Response of Adjacent Building for Seismic Pounding Effect on Bare Frame and Masonry Infill Frame

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Abstract – *The construction of tall buildings is increasing rapidly in all metropolitan cities. Due to this rapid construction, the demand of space for the construction is increasing and parallelly availability of space is decreasing. This leads to construction of buildings without proper space between the buildings. When the strong earthquake vibration strikes the two adjacent buildings or series of buildings which are different in dynamic characteristics and closely spaced, it is expected that they will pound against each other. In this study, the two adjacent towers are modelled and connected by the link element i.e., GAP element which is stiffer than the connected adjacent member in order to study the force, transmitted by the one tower to other. The pounding effect for different framed structures namely bare frame and masonry infill frame are studied at different levels. The pounding effect in bare frame models are studied for the cases that have equal storey height with same number of storeys and equal storey height with unequal number of storey. The pounding effect is evaluated at mid column pounding and at 2/3 height column pounding for these two cases. The same study is extended for masonry infill wall models. The modelling and analysis are carried out using ETABS structural software. Time history analysis was carried out. The parameters that are studied are Pounding force, displacement, and modal time period. The comparison of the results between the bare frame and infill frame are presented in this thesis. In order to achieve the zero-pounding case, the mitigation measures are taken by increasing the lateral stiffness of the towers. Increasing the stiffness of the towers is achieved by providing shear wall at the corners for both the towers. The results of this model are compared with bare frame models and masonry infill models.*

Key Words: *Seismic pounding, Impact force, ETABS 2016, Time history analysis, Masonry wall, Shear wall*

1. INTRODUCTION

The construction of high-rise buildings is tremendously increasing day by day across the globe. This leads to decrease in availability of space for construction and also increase in land value in major cities results in construction of buildings which are too close to each other. This very close construction of adjacent tower of same building or adjacent tower of different building leads to a phenomenon called "Seismic Pounding". The pounding is defined as the collision of adjacent buildings between each other which are different in dynamic characteristics due to insufficient space between them. 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 is a dynamic phenomenon of a building and depends on the many factors such as mass of building, height of building etc. The pounding effect is not critical when the buildings of same Dynamic characteristics i.e., equal number of storey with equal storey height. But the pounding effect is more critical when the two buildings or series of buildings are with different Dynamic characteristics i.e., unequal number of storey with unequal storey height. The pounding can be effectively reduced if the stiffness of building is increased or by the use of various energy dissipation devices. In this thesis, various cases of different dynamic characteristics of bare frame and masonry fames are studied.

2. METHODOLOGY

Two adjacent buildings (tower A and tower B) are considered for the study. The gap between the buildings is 100mm. The plan of tower 1 consists of 5 bays of 6m each in X direction, 4 bays of 6m each in Y direction. The plan of tower 2 consists of 5 bays of 4.5, each in X direction, 4 bays of 6m each in Y direction. Floor height: 3.0 m and Basement Floor height: 3.0 m.

Following are the mathematical models that are prepared and time history analysis is performed on the building. Following are the model cases that are studied in the thesis: -

Case 1: Two bare frame adjacent models with equal number of storey with equal storey height i.e., Tower 1 and Tower 2 of 15 stories
Case 2: Two bare frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories
Case 3: Two bare frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 10 stories and Tower 2 of 15 stories
Case 4: Two bare frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories with mid column pounding

Case 5: Two bare frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories with 2/3 deformable column length pounding
Case 6: Two masonry frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories
Case 7: Two masonry frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories with mid column pounding
Case 8: Two masonry frame adjacent models with unequal number of storey with equal storey height i.e., Tower 1 of 15 stories and Tower 2 of 10 stories with 2/3 deformable column length pounding.

The building will be primarily R.C.C framed structure with columns and beams and floor slabs being used as diaphragms in distribution of lateral forces. The Grade of Concrete in all RCC structural members shall be as follows:

• Concrete grade for column: M 30
• Concrete grade for all slabs and beams: M 25

Table -1: Structural member size of Two towers

Tower	Beam size (mm)	Column size (mm)	Floor slab thickness (mm)	Live load Floor/ Roof (kN/m^2)	Floor finish (kN/m^2)
Tower 1	300X450	450X650	150	3.0 /1.50	1.2
Tower 2	300X450	450X550	150	3.0 /1.50	1.2

The above sizes are worked for the gravity load and a lateral load (Seismic load) and for all design load combinations as per IS 456:2000 for strength and serviceability. The equivalent static earthquake load is calculated based on IS 1893:2002 for the approximate fundamental natural time period of building considering stiffness contribution of infill walls. Then the model is analysed for the Time history data - Imperial valley 5/19/40 0439, El Centro Array #9, 180 (USGS station 117) to find the impact force.

3. STIFFNESS OF LINK ELEMENT

The building gap is modelled 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 may be worked out based on the stiffness of shorter building. These buildings are then joined by GAP element to form the base models as described above. Nonlinear modal time history analysis is performed on the models. For the modal analysis Ritz vector are used.

4. MODELS

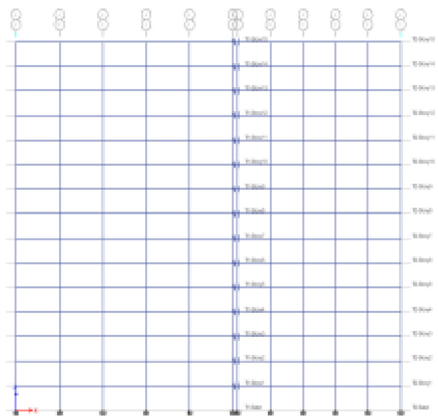


Figure -1 Case 1

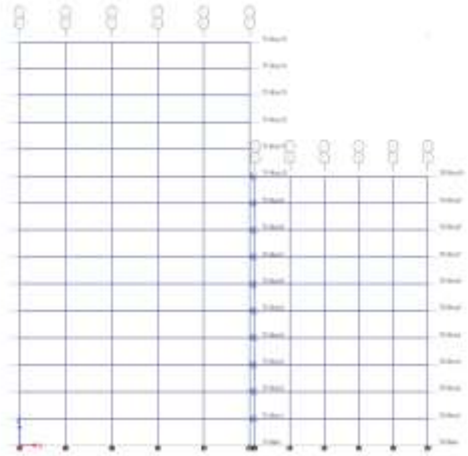


Figure -2 Case 2

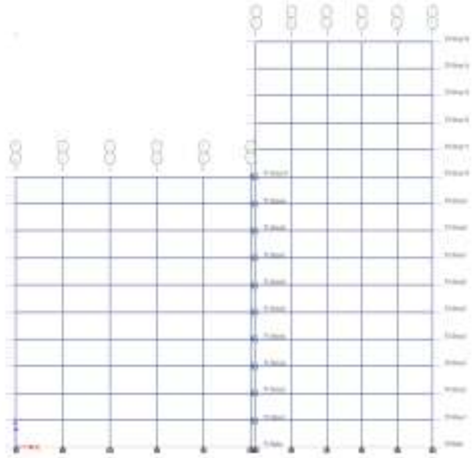


Figure -3 Case 3

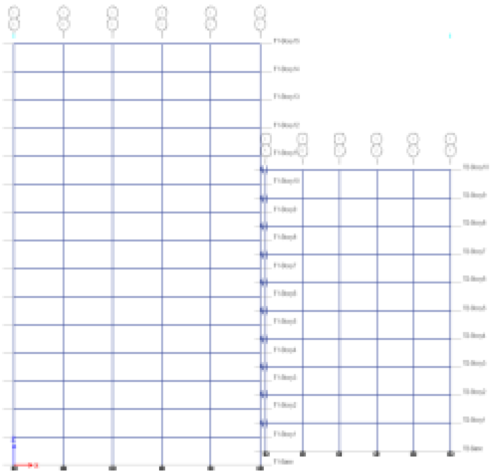


Figure -4 Case 4

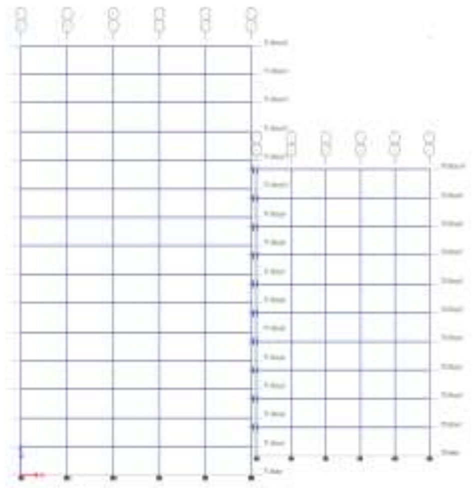


Figure -5 Case 5

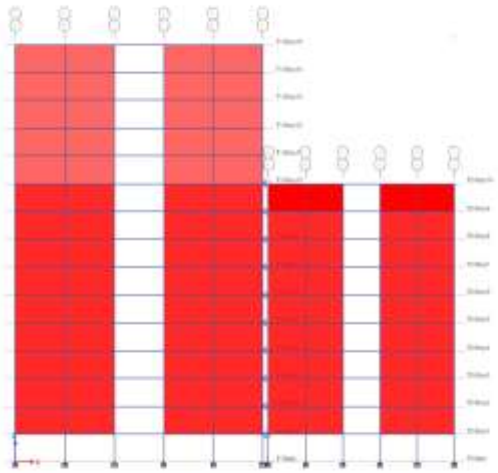


Figure -6 Case 6

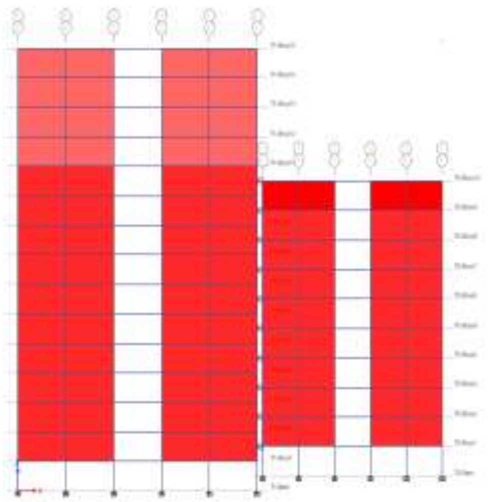


Figure -7 Case 7

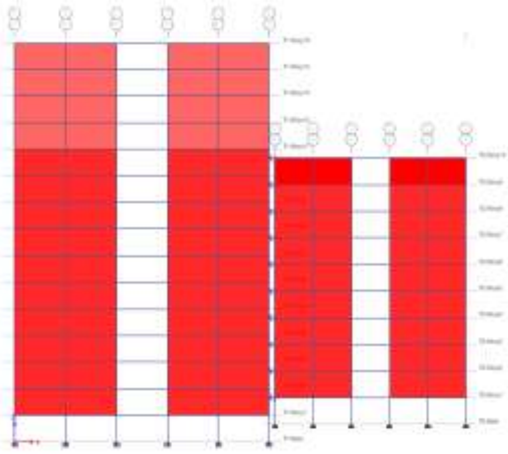


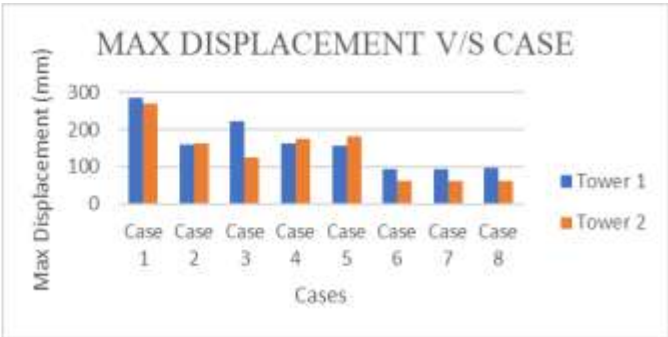
Figure -8 Case 8

5. RESULTS

The result of seismic pounding effect for above shown model is tabulated below. Tower wise max displacement, Impact force and modal time period was shown below.

Table -2: Displacement results

Case	Max displacement (mm)		Additional gap required between the towers as against the assumed value
	Tower 1	Tower 2	
Case 1	284.734	269.229	(284.734+269.229)-100 =453.963mm
Case 2	159.092	161.77	(159.092+161.77)-100 = 220.862mm
Case 3	221.723	122.966	(221.723+122.966)-100 =244.689mm
Case 4	163.063	175.878	(163.063+175.875)-100 =238.941mm
Case 5	157.392	180.779	(157.392+180.779)-100 =238.171mm
Case 6	94.476	61.247	(94.476+61.247)-100 = 55.723mm
Case 7	94.462	61.247	(94.462+61.247)-100 = 55.709mm
Case 8	95.565	61.665	(95.565+61.665)-100 = 57.23mm



Graph-1 Max displacement V/S Case

Table -3: Max Pounding force results

Case	Max Pounding force (kN)
Case 1	1961.7335
Case 2	4439.0635
Case 3	3569.2584
Case 4	4695.5436
Case 5	4819.5739
Case 6	783.3059
Case 7	1125.5591
Case 8	1269.7559

Graph-2 Max Pounding force V/S Case

Table -4: Modal Time period results

Case	Tower 1 (Sec)	Tower 2 (Sec)
Case 1	3.266	2.978
Case 2	3.266	1.95
Case 3	2.135	2.978
Case 4	3.266	1.95
Case 5	3.266	1.95
Case 6	0.968	0.625
Case 7	0.968	0.625
Case 8	0.968	0.625

6. MITIGATION MEASURE (Case 9)

From the results of case 8, the pounding force and displacement is reduced compared to case 5. Again, in order to reduce the pounding force and displacement, the mitigation measure is taken to case 8 by providing the shear wall of 200mm at the corners. Comparison of Case 8 and Case 9 results are shown below

Table -5: Comparison of Displacement result

Case	Tower 1 (mm)	Tower 2 (mm)
Case 8	95.565	61.665
Case 9	66.836	74.553

Graph-3 Comparison of Displacement result

Table -6: Comparison of Pounding force result

Case	Pounding force (kN)
Case 8	1269.7559
Case 9	0

Table -6: Comparison of Modal time result

Case	Tower 1 (Sec)	Tower 2 (Sec)
Case 8	0.968	0.625
Case 9	0.857	0.575

7. CONCLUSIONS

Pounding is highly unpredictable and dynamic phenomenon. In this thesis efforts are made to study some of the factors influencing the pounding forces such as gap between the adjacent building, mass of buildings and level difference between the buildings. One of the mitigation techniques for avoiding pounding by improvement in stiffness is also studied in detail. The major conclusions obtained from the study are enlisted here

•It is always important and recommended to provide sufficient gap between the adjacent buildings. The safe gap between the buildings should be properly calculated as per the codal provision.

•From the analysis result we can see that the pounding force is increased from M1 to M2, from M2 to M4, and from M4 to M5 in bare frame models.

•The pounding force occurring at 2/3 deformable column length for model M5 is found to be maximum compared to all other cases in bare frame.

•The pounding force in the masonry frame is reduced compared to the respective bare frame models because of increase in lateral stiffness.

•For M9 model the shear walls at corners is considered in addition to masonry wall. The lateral stiffness is further enhanced due to the introduction of shear wall as compared to M8 model.

•The pounding force is found to be zero in M9 model. The pounding can be effectively controlled by suitably modifying the stiffness of the building. However, the stiffness modification using shear wall are found to be more effective when they are incorporated for the taller building. The decrease in the impact force is observed in the mitigation model (M9) due to increase in the lateral stiffness and reduction in the displacement result due to shear wall.

•From the analysis, the modal time period of the models decreases as the stiffness of the model increases.

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