Literature review on Seismic Pounding of Adjacent Buildings

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Abstract - *Structures are built close to each other in various cities and urban areas where cost of land is high and availability of land is difficult. Due to this closeness, the structures may collide with each other when subjected to any vibration or earthquake. This collision of buildings or its different parts during the vibration is called pounding which result in architectural and structural damages or collapse of the entire structure. The difference in structural properties, floor height and floor level with insufficient gap between the buildings also effects in structural pounding. Here, a discussion of previous works and studies regarding the structural pounding, its causes and the mitigation measures is given.*

Key Words: Structural pounding, Building collision, Adjacent buildings, Seismic separation distance, Pounding analysis

1.INTRODUCTION

The Seismic Pounding can be defined as the collision of adjacent buildings during the earthquakes. The principle reason for the pounding effect is the insufficient gap in between the adjacent buildings. It 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 during an earthquake when adjacent buildings of different dynamic characteristics vibrate out of phase at-rest separation is insufficient. 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.

Also, Poundings may occur because of structural irregularities. For example eccentricity between mass rigidity centers cause torsion in the structure. Pounding is very complex phenomenon. It could lead to infill wall damage, plastic deformation, column shear failure, local crushing and possible 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 causing more damage and instability to the building. The patterns of the damage vary from minor and architectural damages to major structural damages to even total loss of the building function and its stability. In other words, pounding phenomena in adjacent buildings can be catastrophic and more dangerous than the effect of earthquake on a single building.

1.1 Causes of Pounding

The various causes of pounding are as follows:-

- Adjacent buildings with the same heights and the same door levels
- Adjacent buildings with same floor levels but different heights
- Adjacent structures with different total height and floor levels
- Structures are situated in a row
- Adjacent units of the same buildings which are connected by one or more bridges or through expansion joints.
- Structures having different dynamic characteristics, which are separated by a distance small enough so that pounding can occur.
- Pounding occurres at the unsupported part (e.g., mid-height) of column or wall.
- Construction according to the earlier code that was vague on separation distance.
- Possible settlement and rocking of the structures located on soft soils.
- Buildings having irregular lateral load resisting systems in plan rotate during an earthquake

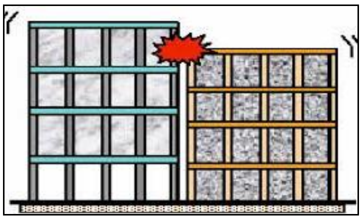

Fig-1: Pounding of Adjacent Buildings

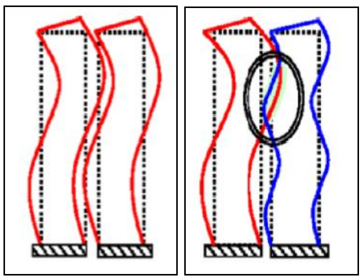

Fig-2 : a) Similar seismic behaviour b) Different seismic behavior

The main objective of this paper is to understand the terms related to structural pounding, causes of pounding, importance of providing enough separation distance and the points to be checked before constructing adjacent buildings. Figure 1 shows the pounding of adjacent buildings and figure 2 shows the similar seismic behavior and Different seismic behavior of adjacent buildings.

2. RELATED WORKS

To study the concepts of seismic pounding of adjacent structures we have studied many papers. As we know, the seismic pounding results in serious structural and architectural damages to the adjacent buildings which leads to huge damage and high risk of life. It is important to conduct studies to find out measures to mitigate structural pounding. Some previous papers regarding this topic which can give good research based knowledge on this matter, its causes and measures to mitigate the effect is discussed here.

A. Joshi, Pushpa Kumari and etal (2012) [1]; studied on near-field and far-field simulation of accelerograms of Sikkim earthquake of september 18, 2011 using modified semi-empirical approach. Various strong motion properties like directivity effect and dependence of peak ground acceleration with respect to surface projection of source model have been studied in detail in the present work. Sikkim earthquake of magnitude 6.9 (M_w) that occurred on September 18, 2011 has been recorded at various near-field and far-field strong motion stations. The modified semi-empirical technique was used to confirm the location and parameters of rupture responsible for this earthquake. Strong motion record obtained from the iterative modelling of the rupture plane has been compared with available strong motion records from near as well as far-field stations in terms of root mean square error between observed and simulated records. Final model confirms southward propagating rupture. Simulations at three near-field and twelve far-field stations have been made using final model. Comparison of simulated and observed record has been made in terms of peak ground acceleration and response spectra at 5 % damping.

Chetan J Chitte and etal (2014) [2]; studied about the seismic pounding between the adjacent building structures subjected to near field and far field earthquakes. Two models of G+5 storeyed building, one with live load 1.5KN/m^2, other with 2 KN/m^2 and a model of G+8 storeyed building with live load 1.5 KN/m^2 were modelled. All other properties were almost kept the same. Time history analysis of building structures were done to examine the exact nonlinear behaviour of the building structures using SAP2000. Newmark's direct integration method was adopted and the mass and stiffness proportional coefficients were calculated according to the frequency of the structure in two consecutive modes in same direction. They concluded that the displacement for near source is much greater than the far source ground motion.

Mahdi Heydari and Mahdi Mousavi (2015) [3]; studied on seismic effects of near-field and far-field earthquakes on relative displacement of seven-storey concrete building with shear wall. The characterization of near-field earthquakes and their descriptions were used to define the differences between near-field and far-field earthquakes in regard to radically distinctive responses of structures. In this study, the incremental dynamic analysis of a seven-storey building with concrete structure for few near-field and far-field earthquakes was done and the associated diagrams of relative structural displacement were compared. At the end, the comparison of these plots were used to denote the differences in the structural behaviours of these two types of earthquakes. The comparison of relative displacement for near-field and far-field stations of an identical earthquake showed a difference of 35.6 percent.

Mariella Diaferio and Dora Foti (2015) [4]; studied on nonlinear dynamic behavior of a fixed base reinforced concrete 2D frame subjected to near-field earthquakes. The R.C. frame considered has six levels and two equal span which has been designed as per the instructions provided in Eurocode 2 exclusively under gravity loads, as lots of the existing buildings. The nonlinearity of the frame has been assumed with a diffuse plasticity and a fiber modeling has been considered for the structural elements. The results concluded that the nodal areas proceed from yield until failure due to the amplification produced by the earthquake. Failure is observed only in the columns while no section of the beams reaches the failure.

M. Davoodi and M. Sadjadi (2015) [5]; studied on near-field and far-field strong ground motion effects on soil-structure SDOF system. A total 71 records were selected in which near-field ground motions have been classified into two categories: first, records with a strong velocity pulse, (i.e. forward-directivity); second, records with a residual ground displacement (i.e. fling-step). Findings from the study reveal that pulse-type near-field records generally produce greater seismic responses than far-field motions especially at high structure-to-soil stiffness ratios. Moreover, the importance of considering SSI effects in design of structures is investigated through an example. Finally, parametric study between Peak Ground Velocity to Peak Ground Acceleration ratio (PGV/PGA) of pulse-like ground motions and maximum relative displacement indicate that with increase in structure-to-soil stiffness ratios, earthquakes with higher PGV/PGA ratio produce greater responses.

Mohammed Jameel and et.al (2013) [6]; studied on the seismic induced pounding between neighbouring multi-storey structures by non-linear FEM analysis. The results were obtained in the form of storey shear, pounding force, storey drift, point displacement and acceleration. They concluded that the acceleration at pounding level significantly increases during collision of building. The generated extra pounding force may cause severe damage to structural members of structures. Pounding produces shear at various story levels, which are greater than those obtained from no pounding case. Building with more height suffers greater damage than shorter building when pounding occurs. Increasing gap distance tends to reduce story shear in consistent manner.

M Phani Kumar and J D Chaitanya Kumar (2015) [7] studied on seismic pounding of the adjacent buildings with different heights. The study is based on seismic pounding effect between adjacent buildings by linear and nonlinear dynamic analysis using ETABS (Non Linear) computer program. A detailed parametric study is carried out to investigate the effect of various parameters on the structural pounding by Response Spectrum (Linear Dynamic) Analysis for medium soil at zone V and Time History (Non-Linear Dynamic) Analysis for Bhuj earthquake recorded excitation on different models with varying separation distances. Pounding forces can be calculated using commercial software packages like ETABS where nonlinear gap elements between the adjacent building floors are used to calculate pounding forces.It is concluded that it is necessary to carry out non-linear dynamic analysis to know the actual response of the structure.

Pankita L. Patel and Prof. Umang Parekh (2016) [8] studied on the performance of intez tank under near fault and far field earthquake motion. Seismic effect of different shape and types of elevated water tank due to near field and far field earthquake were studied. Intez types of elevated water tanks with different staging height 12m, 16m, 20m and different capacity were selected. Intez tanks of two different staging profiles such as shaft and frame and simulated to near fault and far field ground motion were modelled using Staad Pro. software. Here time history analysis records from past earthquake ground motion records were used. Seismic responses including base shear were observed under different earthquake time history records.

Ravindranatha, Tauseef M Honnyal and etal(2014) [11] studied on the seismic pounding between adjacent buildings. Prevention techniques of pounding between adjacent buildings due to earthquakes are studied. Constructing new RC walls, cross bracing system and combined RC wall & bracing, with proper placement are proposed as possible prevention techniques for pounding between adjacent buildings. An adjacent building combination of G+8 and G+5 storeys with 80mm expansion joint was analysed using time history of elcentro earthquake data. It is concluded that all the prevention methods that are used in this study proved to be effective to prevent pounding between adjacent buildings and a safe separation distance should be provided according to FEMA-273.

Seyed Morteza Zinati Yazdi and Mohammad Taghi Kazemi (2016) [12]; studied on damages in RC frames under near field earthquakes using a damage index. The Erduran damage index, an efficient way to calculate damage, was employed to analyse two 4 and 8 story RC moment frame buildings. The buildings with moderate and high ductility were designed by the strength criteria. Seven pairs of near field and far field earthquakes were scaled and used for dynamic nonlinear time history analysis. We observe from the results that most of the components of the structures under near field earthquakes sustained severe damages and in some cases even component failure. Components of the structures under near field earthquakes suffered from 30% more of damage, on average, than that under far field earthquakes.

S. Yaghmaei-Sabegh and N. Jalali-Milani (2012) [14]; studied about the pounding force response spectra for adjacent elastic structures subjected to near field and far field ground motions, Both the adjacent buildings were modelled simply as a SDOF systems and pounding effect has been simulated by applying the nonlinear viscoelastic model. In the analysis, the effect of different parameters, such as mass, damping ratio has been studied. The effects of gap distance on maximum pounding force due to near and far-field earthquake ground motions were investigated. They concluded that the considered parameters have a significant influence on the value of maximum pounding force. Results have shown that, the huge energy of an earthquake in some cases leads to an increase in the value of pounding force during increasing gap distance.

Tavakoli H.R and etal (2011) [15] studied on the response of RC structures subjected to near-fault and far-fault earthquake motions considering soil-structure interaction. The effects of soil-structure interaction were evaluated for a 3-story building, a 7-story building and a 15-story building. The ordinary moment resisting frame system was considered for all example buildings as lateral force-resisting system. For all buildings time-history analysis were performed under 3 example earthquake motions. For all analysis both near-field and far-field earthquake were considered. The main evaluated parameters were period of structure, base shear, global displacement and story drifts. Results based on linear time-history analysis had shown that considering the soil-structure interaction increases period of structure and story drifts and also had noticeable and significant effects on global displacement and base shear.

Vahid Sharif, Farhad Behnamfar (2012) [16]; studied on the effects of near-field earthquakes on the behaviour of moment resisting frames. In this paper, in addition to a brief review on the special characteristics of near-field earthquakes, using actual records of these ground motions and pulse-like inputs simulating near-filed records, the effects of this type of earthquakes on the distribution of the maximum shear force and flexural moment demands are evaluated. Results show that the response is very sensitive to the ratio of natural period of structure to the governing period of ground shaking pulse, such that, in some cases it leads to increasing force demand ratios of structure and even transmitting its centroid to upper stories.

3. DISCUSSION

One of the important problem in avoiding the construction of adjacent buildings in urban areas is the high land cost and less availability of enough land. Due to these reasons different buildings constructed for different purposes with different structural properties may not have enough gap in between them to avoid pounding effect. So it is important to do research and find those methods to avoid or reduce the risk of pounding. Already several researches have been conducted by many researchers on this topic and there are many things yet to be studied and analyzed out to have more effective methods for mitigating the same.

4. CONCLUSION

This paper gives effective information about the topic seismic pounding and also have given a survey of some papers related to the topic along with the important data considered and obtained for and from the study. This paper will be helpful enough to find useful journals to study about the topic and to conduct continued researches on the topic.

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BIOGRAPHIES

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