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Investigation of Effective Mitigation Techniques to Avoid Pounding

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Abstract: *The adjacent buildings collide and collapse during moderate to strong ground vibrations cause by earthquakes. Actually, the separation distance of many buildings is an adequate to accommodate their relative motions, so building vibrate out of phase and collapse. Among the possible structural damages the seismic induced pounding has been commonly observed phenomenon.Pounding is one of the main causes of severe building damages in earthquake..While seismic pounding can be prevented by providing adequate safe code specified separation distances, sometimes getting of required safe separations is not possible in metropolitan areas because buildings are built very close to each other due to high land value, limited availability of land space, mitigation of pounding phenomenon may be categorized as improvement in stiffness or by damping. In this study the stiffness improvement measure is studied in detail. The improvement in lateral stiffness of building can be achieved by providing shear walls or by providing diagonal bracing. Both these measures are studied here. In case of unequal heights of the building separated by expansion gap smaller building is naturally stiffer as far as lateral resistance is concerned. The pounding can be effectively controlled using stiffness modification for building, however the stiffness modification using shear wall or bracing are found to be more effective when they are incorporated for the taller building.*

Key words: seismic pounding ,Shear wall, Bracing, Nonlinear time history analysis.

1.INTRODUCTION

The construction industry is growing very fast across the globe as such the demand for the space is increasing day by day. Due to lack of availability of space lots of buildings are constructed very close to each other this leads to a phenomenon called ñSeismic Poundingò.

The pounding means a collision of adjacent building to each other due to insufficient space between the buildings. The two building or a part of the same building is separated by a gap called as expansion gap or seismic gap. If the sufficient gap is provided for the building to cater the seismic displacement demand the gap is categorized as ñSeismic Jointò. If gap is provided only to cater the expansion and contraction of building that gap is called as ñExpansion Jointò. It is always desirable to have seismic joint between two adjacent building or a part of the same building but due to some unavoidable circumstances this may not be possible for all buildings and this leads to seismic pounding.

Pounding of building is a dynamic phenomenon and depends on the many factors such as mass of building, height of building etc. The pound is more critical when the floor height of two adjacent building is unequal because the impact will be at the middle of columns. The pounding can be effectively reduced if the stiffness of building is increased. In this study various measures to reduce the pounding of building is studied and presented.

2. Methodology

Two adjacent buildings are considered to be separated by an expansion gap of 50mm. First building is G+13 and second building is G+8. To demonstrate that the provided gap is only a expansion gap and not a seismic gap an equivalent static analysis is performed on the two building separately to calculate the maximum lateral displacement. The actual seismic gap required as per clause 7.11.3 of IS 1893:2002 is calculated as 877 mm and hence the seismic pounding occurs in the buildings.Pounding is purely dynamic in nature and it is very difficult to actually predict the pounding force which is highly uncertain. The pounding force is dependent on various building properties. To have an better idea of the pounding force the buildings are then subjected to three earthquake ground motion characteristics namely El Centro, Uttarkashi and Chamoli earthquake. The effect of pounding is studied by improving the stiffness of tall building and by smaller building. Here only one building at a time is strengthen and hence the structural systems for the two separated buildings are not same.

Five different models are considered for the study. They are described below

Model I (M1): G+13 and G+8 buildings with separation gap of 50mm. The taller building and smaller building is of bare frame system without any stiffness improvement. This model is considered as bench mark model.

Model II (M2): G+13 and G+8 adjacent building with separation gap of 50mm. The taller building consisting of dual type structural system with shear walls located at periphery of building and smaller building is having bare frame structural system

Model III (M3): G+13 and G+8 adjacent building with separation gap of 50mm. The smaller building consisting of dual type structural system with shear walls located at periphery of building and taller building is having bare frame structural system.

Model IV (M4): G+13 and G+8 adjacent building with separation gap of 50mm. The taller building consisting of braced frame structural system with diagonal ñXò pattern bracing provided at periphery of building and smaller building is having bare frame structural system.

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Model V (M5): G+13 and G+8 adjacent building with separation gap of 50mm. The smaller building consisting of braced frame structural system with diagonal ñXò pattern bracing provided at periphery of building and taller building is having bare frame structural system.

To decide the adequacy of structural members the each of the building is analysed by equivalent static analysis and designed by the EATBS analysis package.

The various load combinations for strength and serviceability used for the design of members are listed bellow.

1. 1.5 (DL + LL + RLL)
2. 1.2 (DL + LL + RLL + EQX)
3. 1.2 (DL + LL + RLL - EQX)
4. 1.2 (DL+ LL + RLL + EQY)
5. 1.2 (DL + LL + RLL - EQY)
6. 0.9DL + 1.5EQY
7. 0.9DL - 1.5EQY
8. 1.5 (DL+ EQX)
9. 1.5 (DL - EQX)
10. 1.5 (DL + EQY)
11. 1.5 (DL - EQY)
12. 0.9DL + 1.5EQX
13. 0.9DL - 1.5EQX

These buildings are then join by GAP element to form the base models as described above. Nonlinear modal time history analysis is performed on the above five models. For the modal analysis Ritzs vector are used. The various parameters such as pounding force at each level, link deformation etc are compared and presented. The seismic data used for the analysis is shown in table 1.

Table 1.Data used for analysis

Response reduction	5
factor	1.5
Importance factor	Medium
Soil condition	230mm
External wall	115mm
Internal wall	200mm
Thickness of shear	18 KN/m^3
wall	25KN/m^3
Unit weight of Brick	150mm
masonry	3.2m
Unit weight of RC	Fe 415
Thickness of slab	M 30
Floor to floor height	1.875 KN/m^2
Grade of steel	3.0 KN/m^2
Grade of concrete	1m
Floor finish	
Live load	SMRF
Height of parapet wall	
Type of frame	

2.1Modeling and Analysis

The three dimensional mathematical model of the building is prepared by using ETABS analysis package. The beams and column are modeled by using two nodded beam element. Being a lateral load analysis slab is modeled using membrane element with 3 DOF at each node. The shear wall is modeled by shell element with 6 DOF at each node. The building gap is modeled by using nonlinear link element with GAP properties. The stiffness of GAP element does not affect the analysis results however it is found from the available literature that the Gap element should be approximately 20 times stiffer than the lateral storey stiffness of stiffer building. The shorter building is considered as stiffer building and stiffness of GAP element is worked out based on the stiffness of shorter building.

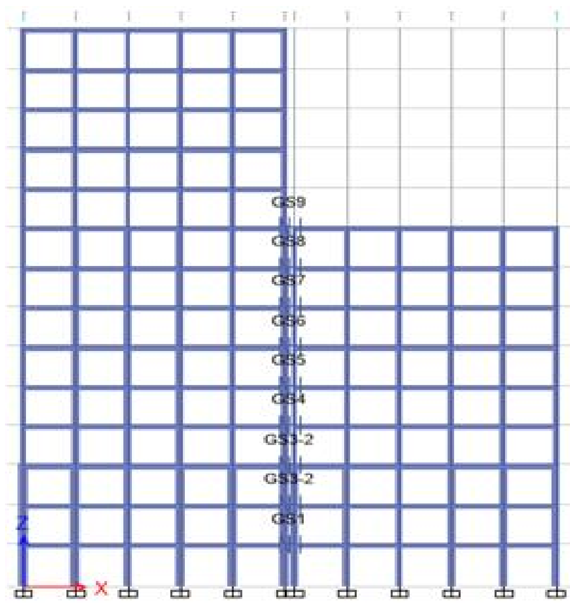

Figure1. Building Mathematical model M1

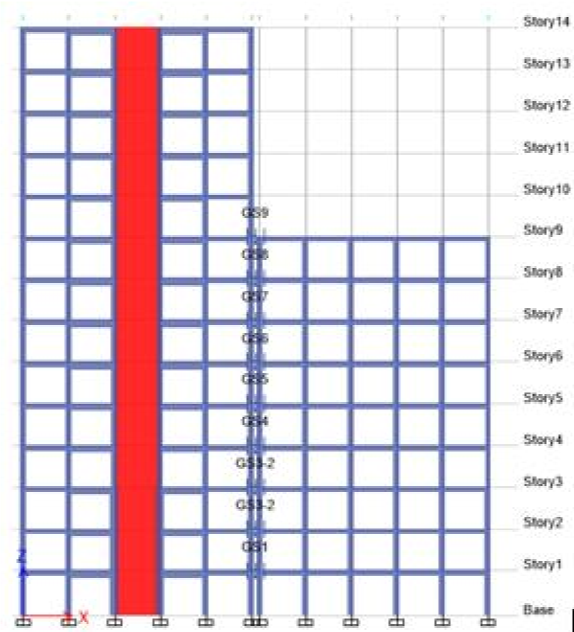

Figure 2. Building Mathematical model M2

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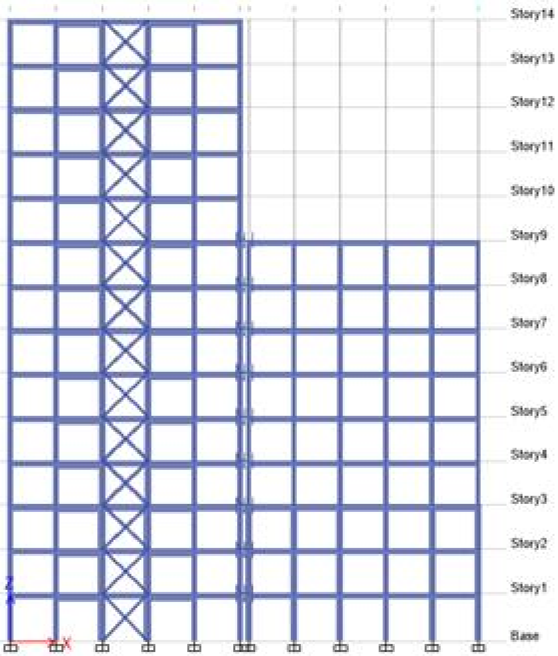
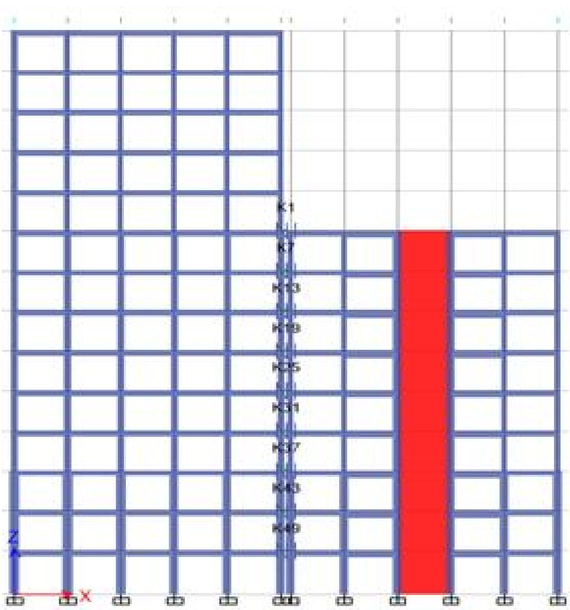


Figure 3. Building Mathematical model M3

Model M4

Figure 4. Building Mathematical model M4



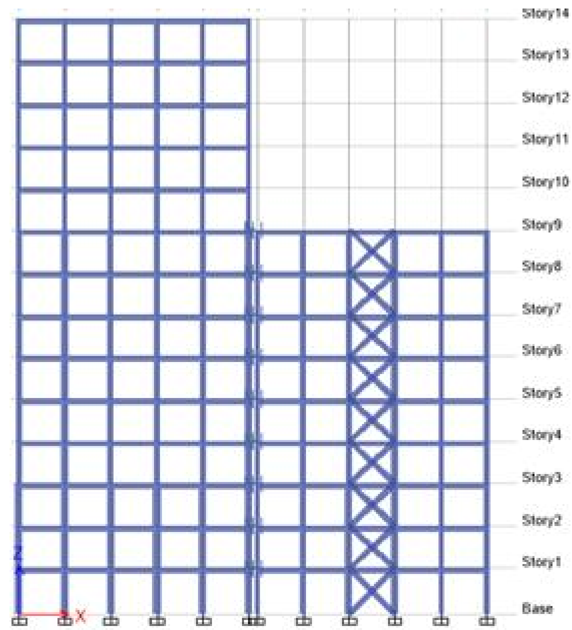


Figure 5. Building Mathematical model M5

2.2 Results And Discussion

The results obtained from the analysis are presented here for different earthquake motions in terms of pounding force.

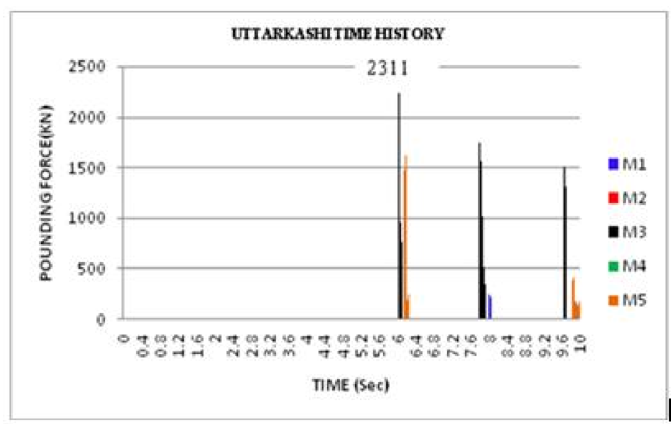


Figure 6 Time history of Pounding force at Roof Level (Uttarkashi)

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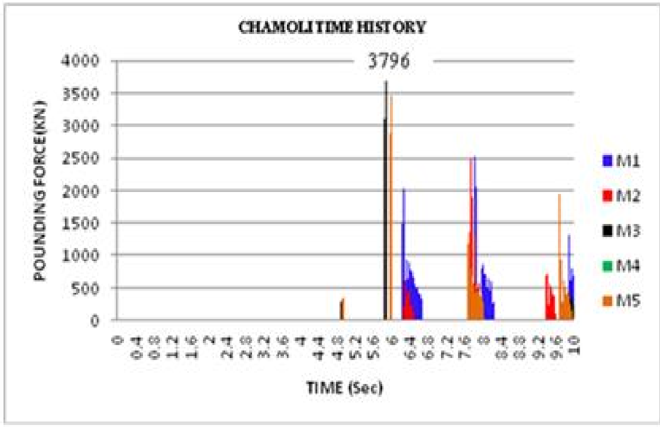


Figure 7 Time history of Pounding force at Roof Level (Chamoli)

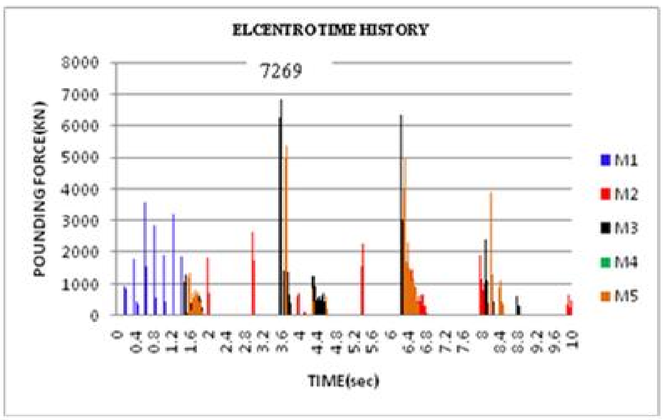


Figure 8 Time history of Pounding force at Roof Level (El Centro)

The maximum pounding force is found for El central earthquake. It is observed that there is no pounding at roof level for model M4. The pounding is a dynamic phenomenon and for model M4 it may occur at some other level of building. The level wise pounding force are presented below.

Figure 9Storey wise maximum Impact force (Uttarkashi)

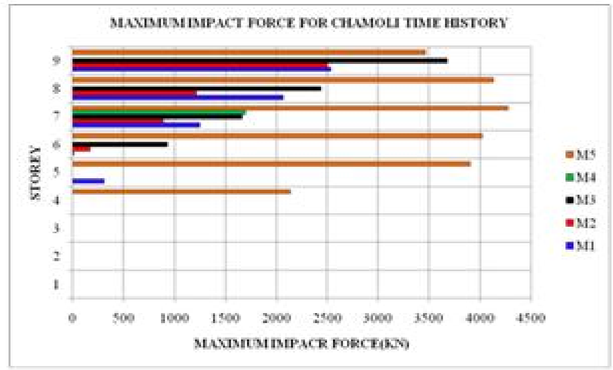
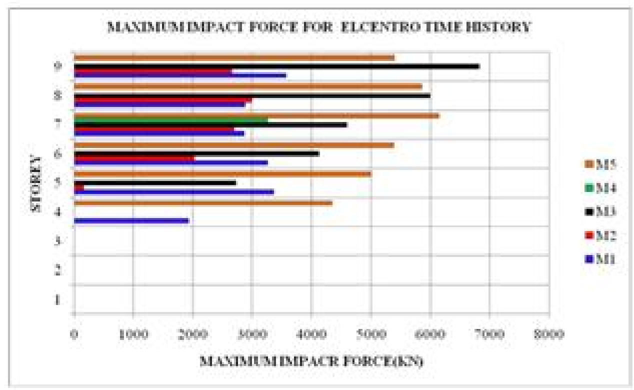


Figure 10Storey wise maximum impact force (Chamoli)

Figure 11Storey wise maximum impact force (El Centro)



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The observations of maximum impact force at different level shows that the impact is very less in model M4 (Bracing to taller building) and found to be maximum in model M3 (Shear wall provided to shorter building).

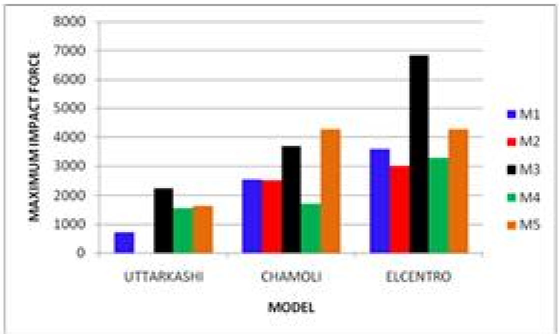

Figure 12 Maximum Impact force

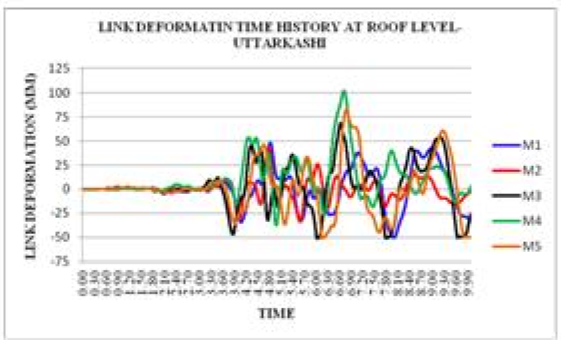

Figure 13 Link Deformation Time History for Uttarkashi (Link ID K3)

By observation of all above results it should be noted that applying the improvement in stiffness to a smaller building will not prove to be efficient as far as pounding force is concern. Maximum Pounding force in model M3 (SW to smaller building) is approximately 2.5 times more than model M2 (SW to taller building) for El Centro earthquake. The El Centro earthquake is more destructive than other two earthquakes. The link deformation in model M1 is observed to be more at initial stages of time and then the deformation is almost negligible. The displacement time history for gap element shows that the maximum negative displacement for any of the time history is limited to 50mm which is actual gap between the building this demonstrate the working of gap element. The gap element is compression only element the displacement over 50mm is transfer in the form of pounding force generated at that level.

CONCLUSION

- The impact force at roof level was found to be minimum in model M2 for uttarkashi and Elcentro time history and in model M4 in chamoli time history. There is 30% reduction in roof level impact force for model M2 compared to model M1(Bench mark model) for Elcentro time history.
- Level wise impact force is minimum in model M2 for all time histories.
- The maximum impact force out of all level shows that zero impact force in Model M2 for uttarkashi earthquake. For chamoli earthquake model M4 has minimum impact force which is around 33% less compared to model M1(Bench mark model). For Elcentro time history model M2 has minimum impact force which is 17% less than model M1.
- Pounding is highly dynamic in nature and it is very difficult to predict exact intensity and magnitude of pounding. It is observed that each time history will give different impact force at different level with different magnitude
- The pounding can be effectively controlled using stiffness modification for building, however the stiffness modification using shear wall or bracing are found to be more effective when they are incorporated for the taller building.

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