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POUNDING DAMAGES OF ADJACENT BUILDING DURING EARTHQUAKE

Atul S.Kurzekar , Rajiv Pazare, Mayuri Chandak

Faculty of P.I.E.T Engineering College, Nagpur University, India.

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Corresponding Author

Mr. Atul S. Kurzekar

Abstract

Pounding between adjacent structures is commonly observed phenomenon during earthquakes. In metropolitan areas, due to increasing population and land values buildings have been constructed very close to each other, therefore there is a need to investigate this phenomenon. This paper begins with a general study on the effect of pounding and some measures to reduce the damaging effects of pounding and the final part of paper explains the minimum seismic gap between buildings for rigid floor diaphragm idealizations by response spectrum and time history analysis using sap2000.

INTRODUCTION

During past earthquakes many buildings were damaged due to failure of structural and geotechnical components. Among structural failure components, damage due to seismic pounding (i.e. collisions between adjacent structures due to earthquakes) has been frequently observed in past earthquakes. During 2007 Niigata Chuetsu-Oki Japan Earthquake pounding damage was observed to school buildings. This type of damage had occurred when slab levels of adjacent structures were located at different elevations. figure 1. illustrated that pounding occurred between two – three storey structures during Wenchuan earthquake in 2008. Due to insufficient separation distance, two storey structure was colliding with existing three storey structure. Figure 2. illustrated that pounding occurred between an old and new buildings during L'Aquila earthquake in 2009. There would be slight damage to new structure. Figure3. Illustrated 2011 Sikkim earthquake (near India-Nepal border).

Structural pounding damage in structures can arise from the following: (1) Adjacent buildings with the same heights and the same floor levels (2) Same floor levels but with different heights (3) Different total height and with different floor levels (4) Structures are situated in a row (5) Structures having different dynamic characteristics (6) Pounding occurred at the unsupported part (e.g., mid-height) of column or wall resulting in severe pounding damage. (7) Buildings having irregular lateral load resisting systems in plan rotate during an earthquake, and due to the torsional rotations, pounding occurs near the building periphery against the adjacent buildings. Among all the causes for structural pounding damage, the most effective way to mitigate and reduce the damage of structures from pounding is to provide minimum separation distance between the adjacent structures. So, it is essentially very important to study the pounding of buildings during earthquakes not only for safety but also to establish appropriate design guidelines.

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Fig 1 Pounding Occurred Between Two & Three Storey Structures during 12 DEC. 2008, Wenchuan Earthquake

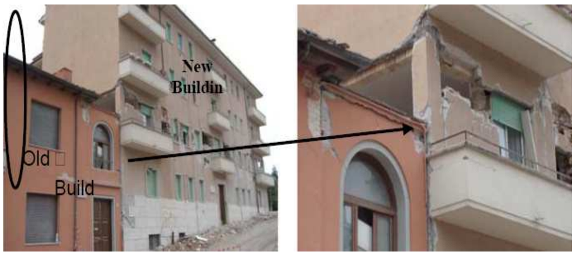

Fig 2. Pounding Between New & Old Building During 6 April 2009, Aquila Earthquake.

Fig.3. 2011 Sikkim Earthquake (near India-Nepal border)

Seismic Pounding Effect between Buildings

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. Seismic pounding between two adjacent buildings occur an earthquake, different dynamic characteristics, adjustment building vibrate out of phase, at rest separation is insufficient.

Fig. 4. Pounding Damages of Adjacent Building.

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. Flashing, piping, fire sprinkler lines, HVAC ducts, partitions, and flooring all have to be detailed to accommodate the seismic movement expected at these locations when the two structures move closer together or further apart. 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.

Bureau Of Indian Standards clearly gives in its code IS 4326 that a Separation Section is to be provided between buildings. Separation Section is defined as `A gap of specified width between adjacent buildings or parts of the same building, either left uncovered or covered suitably to permit movement in order to avoid hammering due to earthquake `. Further it states that ` For buildings of height greater than 40 meters, it will be desirable to carry out model or dynamic analysis of the structures in order to compute the drift at each storey, and the gap width between the adjoining structures shall not be less than the sum of their dynamic deflections at any level.` Thus it is advised to provide adequate gap between two buildings greater than the sum of the expected bending of both the buildings at their top, so that they have enough space to vibrate. Separation of adjoining structures or parts of the same structure is required for. Structures having different total heights or storey heights and different dynamic characteristics. This is to avoid collision during an earthquake. Minimum width of separation gaps as mentioned in 5.1.1 of IS 1893 : 1984, shall be as specified in Table 1.1 The design seismic coefficient to be used shall be in accordance with IS 1893 : 1984.

Structural Modeling and Analysis

In order to evaluate the Seismic gap between buildings with rigid floor diaphragms using response spectrum and time history analysis two sample building was adopted. The finite element analysis software SAP2000 Nonlinear [31] is utilized to create 3D model and run all analyses. The software is able to predict the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity.

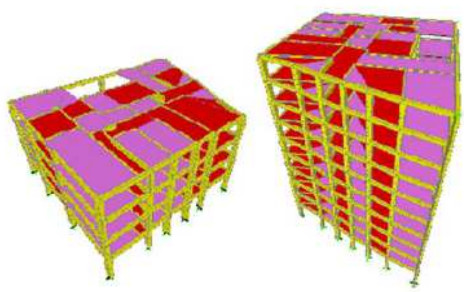

Fig.5.-3-D view of four storey and ten storey building created in SAP-2000.

ANALYSIS OF THE STRUCTURE

1. Response Spectrum Analysis

Here we are primarily concerned with observing the deformations, forces and moments induced in the structure due to dead, live loads and earthquake loads. The load case 'Dead' takes care of the self weight of the frame members and the area sections. The wall loads have been defined under a separate load case 'Wall' and the live loads under the case 'Live'. Analysis is carried out for all three cases for obtaining the above mentioned parameters. Modal analysis is carried out for obtaining the natural frequencies, modal mass participation ratios and other modal parameters of the structure. Response spectrum analysis of the three models is done in the zone v. For the Seismic pounding effect between adjacent buildings, response spectrum analysis is carried out using the spectra for medium soil as per **IS 1893 (Part 1) 2002.** The values of the spectral acceleration coefficient (Sa/g) for the time periods of 0.00 to= 4.00 seconds calculated as per the above equations and the plot of spectral acceleration.

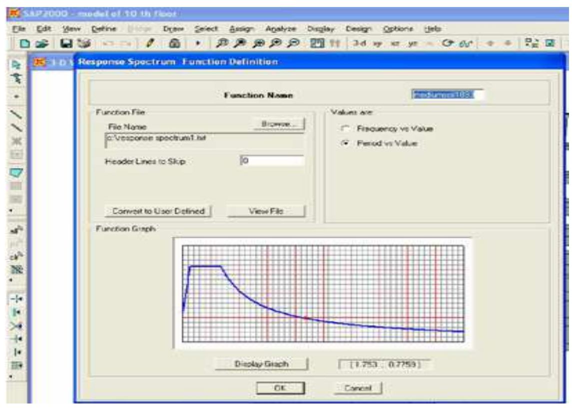

Fig.6- Defining response spectrum function (Sa/g) Vs. Period in SAP2000.

2. Time History Analysis of the structure

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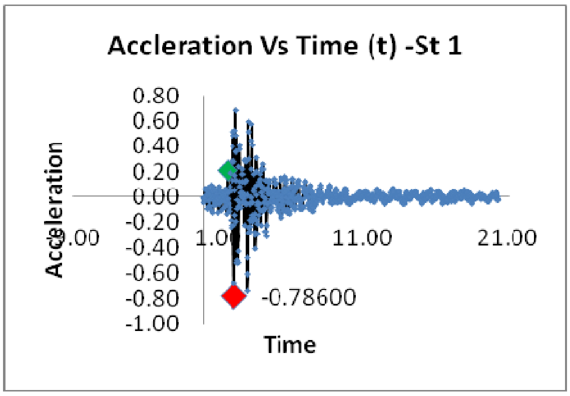
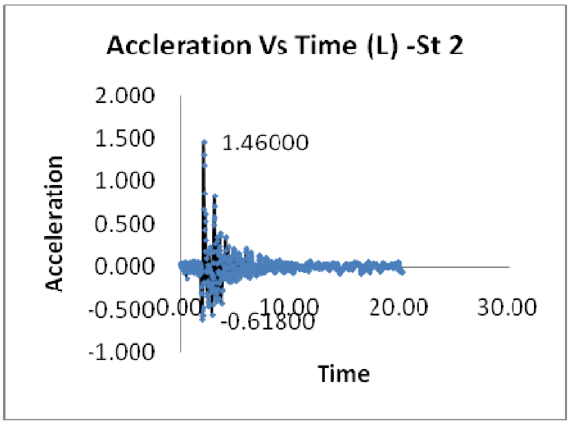
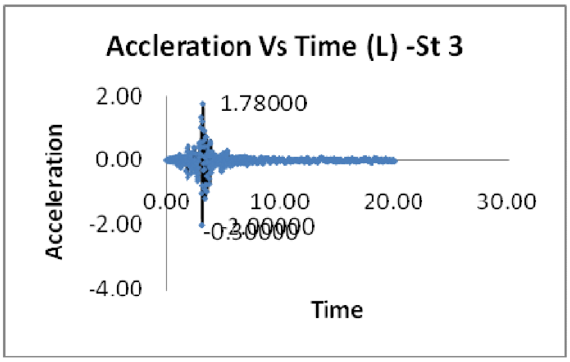
Time History analysis has been carried out using the Earthquake record of Kangra and Nagrota earthquake for obtaining the various floor responses. The record has 1922 data points with a sampling period of 0.02 seconds. The peak ground acceleration is 0.319g. Newmark's direct integration method has been adopted and the mass and stiffness proportional coefficients have been calculated taking into account the frequency of the structure in two consecutive modes in the same direction.







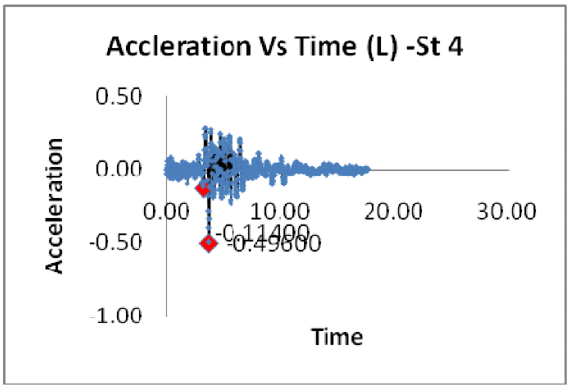


Fig: 7. Time history plot of Kangra and Nagroa earthquake.(A vs t-st1/2/3/4)

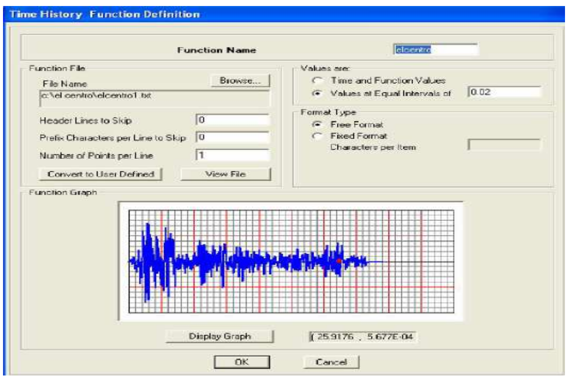


Fig.-Defining time history function (kangra and Nagrota) in SAP-2000.

Results and Discussion

1. Response spectrum analysis

Response spectrum analysis has been carried out as per the response spectra mentioned in IS 1893(part1) 2002. The displacements for a particular joint at the top floor for two models have been tabulated as below

Analysis of Four storey buildings

Load Combinations	Displacements in m		
	Longer (X)	Shorter (Y)	Vertical (Z)
1.5(DL+LL)	0.0200	0.0200	-0.011
1.2(DL+LL+EL)	0.0212	0.0212	-0.003
1.2(DL+LL-EL)	0.0212	0.0212	-0.003
1.5(DL+EL)	0.028	0.028	-0.003
1.5(DL-EL)	0.028	0.028	-0.003
0.9DL+1.5EL	0.028	0.028	-0.001
0.9DL-1.5EL	0.028	0.028	-0.001

Table 4.1 Displacement at the top floor in m for four storey buildings

Analysis of Ten storey buildings (G+10)

Load Combinations	Displacements in m		
	Longer (X)	Shorter (Y)	Vertical (Z)
1.5(DL+LL)	0.0300	0.0300	-0.0029
1.2(DL+LL+EL)	0.0500	0.0500	-0.0017
1.2(DL+LL-EL)	0.0500	0.0500	-0.0031
1.5(DL+EL)	0.0612	0.0612	-0.0017
1.5(DL-EL)	0.0612	0.0612	-0.0017
0.9DL+1.5EL	0.0612	0.0612	-0.0007
0.9DL-1.5EL	0.0612	0.0612	-0.0007

Table 4.2 Displacement at the top floor in m for ten storey buildings

Time History Analysis

Time history analysis has been carried out using the record of Kangra and Nagrota earthquake for obtaining the various floor responses.

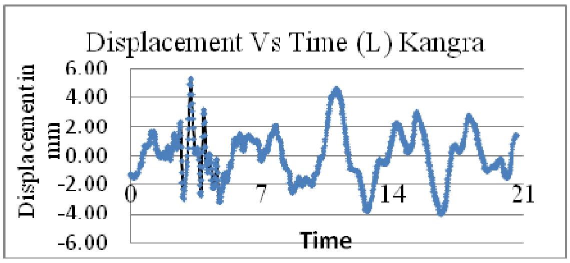


Fig: Displacement time history of top floor (shorter direction) – model 1.

Peak roof displacement of four storey building as obtained from time history analysis in SAP2000 is 0.008132m

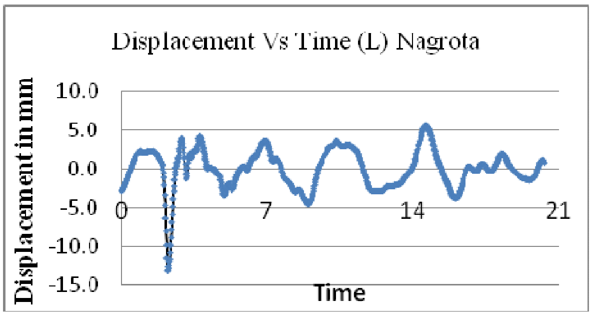


Fig: Displacement time history of top floor (shorter direction) – model 2

Peak roof displacement of ten storey building as obtained from time history analysis in SAP2000 is 0.009947m

Conclusion

Response spectrum result for pounding case is observed. From the above result it have been seen that considering equal floor levels between adjacent buildings the maximum displacement is for Four storey buildings (G+4) is 0.056m against the 0.08m seismic gap between the adjacent buildings provided as per IS 4326-2005 and for Ten storey buildings (G+10) is 0.1222m which is much less then the seismic gap provided between the adjacent buildings as per IS 4326-2005.

From time history analysis, it can be observed that all the two models have exhibited amplified responses for the top floor. The ten storey building has exhibited

maximum response between the two models.

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