A Comparative Study on the Mitigation of Seismic Response of Two Adjacent Buildings by Using Viscous Dampers Study

C. L. Mahesh Kumar, K. G. Shwetha, and Shadab Khan

Abstract For a long time, the dampers have been used as a method to mitigate earthquake force in structures. These dampers are traditionally provided inside the buildings. Thereby, in this paper, a different approach is being adapted by carrying out a comparative study between two adjacent RCC buildings of fifteen and ten story buildings in which: (i) No dampers are Provided in Buildings (ii) The dampers are being provided between the two buildings, (iii) dampers are being provided inside the buildings. Further, parameters such as variation in base shear and displacement of the buildings are taken under consideration to draw a proper comparison between the above three cases. The results were obtained for the optimized placement of the damper case after carrying out an extensive trial and error process. Results have shown that connecting the adjacent buildings of different fundamental frequencies by these dampers can effectively reduce the earthquake-induced responses of either building. Providing dampers inside the building gave better results than providing the dampers between the buildings.

Keywords Adjacent connected buildings · Viscous dampers · Seismic response · Displacements · Base shear · Mitigation · Lateral forces

1 Introduction

In this paper, two adjacent RCC buildings of fifteen and ten story buildings are considered and dampers are provided in-between them in case 2 and inside the buildings in case 3 as shown in Figs. 2 and 3, in order to reduce the response of

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this structure by dissipating the seismic energy. From the various studies carried out, it was found that providing dampers can effectively reduce the earthquake-induced responses of building [1–4]. And also reduce both drift-sensitive and acceleration-sensitive damage [5]. The study also showed that linking two buildings allows us to reduce the in-between gap size substantially while structural pounding can be still prevented [6]. Further, it was noted that it is not necessary to provide dampers at all floors but lesser dampers at appropriate locations can also significantly reduce the earthquake response.

The dampers are the devices that divert a portion of forces acting on the structures onto themselves and mitigate those forces by vibration, friction, or movement, etc. In this paper, viscous dampers are used, these devices consist of a viscous fluid which is displaced by being forced through a small opening called as orifice, and hence the work is done by using a part of seismic forces which were acting on the structure. The present paper aims at analyzing seismic response of adjacent buildings with and without being connected by viscous dampers by using response spectrum analysis and also the results obtained between the dampers being provided between the buildings and dampers being provided inside the buildings.

2 Methodology

2.1 Details of Buildings

In this paper, E-Tabs 2016 tool is used for modeling the buildings and E-TABS is an analysis and designing software used in the industry. It stands for "extended three-dimensional analysis of building system." E-TABS is a powerful program that can greatly enhance an engineer's analysis and design capabilities for structures. The details of buildings taken for study are shown in Table 1.

As the pounding effect parameter is not considered in this paper, a safe distance of one meter is considered between the adjacent buildings to satisfy the code provision of IS 1893:2016, clause 7.11.1. T1 is the fifteen-story building and T2 is ten-story building and the plan view of considered buildings is as shown in Fig. 1.

2.2 Damper Data

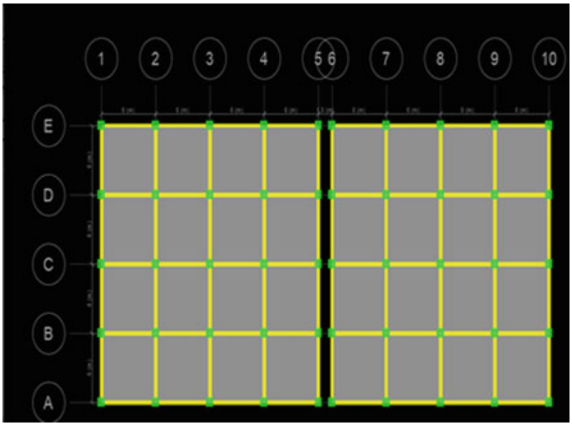
Stiffness coefficient of the damper is calculated by taking lateral load by displacement for each floor, and then finding an average for all those stiffness's. Damping coefficient is found by considering the buildings to be vibrating freely after the initial excitation, thereby using the formula.

$$C = 2 * m * w * \xi \quad (1)$$

where ξ = (zeta) damping ratio = 1 m = mass of each story.

w = natural frequency of the mode shapes.

Fig. 1 Plan view of fifteen and twenty story buildings



Parameter	Value
Average stiffness coefficient	35,932.3 KN/m
Damping coefficient	19,165.91 KNs/m

2.3 *Placement of Dampers*

In the case two of providing dampers in-between the buildings, dampers were provided in an X bracing and iterations such as dampers between all the floors, alternate floors, etc., were carried out and the optimized placement of dampers was determined. It was found that 24 number of dampers were needed to make the building stable based on code criteria. Four dampers were provided each in 10th, 5th, and 3rd storied level. Also six dampers were provided each in 1st and 2nd storied level.

Therefore, 24 dampers were used in case three as well to establish a proper comparison. The dampers were distributed in the two buildings in 3:2 ratio (that is 14 dampers in T1 and 10 dampers in T2 building), based on the adjacent building height ratio. In case 3 as well, variations such as the dampers being provided in the base floor, two dampers being provided in all floors, etc., were carried out and then providing dampers in inverted v shape in alternate floors was selected as it gave the best result (Figs. 2 and 3).

3 Results and Discussion

The following graphs represent the change in the values of base shear and displacement in the following cases.

No damper case.
Dampers provided in-between the adjacent building (external).
Dampers provided inside the buildings (internal).

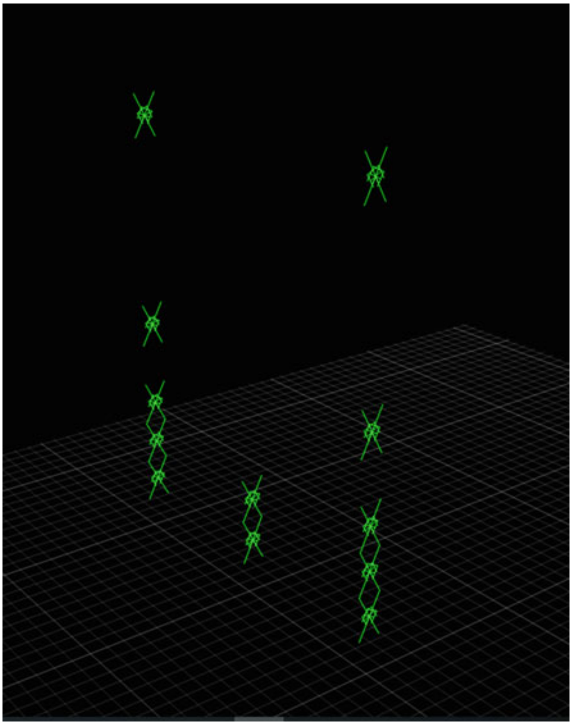


Fig. 2 Dampers provided in-between the buildings (external)

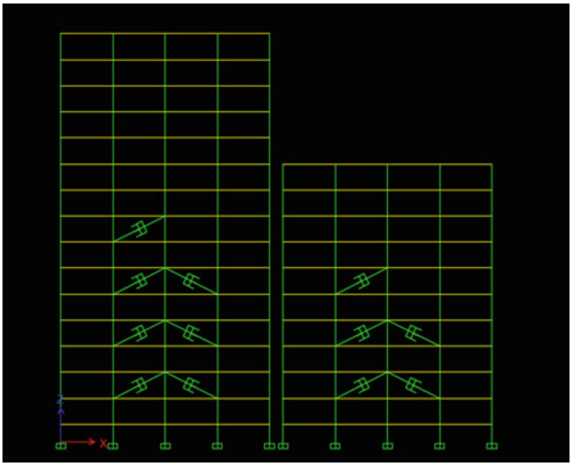


Fig. 3 Dampers provided inside the building (internal)

Fig. 4 Base shear for T1 building

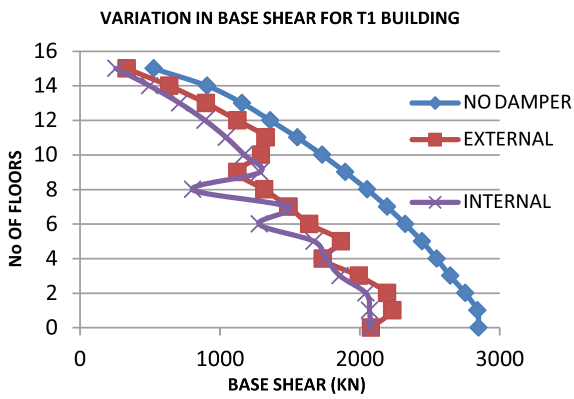
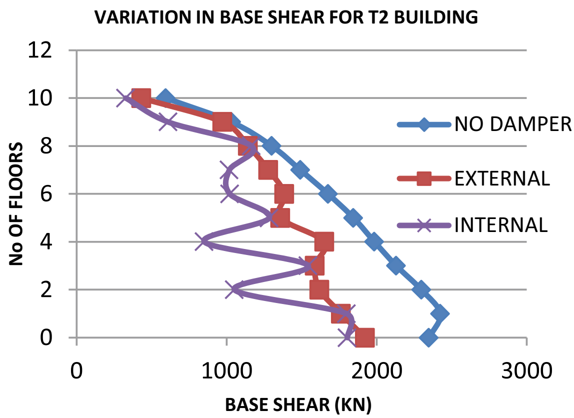


Fig. 5 Base shear for T2 building



3.1 Base Shear

For the T1 building, when compared with no damper case, there is a 26.98% decrease in base shear for case 2, and 27.19% decrease in case 3. For T2 building, when compared with no damper case, there is an 18.17% decrease in base shear for case 2 and 23.19% decrease in case 3. The variations in base shear for T1 and T2 buildings are shown in Figs. 4 and 5.

3.2 Displacements

The displacement value obtained for T1 was 179.27 mm for case 2 and 140.69 mm for case 3. T2 building's displacement value for case 2 was 120.332 mm and for case 3 it was 80.55 mm. For this iteration, the T1 building satisfies the code limitations

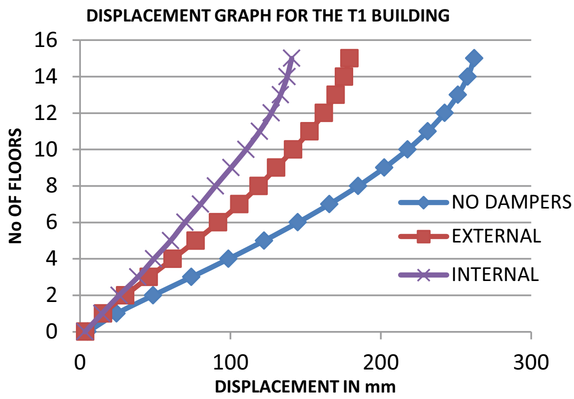


Fig. 6 Displacements for T1 building

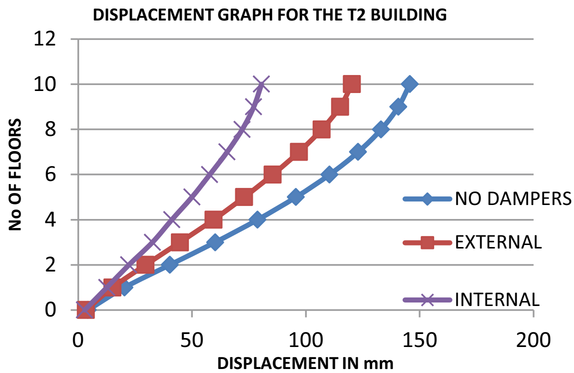


Fig. 7 Displacements for T2 building

of IS code, whereas the T2 building fails in case 2 by a near 0.3 mm value. The variations in displacments for T1 and T2 buildings is shown in Figs. 6 and 7.

3.3 Story Velocity

For the T1 building, when compared with no damper case, there is a 21.52% decrease in story velocity for case 2, and 39.19% decrease in case 3. For T2 building, when compared with no damper case, there is a 35.19% decrease in story velocity for case 2 and 38.12% decrease in case 3. The variations of story velocity for T1 and T2 Buildings are shown in Figs. 8 and 9.

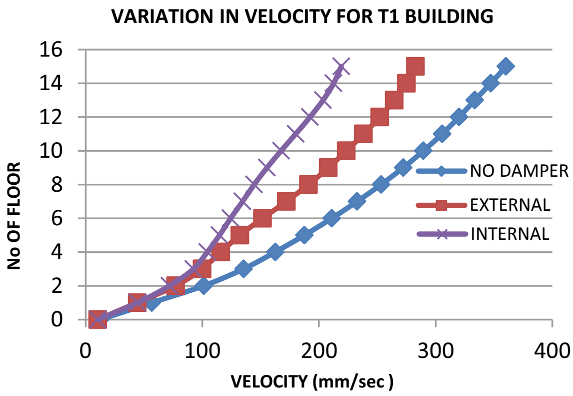


Fig. 8 Story velocity for T1 building

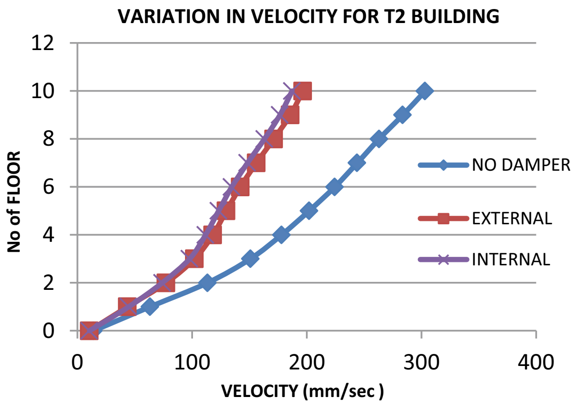


Fig. 9 Story velocity for T2 building

4 Conclusions

From the above graphs, it is clear that dampers provided inside the building give better results than dampers provided in-between the buildings. The results are in agreement with the study carried out that the effects of the viscous damper is lesser on taller building when compared to shorter building [6]. Following inferences can be made from the results above.

(1) The base shear values decrease in both the cases for T1 building and not much variation is noted in the overall reduction which was found to be 27% approximately. For the T2 building, the case 3 gave a 5% more reduction in base shear compared to case 2.

(2) The displacement values decrease in both the iterations, by about 82.93 mm for case 2 and 121.51 mm for case 3 in T1 building and by about 25.38 mm for case 2 and 65.15 mm for case 3 in T2 building.

Table 1 Buildings data

Properties	Values
Structure type	Ordinary moment resisting frame
No. of story	15 story (T1), 10 story (T2)
Typical story height	3 m
Seismic zone	V
Soil	Soft soil
Grade of concrete	M30
Grade of steel (fy)	Fe 500
Slab thickness	175 mm
Column size	500 × 500 mm
Beam size	250 × 500 mm

(3) The story velocity value decreases in both iteration 21.52% for case 2 and 39.19% for case 3 in the T1 building and by about 35.19% in case 2 and 38.12% in case 3 in the T2 building.
(4) We can conclude that dampers provided inside the building give better displacement result than the dampers provided in-between the buildings. But overall base shear was found to be almost the same.

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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