Seismic Pounding Effects In Buildings

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Abstract- *Pounding of the structure was determined by considering the buildings with equal heights and unequal heights for zone V. The minimum separation distance between the buildings is taken as per IS: 4326-2000. The three method of analysis has been conducted for modeling of buildings such as, equivalent static analysis, and response spectrum analysis and time history method. By the above three methods of analysis the pounding effect between the buildings is observed that, pounding occurs only in unequal heights where as in equal heights of buildings due to similar characteristics of structures the pounding effect doesn't occurs. This effect of pounding can be mitigated by using the energy dissipating device like viscos-elastic dampers and springs are provided in between the adjacent buildings. To estimate the seismic demands, nonlinearities in the structure are to be considered when the structure enters into inelastic range during devastating earthquakes. Despite the increase in the accuracy and efficiency of the computational tools related to dynamic inelastic analysis, engineers tend to adopt simplified non-linear static procedures instead of rigorous non-linear dynamic analysis when evaluating seismic demands. This is due to the problems related to its complexities and suitability for practical design applications. The push over analysis is a static, nonlinear procedure that can be used to estimate the dynamic needs imposed on a structure by earthquake ground motions. This project entitled "Seismic Pounding Effects in Buildings." aims at studying seismic gap between adjacent buildings by dynamic and pushover analysis in ETAB.*

Keywords- Adjacent building, pounding (impact), seismic load, gap, etab.

I. INTRODUCTION

Investigations of past and recent earthquake damage have illustrated that the building structures are vulnerable to severe damage and/or collapse during moderate to strong ground motion. An earthquake with a magnitude of six is capable of causing severe damages of engineered buildings, bridges, industrial and port facilities as well as giving rise to great economic losses. Several destructive earthquakes have hit Egypt in both historical and recent times from distant and near earthquakes. The annual energy release in Egypt and its vicinity is equivalent to an earthquake with magnitude varying from 5.5 to 7.3. Pounding between closely spaced building structures can be a serious hazard in seismically active areas. Investigations of past and recent earthquakes damage have illustrated several instances of pounding damage (Astaneh-Asl et al.1994, Northridge Reconnaissance Team 1996, Kasai&Maison 1991) in both building and bridge structures. Pounding damage was observed during the 1985 Mexico earthquake, the 1988 Sequenay earthquake in Canada, the 1992 Cairo earthquake, the 1994 Northridge earthquake, the 1995 Kobe earthquake and 1999 Kocaeli earthquake. Significant pounding was observed at sites over 90 km from the epicenter thus indicating the possible catastrophic damage that may occur during future earthquakes having closer epicenters.

Pounding of adjacent buildings could have worse damage as adjacent buildings with different dynamic characteristics which vibrate out of phase and there is insufficient separation distance or energy dissipation system to accommodate the relative motions of adjacent buildings. Past seismic codes did not give definite guidelines to preclude pounding, because of this and due to economic considerations including maximum land usage requirements, especially in the high density populated areas of cities, there are many buildings worldwide which are already built in contact or extremely close to another that could suffer pounding damage in future earthquakes.

A large separation is controversial from both technical (difficulty in using expansion joint) and economical loss of land usage) views. The highly congested building system in many metropolitan cities constitutes a major concern for seismic pounding damage. For these reasons, it has been widely accepted that pounding is an undesirable phenomenon thatshould be prevented or mitigated zones in connection with the corresponding design ground acceleration values will lead in many cases to earthquake actions which are remarkably higher than defined by the design codes used up to now.

The focus of this study is the development of an analytical model and methodology for the formulation of the adjacent building-pounding problem based on the classical impact theory, an investigation through parametric study to identify the most important parameters is carried out. The main objective and scope are to evaluate the effects of structural pounding on the global response of building structures; to determine the minimum seismic gap between buildings and provide engineers with practical analytical tools for predicting pounding response and damage. A realistic pounding model is used for studying the response of structural system under the condition of structural pounding during elcentro earthquakes for medium soil condition at seismic zone V.

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

1. During An Earthquake
2. Different Dynamic Characteristics
3. Adjacent Buildings Vibrate Out Of Phase
4. At-Rest Separation Is Insufficient

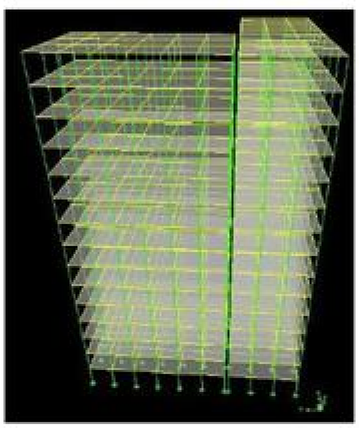

Fig.1 View of Ten and Fifteen storey adjacent buildings created in ETABS

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.

II. REVIEW OF LITERATURE

Basic concepts on which the seismic pounding effect occurs between adjacent buildings. He identified the conditions under which the seismic pounding will occur between buildings and adequate information and, perhaps more importantly, pounding situation analyzed. From his research it was found that an elastic model cannot predict correctly the behaviors of the structure due to seismic pounding. Therefore non-elastic analysis is to be done to predict the required seismic gap between buildings.[2]

The fundamental questions concerning theapplication of the nonlinear analysis and its feasibility and limitations in predicting seismic pounding gap between buildings. In his analysis, elastoplastic multi-degree-of-freedom lumped mass models are used to simulate the structural behavior and non-linear viscoelastic impact elements are applied to model collisions. The results of the study prove that pounding may have considerable influence on behavior of the structures.[3]

Developed and implemented a tool for the inelasticanalysis of seismic pounding effect between buildings. They carried out a parametric study on buildings pounding response as well as proper seismic hazard mitigation practice for adjacent buildings. Three categories of recorded earthquake excitation were used for input. He studied the effect of impact using linear and nonlinear contact force model for different separation distances and compared with nominal model without pounding consideration.[4]

The earthquake induced pounding between adjacent buildings. They idealized the building as lumped-mass, shear beam type, multi-degree-of-freedom (MDOF) systems with bilinear force-deformation characteristics and with bases supported on translational and rocking spring-dashpots. Collisions between adjacent masses can occur at any level and are simulated by means of viscoelastic impact elements. [5]

They used five real earthquake motions to study the effects of the following factors: building configuration and relative size, seismic separation distance and impact element properties. It was found that pounding can cause high overstresses, mainly when the colliding buildings have significantly different heights, periods or masses. They suggests a possibility for introducing a set of conditionsinto the codes, combined with some special measures, as an alternative to the seismic separation requirement.[6]

It presented a simple computer based pushover analysis technique for performance based design of building frameworks subject to earthquake loading. The concept is based on conventional displacement method of elastic analysis. To measure the degree of plastification the term plasticity factor was used. The standard elastic and geometric stiffness matrices for frame elements are progressively modified to account for non-linear elastic-plastic behavior under constant gravity loads and incrementally increasing lateral loads.[7]

The performance of structures for various load patterns and variety of natural periods by performing pushover and nonlinear dynamic time history analysis and concluded that for taller structures pushover analysis is underestimating seismic demands.[8]

III. STRUCTURAL MODELING AND ANALYSIS

1. General

In order to evaluate the Seismic gap between buildings with rigid floor diaphragms using dynamic and pushover procedures two sample building was adopted The details of the building are reproduced. The finite element analysis software ETAB Nonlinear 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. The software accepts static loads (either forces or displacements) as well as dynamic (accelerations) actions and has the ability to perform eigenvalues, nonlinear static pushover and nonlinear dynamic analyses.

2. Details of the Models

The models which have been adopted for study are asymmetric four storey(G+4) and eight storey (G+8) buildings. The buildings are consist of square columns with dimension 500mm x 500mm, all beams with dimension 350mm x 250mm. The floor slabs are taken as 125mm thick. The foundation height is 1.5m and the height of the all four stories is 3m. The modulus of elasticity and shear modulus of concrete have been taken as E = 2.55 ×107 kN/m2 and G = 1.06 ×107 kN/m2.

Two models have been considered for the purpose of the study.

1. **Four storey(G+4) adjacent building with equal floor levels.**
2. **2 Eight storey(G+8) adjacent buildings with Unequal floor levels.**

The plan and sectional elevation of the two buildings are as shown below.

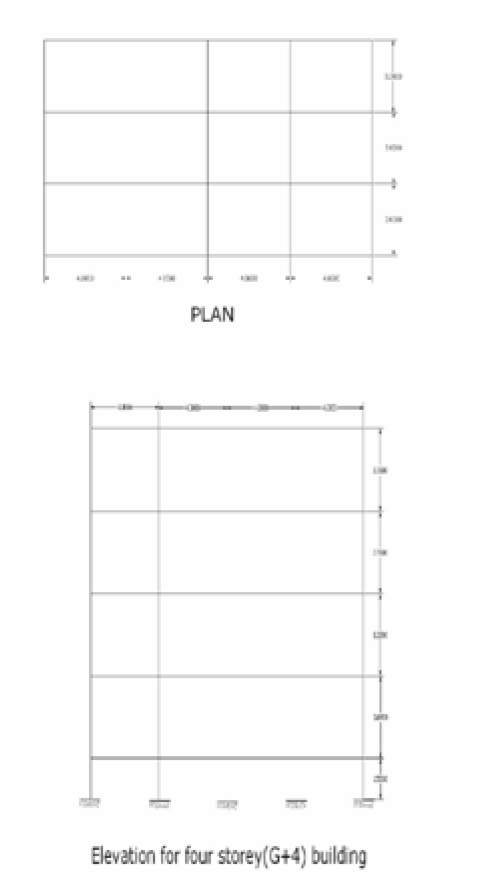

Fig 2 Plan and elevation of the two model buildings.

In present work is to study the pounding of the structure for same height and different height for the zone V. The different height structure consists of storey 8 and storey 5.The same height building consisting of storey8. Dampers and contact elements are used to control pounding effects and reduce the displacement. Finally the analysis results in the high rise building such as storey drift, storey displacement, and base shear has been observed.

A. Building with Unequal Height

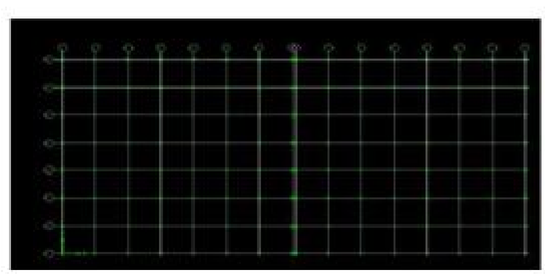

Fig. 3: The Plan and columns representation of the building

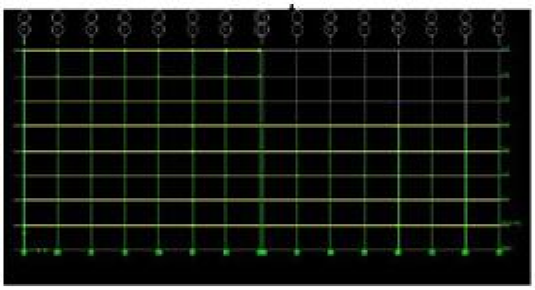

Fig. 4: The front elevation of Building with unequal height

The type of building is commercial building of 8 story and 5 story building and the soil type is medium 2 and its response reduction factor is 5,it comes under zones V with an importance factor 1. This building consists 7 X 7 with frame system of SMRF. Total height of building 24m & 15m respectively and floor height is about 3m. Density of brick masonry is about 19.2 kN/m2 with Poisson ratio of concrete 0.15. the spacing between column is 5m. the live load acting on floor is about 2kn/m2 and for roofs 1kn/m2 and superimposed dead load 11.26kn/m2 & 3.31kn/m2 (parapet wall). Concrete used for this building M25 of concrete strength 25mpa.Modulus elasticity of concrete is taken as

$E_{fc} = 5000$
$\sqrt{f_{ck}} = 5000 X\sqrt{25} = 25000X10^3$ the grade of steel used as Fe 415.

B. Building with Equal Height

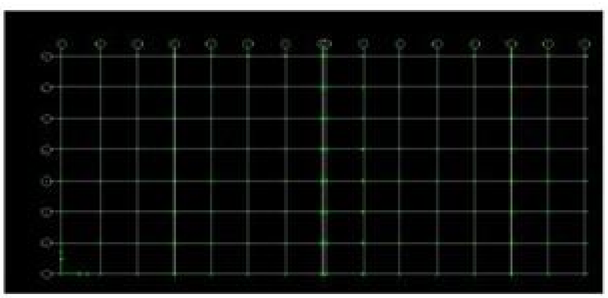

Fig. 5: The Plan and Column representation of building for equal height

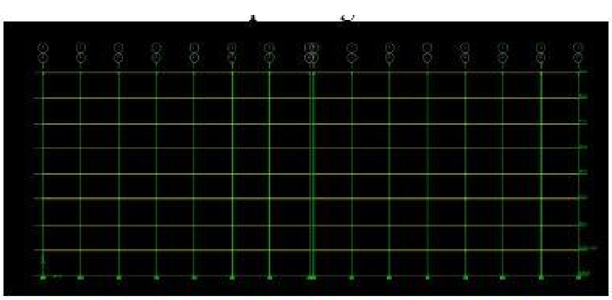

Fig. 6: The elevation of building with equal height

IV. RESULTS AND DISCUSSION

4.1 General

ETAB is used to compute the response of a four (G+4) and eight storey (G+8) buildings for rigid floor diaphragm Linear Dynamic (response spectrum), Non Linear Dynamic (time history) and push over analysis.

Results from Response Spectrum analysis are observed for the natural frequencies and modal mass participation ratios and Displacements of the joints to determine the seismic pounding gap between adjacent structures of two models.

Results from time history analysis have been used to observe and compare the floor responses of all the two models. Pushover curves and capacity spectrum curves results have been used to observe and compare the displacement of the buildings in the performance point for three different lateral load patterns.

4.2 Analysis of Four storey buildings (G+4)

Table 1 Displacement at the top floor in m for four storey buildings

Load Combinations	Displacements in m		
	Longer (X)	Shorter (Y)	Vertical (Z)
1.5(DL+LL)	-4.316*10-18	-4.916*10-18	-0.011
1.2(DL+LL+EL)	0.0184	0.0184	-0.0004
1.2(DL+LL-EL)	0.0184	0.0184	-0.0004
1.5(DL+EL)	0.023	0.023	-0.0004
1.5(DL-EL)	0.023	0.023	-0.0004
0.9DL+1.5EL	0.023	0.023	-0.0001
0.9DL-1.5EL	0.023	0.023	-0.0001

4.3 Analysis of Eight storey buildings (G+8)

Table 2 Displacement at the top floor in m for eight storey buildings Conclusion

Load Combinations	Displacements in m		
	Longer (X)	Shorter (Y)	Vertical (Z)
1.5(DL+LL)	$-9.612*10^{-18}$	$2.667*10^{-18}$	-0.0026
1.2(DL+LL+EL)	0.0378	0.0378	-0.0015
1.2(DL+LL-EL)	0.0378	0.0378	-0.0028
1.5(DL+EL)	0.0472	0.0472	-0.0014
1.5(DL-EL)	0.0472	0.0472	-0.0014
0.9DL+1.5EL	0.0472	0.0472	-0.0005
0.9DL-1.5EL	0.0472	0.0472	-0.0005

V. CONCLUSION

Pounding is reduced by providing energy dissipaters such as springs and viscoelastic dampers in the building.The first phase of the study involves the creation and analysis of the model and Linear dynamic analysis (Response Spectrum Analysis) for medium soil condition has been carried out on those models to observe displacement at the joint of the structure. Depending upon the analysis results, modification of the same for the purpose of no pounding is carried out on those models. Based on the observations from the analysis results, the following conclusions can be drawn. Response Spectrum analysis gives result that the two models have displacement within the permissible limit for seismic pounding between adjacent buildings with the seismic gap provided as per IS 4326-2005. It was found that minimum seismic gap can be providing 0.012m per storey between two four storey building and two eight storey building for no seismic pounding between buildings.In the second phase of the project Nonlinear dynamic analysis with Elcentro earthquake excitation data as input is carried out on those models to observe the behaviour of the structure under earthquake excitation.

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