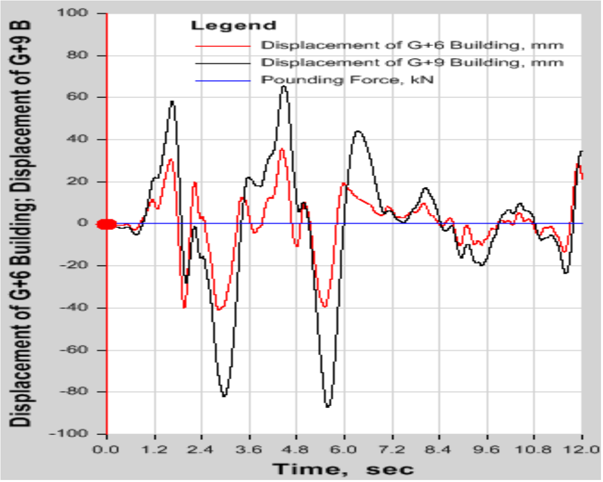


Fig -10: Displacement time history and pounding force of of buildings with FVD at all outer bays

Table -3: Displacement of Buildings with and without dampers

Cases	Displacement in mm			
	G+9 Building		G+6 Building	
	Maximum positive	Maximum negative	Maximum positive	Maximum negative
Without dampers	+140	-134.64	+144.91	-119.29
With FVD at outer mid bays	+108.96	-119.85	+66.16	-69.79
With FVD at outer end bays	+75.36	-106.31	+46.58	-55.15
With FVD at all outer bays	+65.65	-87.35	+35.86	- 41.08

Displacement of buildings is reduced more when FVD is provided at all outer bays of buildings. Displacement of G+9 building is reduced maximum up to 53.1% and displacement of G+6 building is reduced maximum up to 75% by providing FVD at all outer bays.

Table -4: Pounding force and number of impacts with and without dampers

Cases	Pounding force in KN	No. of Impacts
Without dampers	1158	78
With FVD at outer mid bays	0	0
With FVD at outer end bays	0	0
With FVD at all bays	0	0

5.3 Storey response

Storey response plot of G+9 and G+6 buildings with and without dampers at different location of buildings are shown in Fig.16 and Fig.17 respectively.

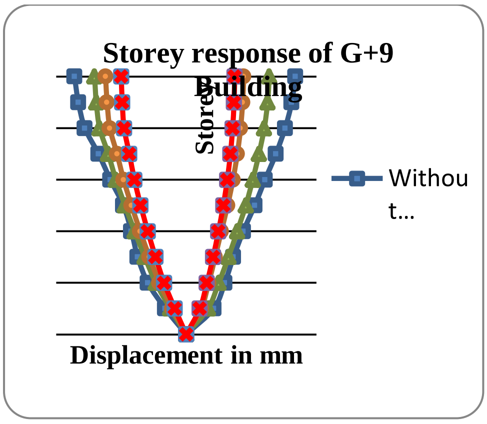


Fig -11: Storey response plot of G+9 Building

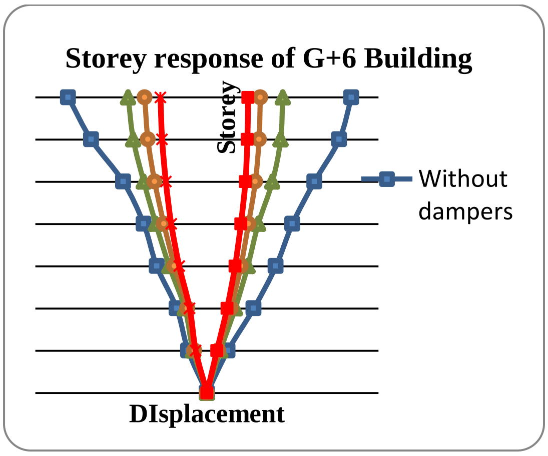


Fig -12: Storey response plot of G+6 Building

6. CONCLUSIONS

Following conclusions are drawn from the current study:

- Time period, displacement, number of impacts, pounding force and storey responses of buildings are more for buildings without dampers.
- Time period, displacement, number of impacts, pounding force and storey responses of buildings are reduced by providing dampers.
- Time period, displacement and storey responses can be reduced more by providing FVD at all outer bays of buildings.
- Pounding force generated at the link element and numbers of impacts are zero for buildings with FVD. So buildings are safe from pounding and collapse
- Buildings with FVD placed at all outer bays are more preferred.
- If economy is considered, buildings with FVD placed at all outer mid bays are also preferred

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