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Seismic Behaviour Of Rcc Multi Storey Building With Retaining Wall

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Abstract - **The parking area is provided in the basement floors for most of the buildings. To retain the soil, the basement floor has a retaining wall around the periphery of the building.The outside periphery of the building is supported on the retaining wall and columns. Horizontal soil pressure acts on the retaining wall of the building structure. On the outer periphery of the lateral earth pressure building structure, attempts are being made to study the effect of seismic forces on a building with retaining wall.For three distinct story height models, seismic analysis is performed. In addition to interaction with soil structure using linear time history analysis in ETABS, the models are equipped with single basement floor and double basement floor as well as lateral earth pressure acting on the retaining wall. Together they're all 12 models. The structure response is explored in terms of base shear, roof displacement and maximum story drift.The models interacting with lateral earth pressure and soil structure the percentage increase in base shear is 30-42 percent and 30-48 percent in X and Y direction for single story basement. The base shear is risen 15-30 percent for the double story cellar and 60 percent for the soil structure interaction along X and Y axis. Models with lateral stress acting on retaining wall together with earthquake force the highest roof displacement is observed in Model 3 with 42% and 48% along X and Y direction for single basement floor when considering groundwater interaction. And the model 3 is improved 60 percent for double basement ground when considering soil structure interaction.**

keywords - **Retaining wall, Soil structure interaction, linear time history, base shear, Roof displacement.**

I. INTRODUCTION

1.1 General: Earthquakes are one of the most destructive natural hazards causing considerable loss of life and livelihood. It is the surface shaking of the earth that is sufficiently violent to cause severe harm and kill thousands of individuals. They are triggered by the Earth's crust's sudden release of energy arising from tectonic plate movements. This power is released in the form of seismic waves. Earthquakes are the most unexpected and devastating natural disasters. In the worst case scenario, the enormous quantity of energy released during an earthquake can cause significant harm or destroy significant buildings. In this age of high-rise building harm from an earthquake to poorly built building / structure to resist earthquake forces can lead to greater lives and infrastructure loss. It is therefore very essential to identify the conduct of buildings during an earthquake.

Parking has been a major user of developable land since the 1960s. There are prevalent multi-store car parks, underground or basement car parks, and multi-functional construction car parks. Although multi-store vehicle parks are found primarily in city and city centres, they also feature in airports, retail centres, conference centres, hotels, residential developments, workplaces (both offices and factories), entertainment venues, railway stations, and sports facilities. Underground parking offers many long-term advantages such as maintaining prime real estate, providing convenient, centrally located parking, and removing street front parking structures. Deep underground basements that were early incorporated into the general project layout in urban development projects give many intrinsic changes to the overall quality and value of the project and its surrounding community. The present research includes the seismic conduct with the retention of reinforced concrete buildings walls. The research includes an analysis of the conduct of the retention wall in the RCC multi-storey construction during the earthquake.

1.2 Soil Structure Interaction: A recent earthquake study has shown that understanding the link between the buildings vibration period and the supporting soil's vibration period is very important in determining the seismic response of the structure. The pattern of structural damage is directly related to the depth of soil alluvium over the bedrock, which is directly related to the vibration period of the soil. The nature of the sub-soil can affect the structure's response in three ways:

- The phenomenon of soil amplification may occur so that the seismic excitation at the bedrock is modified during transmission through the overlying soils to the foundation. This may cause attenuation.
- Fixed base dynamic properties of the structure may be significantly modified by presence of soil overlying the bedrock. This will include changes in the mode shape and period of vibration.
- A significant part of vibration of a flexibly supported structure may be dissipated by material damping and radiation in the supporting medium.

1.2.1 Dynamic Analysis of Soil-Structure Interaction

An ideal model, the earthquake movement should be applied not to the entire soil structure scheme, but to the bedrock. This is not a very realistic method at the moment, as much less is known about bedrock movement than surface movement and the potential results for soil amplification are greatly dispersed. Currently, the realistic analytical methods seem to be those that apply free field movement to the base of the structure or sub-structuring method in which dynamic foundation features predominate and soil and structure reactions are superimposed on each other.

Soil Models: The model methods are:
1.Spring model – equivalent static springs and viscous damping at base level only
2.Lumped masses model – shear beam analogy using continua or lumped masses and springs distributed vertically through the soil profile.

- Semi-infinite model
- Finite –element model.

Spring Model: The simplest method of modelling soil to use springs at the level to represent the horizontal, rocking, vertical, and torsional stiffness of the soil.

a. This is simplest model for analyzing the rocking motion of a building due to ground disturbance.
b. In this model , the building is assumed to be supported by springs, which resists the rotation of the building , is identified as the rocking spring.
c. The spring stiffness depends on the shear modulus , which in turn varies with the level of shear strain.
d. Hence for the linear elastic calculation, the spring stiffness is calculated to a value of shear strain less than maximum expected value.
e. If the spring stiffness at low strain is kr, then the value of k equal to 0.67kr, may be used for analysis.
f. A series of comparative analysis may be done using a range of value of k.

1.3 Effect of Building Configuration

Configuration can be described as: the size and design of the construction, the size and place of structural components, and the nature, size and place of non-structural components that may influence the efficiency of the structure. The latter includes elements such as heavy non-structural walls, staircases, outside wall panels and heavy items of equipment.

If the setup is nice, the seismic design will be easy and cost-effective, and better efficiency will be guaranteed. The seismic design will be expensive if the configuration is bad and good performance will be less than certain.

1.4 Need of The Study: Conventional structure design methods neglect the SSI effects. For a low-rise construction that neglects SSI is sensible, but for a high-rise building and a heavy structure that rests on soft soil, it is necessary to explore the interaction in base and soil that changes the movement of the ground as well as its impact on the structure when considering an excitement from an earthquake. The multi-story building with retaining wall is subjected to lateral forces in relation to the earthquake forces, which is why studying the behavior of the structure is crucial.

1.5 Scope of The Study: The present work is an attempt to study the effects on the earthquake's symmetrical building. The building is provided with retaining wall and the impact of earthquake force is being studied. The comparison is explored taking into account the impact of soil interaction with and without retaining wall. They are 3 models with distinct storey height such as 8 story, 12 story, 16 story size 25x25 m each model is explored with single floor and basement with retaining wall with and without soil structure interaction. So all 12 designs are together. In the ETABS software, seismic analysis is performed using the Linear Dynamic Time History Analysis method.

1.6 Objectives of The Study: The present work aims at the following objectives:

1. To study the effect of earthquake on symmetric multi-storey RCC buildings with basement floor having retaining wall by means of dynamic linear time history analysis.
2. To study the behaviour of the structures in terms of response based on different parameters such as base shear, roof displacement and maximum story drift.
3. To compare the results of the models considering with and without soil-structure interaction on retaining walls.

1.7 Organization of the Report:

Chapter 1 Gives general introduction about earthquakes, effects of building configuration, objectives of work and scope of work.
Chapter 2 Presents the various literatures and their brief review pertaining to the present study.
Chapter 3 Covers the research methodology adopted for this study and gives an insight into the various methods of seismic analysis.
Chapter 4 Provides the details on various analytical models used for this study and their analysis.
Chapter 5 Results and discussions of this study are presented in a detailed manner in this chapter categorized in the form of tables and graphical representation.
Chapter 6 Gives the final conclusions of this study and suggestions for further study.

II. LITERATURE REVIEW

2.1 General

- The general philosophy for earthquake-resistant structure design has undergone some major changes over the past 15 years, following some of the world's most damaging earthquakes. For the engineers to design the houses, forecasting the earthquake response of a structure became more essential, and this became more essential for the engineers to design the structures, making it much easier with seismic data and software improvements. With a focus on a realistic characterization of seismic structural damage and its direct incorporation into the design methodology, new analytical methodologies are proposed.
- In addition, a major emphasis is placed on characterizing all the uncertainties in the design process. Implementing the solution requires the availability of a set of ground movement records (each with three components) that account for the

uncertainties and differences in severity, frequency characteristics and duration due to rupture characteristics and distances of the various faults that may cause motions at the site.

2.2 Overview: Maleki and Mahjoubi (2010): a simple finite element model is introduced in this paper for seismic retention wall analysis. In the behavior of near-wall soil, wall flexibility and elastic free field soil reaction, the model includes nonlinearity. In relation to acceptable accuracy, the benefits of this model are simplicity and flexibility. Analysis was carried out on several soil-wall systems by applying real earthquake records using nonlinear time-history analysis. New distributions of seismic soil pressure are proposed for different soil and boundary conditions based on the results of these analyzes. The soil-wall structure can experience significant displacement in an earthquake. If the soil's wall and free field displacement are equivalent, the wall will have no impact on the pressures of free field soil. This is generally not the case, however, and the distinction in soil and wall displacements generates stress in the soil, particularly near the wall. Therefore, in terms of the distinction between free field soil and wall displacements, the horizontal stresses in the soil behind the wall can be written. With nonlinear springs connected to the wall representing the interfacing soil, this phenomenon can be modelled.

A 3-D finite element dynamic computer program called ANSYS was discussed **by** Garavand et al. (2010) to study the soil structure interaction retaining wall. The information of the assessment is based on the 1995 Kobe earthquake report and the findings were checked with the damage caused by some retaining walls in the earthquake. Soil-structure surface non-linearity, surface-to-surface contact element is used. The reinforcement concrete also operates nonlinear under the dynamic loads and material used. Hence the results of classic methods such as Coulomb and Rankine compared to nonlinear dynamic assessment outcomes. Two types of boundaries were applied to simulate the unbounded nature of the soil medium and the corresponding responses were compared. These boundaries are:
1) Viscous border (dashpot): viscous dampers are mounted on the model's side wall. Damping coefficients were given in normal and perpendicular directions at a particular node where viscous dampers are attached.
2) Boundary of the Kelvin component (spring and dashpot): Kelvin components are also used at the boundary. The Kelvin element's stiffness and damping constant was assessed.

Alireza Ahmdnia et al (2011), studied on basement walls, is an essential component of tall buildings. These walls should be intended to resist the static and seismically induced lateral earth pressures. Since there is no guideline specific to seismic design of basement walls, developers use the Coulomb concept to discover the static active lateral thrust from soil to wall and the Mononobe and Okabe (M-O) method to discover the complete active lateral thrust during seismic loading (static and earthquake-induced). For a long time, structural and geotechnical engineers depended on the use of the famous Mononobe-Okabe (M-O) technique to determine the lateral seismic stress acting on the wall. First, a 24.3 m deep and 150 m wide layer of soil is created and put into balance under the forces of gravity. Then part of the upper soil layer is excavated in lifts to a depth of 11.7 m and a width of 30 m. As each lift has been excavated, lateral pressure (shoring) is applied to retain the soil.Then the basement wall is built, re-establishing worldwide balance. In the next stage, the shoring pressures will be removed and the load transferred from the ground to the basement wall. Modelling the flexural conduct of the walls with yield times equivalent to the corresponding moment resistance.

Vasanth Acharya, Akshaya et al (2014) investigated the efficiency of framed structures under earthquakes, a non-linear static pushover evaluation was performed on a typical multi-storey parking structure. To achieve this goal, in SAP 2000, where the structure is open with rigid floors in all stories, a 3D framed multi-story car parking structure (G+3) is modeled. The impact on seismic performance was made by force irregularities in the present multi-storey car parking structure of R / C frames using nonlinear static push-over assessment based on computational models. It compares the base shear and displacement for the different load combinations in seismic zone IV in different strength irregularities from the non-linear analysis of the output.

The 3D analytical model of G+15 storied structures studied by Pardeshi was produced for symmetric and asymmetric construction models and evaluated using the ETABS software structural analysis tool. Mass and rigidity are two fundamental parameters for evaluating a structural system's dynamic reaction. Depending on the different parameters such as mass-stiffness distribution, foundation types and soil conditions, multi-story structures are treated differently. The results of the irregular structure analysis were compared with the regular structure.

2.3 Critical Appraisal: Maleki and Mahjoubi (2010) analyzed the retention of wall model for several soil wall systems using nonlinear time-history analysis by applying real earthquake records, but the analysis was not performed for the multi-story building with retention wall. Garavand et al (2010), the 3-D finite element dynamic computer program called ANSYS was used to study the soil structure interaction retaining wall. There is no study of a combined effect of multi-story building with retaining wall. Alireza Ahmdnia et al (2011), studied using 2D finite difference computer program called FLAC 6.00 to analyze the non-linear seismic response of the basement wall. A linear analysis of the history of time was not performed. Vasanth Acharya, et al (2014), studied using SAP 2000 to conduct a non-linear static pushover assessment on a typical multi-storey parking structure(G+3). Mahesh and Yogesh (2015), addressed the earthquake reaction of multi-storey symmetric construction is being studied by manual calculation and using ETABS 9.7.1 software.

Considering the effect of earthquake using different methods, a lot has been studied on RCC building. But RCC building behavior with retaining wall and its impact using Dynamic linear time history assessment was not conducted on multi-story building with retaining wall considering the interaction of the soil. Analyzing the outcomes of seismic activity on retaining wall and its impact on construction for distinct tales is therefore performed to study and compare them.

III. METHODOLOGY

3.1General

Since this research deals with the performance of considered constructions that are subject to earthquake forces, seismic analysis must be carried out. Seismic analysis is a sub-set of structural analysis, calculating a building structure's response to earthquakes. There are different techniques for conducting seismic analysis, which are outlined in the following paragraphs.

3.2 Types of Analysis Procedures:

Analysis can be performed after the structure has been modelled to determine the seismically induced forces within the structures. There are various analytical methods that provide varying degrees of precision. The assessment method can be classified based on three primary variables: type of external load applied, structural or structural material behavior, and sort of structural model chosen. The assessment may be further categorized as linear static analysis, linear dynamic analysis, non-linear static analysis, or non-linear dynamic analysis based on the type of internal action and structure behaviour.

Only periodic buildings with restricted height can use linear static analysis or equal static analysis. An elastic time history method can be used to perform linear dynamic analysis in two ways, either by method of superposition mode or by method of response spectrum. This assessment will in a better way generate the impact of greater vibration modes and the real distribution of forces within the elastic range. The techniques still suppose over the height of the structure a set of static incremental lateral load. The method is relatively simple to implement and provides information on the strength, deformation and ductility of the structure and demand distribution, which allows the identification of critical members likely to reach limit states during the earthquake, for which attention should be paid during the design and detailing process. But this technique includes restricted assumptions that neglect loading pattern variety, the impact of greater modes, and resonance effect.

The only technique to describe the structure's real behaviour during an earthquake is a non-linear dynamic analysis or inelastic time history analysis. By considering the elasto-plastic deformation of the structure element, the method is based on the direct numerical integration of the motion equations. This method captures the effect of amplification due to resonance, the variation of displacements at different levels of a frame, an increase in duration of motion, and a tendency of regularization of movements as the level increases from bottom to top.

3.2.1 Equivalent Static Method

Based on the lateral (horizontal) force assumed to be equivalent to the actual (dynamic) loading, seismic analysis of most structures is still carried out. This strategy describes a sequence of forces that act on a construction to represent the earthquake ground movement impact. Based on structure mass and fundamental vibration period and corresponding mode shape, the base shear which is the total horizontal force on the structure is calculated. The base shear is distributed according to the code formula along the height of the structure in terms of lateral forces. This technique is generally conservative with a periodic setup for low to medium height structures.

3.2.2 Response Spectrum Analysis

This technique applies to constructions where the structure's reaction is considerably affected by methods other than basic mode. This approach allows consideration of a building's multiple response modes. In this technique, the reaction of the multi-degree-of-freedom (MDOF) scheme is expressed as the overlap of modal reaction, each modal response being determined from the spectral assessment of single-degree-of-freedom (SDOF) processes, which is the mixed reaction to obtain the complete answer. Analysis of the computer can be used to determine the structure modes. For each mode, a response based on the modal frequency and the modal mass is read from the design spectrum and then combined to provide an estimate of the structure's total response. The model combination techniques used are:

- Absolute-maximum values are added together
- Square root sum of squares (SRSS)
- Complete quadratic combination–(CQC)

3.2.3 Linear Dynamic Analysis or Elastic Time History Analysis

Static processes are appropriate for brief periodic structures. A dynamic procedure is required for large buildings, buildings with torsional irregularities, or non-orthogonal systems. When non-linear behaviour is not involved, a linear time history analysis overcomes all the disadvantages of modal response spectrum analysis. However, this method is time consuming and requires greater computational effort at specified time intervals to calculate the response. The structure's response to ground motions is calculated in the time domain, so an interesting advantage is that the response history preserves relative signs of response quantities.

3.2.4 Non-Linear Static Analysis or Pushover Analysis

Linear processes are relevant when the structure is anticipated to stay almost elastic for ground movement levels or when the design findings in an almost uniform distribution of nonlinear reaction across the structure, linear processes are inconsistent from the performance point of perspective as better performance indicates higher inelastic requirements. A structure's pushover analysis is a static non-linear analysis under continuous vertical loads and lateral loads gradually increasing. Approximately the corresponding static lateral loads are forces caused by the earthquake. This assessment, which would show any premature failure or weakness, obtains a plot of total base shear vs. top displacement in a structure. The analysis is conducted to failure, allowing to determine collapse loads and ductility capacity. Load / displacement incrementally is applied on a building frame, plastic hinges are formed, stiffness degradation is monitored and plastic rotation is monitored and lateral inelastic force versus displacement response is analytically calculated for the entire structure. This sort of assessment makes it possible to identify weakness in the structure.

3.2.5 Non-Linear Dynamic Analysis or Inelastic Time History Analysis

Nonlinear dynamic analysis uses the combination of ground motion records with a detailed structural model, enabling results with relatively low uncertainty to be produced. The detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model in nonlinear dynamic analyzes and the modal responses are combined using schemes like the square-root-sum-of-squares. This is the most rational method of evaluating the performance of the building. Compared to past methods, this is the most strict and time consuming technique. However, some complications are engaged, such as biaxial inelastic reaction of columns, modelling of joint behaviour, interaction of flexural and shear strength, etc. The calculated reaction may also be very susceptible to the features of the individual ground movement used as seismic input; therefore, several analyzes are needed using separate ground movement records.

3.3 Time History Analysis Explanation

As explained earlier analyzes of time history are performed using earthquake ground motion records that have occurred before. Earthquake information typically in the form of moment and acceleration values are registered by machines known as accelerometers. An accelerometer is a tool used at certain runs of time to record seismic disturbances in the form of acceleration values.

3.3.2 Ground Motion Data

A time history record is the most popular way to describe a ground movement. The movement parameter can be a combination of acceleration, velocity, or displacement, or all three. Generally speed is the amount directly measured and the other parameters are the amounts obtained. However, it is also possible to measure displacement and velocity directly. Records ' measured time history includes mistakes from many sources, such as elevated and low frequency noise, base line error, and instrument error. Before being used, these mistakes are deleted from the information. In addition, measured information are digitized in an analogy form before being used as seismic inputs. Digital seismographs are more commonly used in recent years, but in the analogy and digital forms, the various errors mentioned above are equally present. Time records of ground movements are used directly for the evaluation of time domain constructions that are subject to seismic determinist inputs.

The ground motion data is then given as input to the software, which then calculates the structure response such as displacement, velocity, base shear etc. at discrete intervals of time. The ground movement is implemented in the form of loads of acceleration and not as periodic loads used for static analysis. Thus it is as if an earthquake acts on the structure that helps to understand a structure's accurate reaction in the event of an earthquake. This method is the most accurate of all seismic analysis methods provided the structure does not contain any non-linear behaviour.

3.3.3 Different Methods in Time History Analysis

Linear Direct Integration method: A direct-integration time-history solves equations for the entire structure at each time step, as compared with a modal time-history load case, which uses the method of mode superposition.
Non-linear modal method: As described earlier modal time-history analysis uses the method of mode superposition, compared with a direct-integration time-history, which solves equations for the entire structure at each time step. Additionally the structure is assigned with nonlinear properties in the model. Nonlinear modal time-history analysis is also called Fast Nonlinear Analysis (FNA). It is a highly efficient, special-purpose algorithm for analysing structures with limited nonlinearities.

3.4 Numerical Methods for Time History Analysis

1. A second order differential equation, which needs to be solve in order to obtain the displacement . This differential equation can be solved analytically or numerically. Numerical techniques for the solution of the equation will be shown subsequently as the implementation of time history analysis is done with the help of numerical time marching schemes.
2. The most widely used numerical approach for solving dynamic problems is the Newmark-method. It is a step-by-step numerical time integration scheme. Actually, It is a set of solutionmethods with different physical interpretations for different values of The total simulation time is divided into a number of intervals (usually of equal duration Δt) and the unknown displacement (as well as velocity and acceleration) is solved at each instant of time. The method solves the dynamic equation of motion in the (i + 1) th time step based on the results of the ith step.
3. In the solution set suggested by the Newmark-β method, the Constant Average Acceleration (CAA) method is the most popular because of the stability of its solutions and the simplephysical interpretations it provides.

IV. CASE STUDY DESCRIPTION

4.1 General: The study in this work is based on the analyses of a family of structural models representing multi-story symmetrical buildings. A total of 6 models have been considered in this study. The model is compared with and without soil interaction and hence the models were subjected to earthquake motion by using ground motion records.

The dimensions of members were decided based on span-depth considerations initially, then the structure was analysed and designed for gravity loads. The section parameters thus obtained were then used for the time history analysis.

Finite element software ETABS was used to carry out the linear time history analysis.

General Model Data

Models considered are of RCC with steel as rebar material

Concrete: M25 concrete adopted, therefore the characteristic compressive strength of concrete
fck = 25 N/mm^2
Modulus of concrete = E = 5000√fck = 25000

Steel:
Type of steel adopted for reinforcement = Fe500
Density = 78 kN/m^3; Modulus of elasticity = 2 x 10^5 MPa
Yield strength = fy = 500 N/mm^2; Ultimate strength Fu = 485 N/mm^2
BASIC DATA:
Length of spans in x & y directions = 5m
Height of floors = 3m
Height of bottom story =4.5m
Size of columns = 450mm x 450mm
Size of beam = 300 x 500 mm
Poisson ratio =0.4 (saturated soils)
Height of retaining wall = 3 m
Top width of retaining wall = 450mm
Bottom width of retaining wall=1800mm
Lateral earth pressure for single story = 60.75 kN/m
Lateral earth pressure for double story = 168.75 kN/m
Below are Model 1(without Soil structure interaction) & Model 2(with Soil structure interaction)

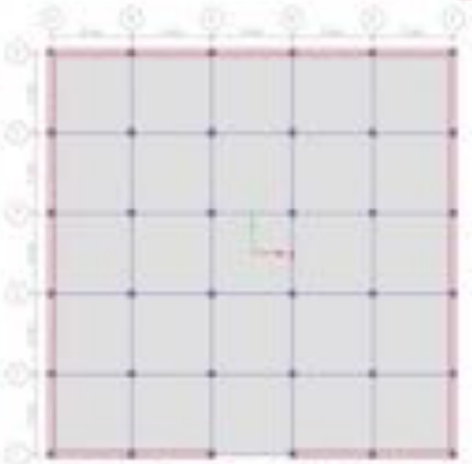


Fig. Showing Plan of 8 Storey Building (Model 1)

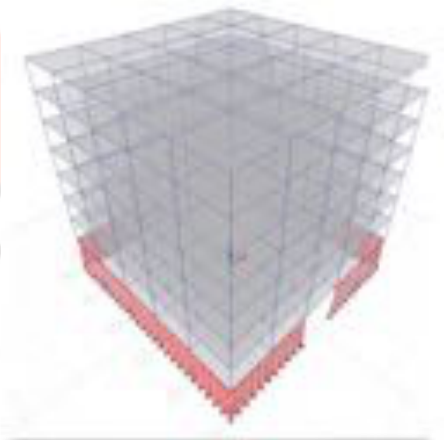


Fig. Showing 3D Elevation of 8 Storey Building (Model 1)

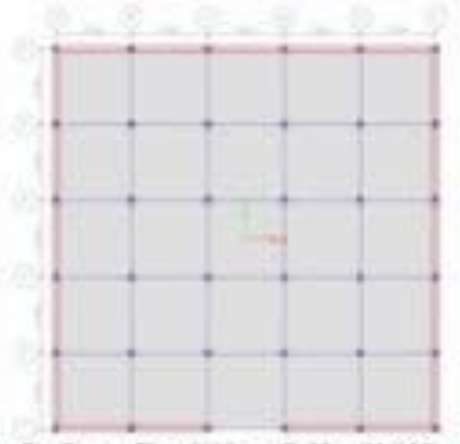


Fig. Showing Plan of 12 Storey Building (Model 2)

Fig. Showing 3D Elevation of 12 Storey Building (Model 2)

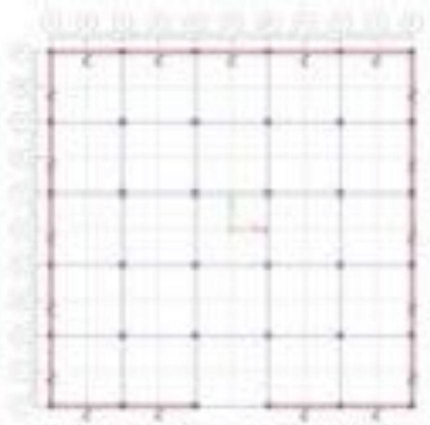


Fig. Showing Plan of 8 Storey Building (Model 1A)

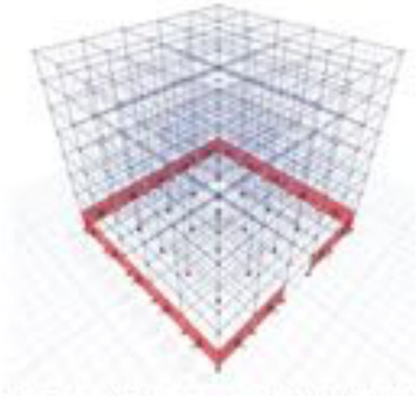


Fig . Showing 3D Elevation of 8 Storey Building (Model 1A)

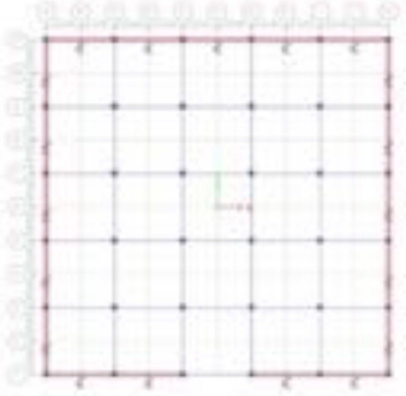


Fig. Showing Plan of 12 Storey Building (Model 2A)

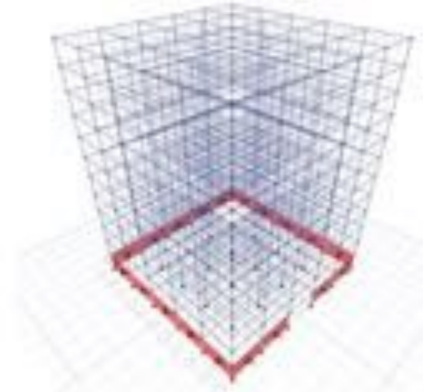


Fig. Showing 3D Elevation of 12 Storey Building (Model 2A)

Linear Time history analysis is performed on the analytical models. The detailed procedure is explained in the following chapter. Etabs has the capability of performing linear and non-linear time history analysis, in this study non-linearity hasn't been considered. Linear direct integration method for time history analysis was adopted as it's the most accurate and comprehensive, the only drawback being that its very time-consuming Newmark's method of numerical integration was selected for this process. The ground motion data selected is the Bhuj earthquake data, this data is in built in the software along with a few other prominent earthquake ground motion data. However, Bhuj data is the most widely adopted one.

4.3 About ETABS V13: All modelling and analysis was carried out in the ETABS v13 finite element software. ETABS is an engineering software product that provides assessment and design for multi-story construction. Modelling instruments and templates, code-based load prescriptions, methods of analysis and solution techniques all co-ordinate with grid-like geometry that is peculiar to this structure class. Basic or advanced systems can be evaluated using ETABS under static or dynamic conditions. Modal and direct-integration time-history analyzes can pair with P-Delta and Large Displacement impacts for a sophisticated evaluation of seismic performance. All of these characteristics and interoperability with a series of platforms for design and documentation make ETABS a coordinated and efficient design tool that ranges from easy 2D frames to elaborate contemporary high-rises. It's a CSI Inc product.

4.4 Basic Assumptions in Modelling

- All the columns in the houses are supposed to be joined by ground diaphragms rigid in their own plane. Therefore, each floor has only two degrees of freedom of translation and one degree of rotation. These degrees of freedom limit the in-plane displacements of all the nodes on the floor. The nodes, however, may have separate vertical displacements.
- Construction columns are supposed to be fixed on a rigid foundation at their base. In this research, the impact of soil-structure interaction is regarded.
- At the intersection of columns and ground diaphragms, only one direction of speed values is implemented. All supports are assumed to move in phase due to the fixed base assumption. The structures do not receive a vertical translation.

V. RESULTS AND DISCUSSION

5.1 General: The results obtained after the analysis have been compiled in this chapter. Many number of parameters may be considered for ascertaining the response of the structure however Select few parameters were considered for the sake of this study. They are presented in table form in this chapter. Then the results of models with and without soil interaction are presented. Their results are shown to ascertain the best of them.

5.2 Base Shear for Single Basement Floor Models: Seismic forces accumulate downward in a building, these forces are greatest at the base of the building. The seismic force at the base of the building is called as base shear. It is the maximum lateral force that will occur due to seismic ground motion at the base of the structure.

Table: Base Shear for Ground Motion in X Direction

Model	Max Base Shear (kN)
Model 1	3026.55 kN
Model 1A	4224.37 kN
Model 2	6423.44 kN
Model 2A	8655.24 kN
Model 3	6740.34 kN
Model 3A	9436.84 kN

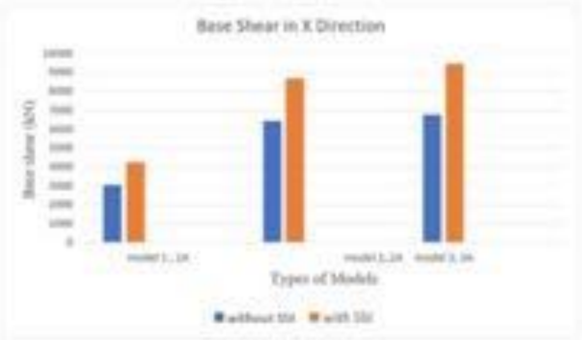


Fig. Base Shear for Ground Motion in X Direction

From the above Fig the base shear is maximum for the model 3 is 6740.37 kN. When soil structure interaction is considered the model 3 show maximum value of 9436.84 kN. The base shear is increasing when number of stories are increased.

Table: Base Shear for Ground Motion in Y Direction

Model	Max Base Shear (kN)
Model 1	6707.17 kN
Model 1A	7443.29 kN
Model 2	9510.82 kN
Model 2A	10658.47 kN
Model 3	11272.45 kN
Model 3A	13072.15 kN

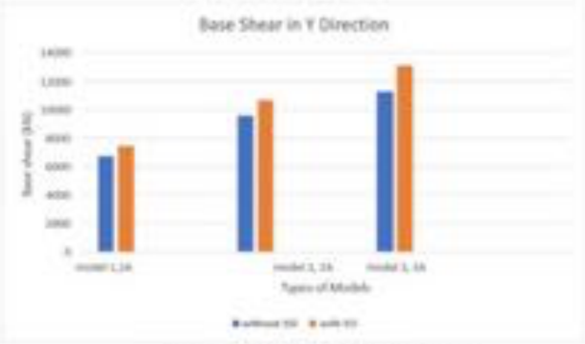


Fig. Base Shear for Ground Motion in Y Direction

From the above fig the base shears for models with soil interaction on retaining walls is increasing. Highest is observed for the model 3. The maximum base shear is for model 3A with 13072.15 kN and minimum base shear is observed in model 1 with 6707.15 kN.

5.3 Base Shear for Double Basement Floor Models

Table: Base Shear for Ground Motion in X Direction

Model	Max Base Shear (kN)
Model 4	12091.7 kN
Model 4A	13060.5 kN
Model 5	18060.09 kN
Model 5A	20078.45 kN
Model 6	19025.17 kN
Model 6A	20725.17 kN

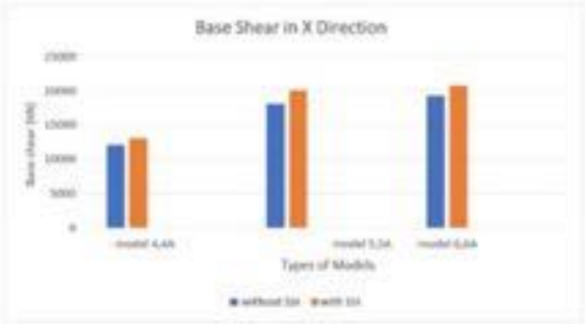


Fig. Base Shear in X Direction

From the fig base shear for Model 1 is 20000.17 kN without soil interaction and with soil structure interaction. The Model 3 show maximum base shear at bottom with a force 20078.45kN.

Table: Base Shear for Ground Motion in Y Direction

Model	Max Base Shear (kN)
Model 4	12091.7 kN
Model 4A	15066.5 kN
Model 5	19925.17 kN
Model 5A	20025.17 kN
Model 6	19710.69 kN
Model 6A	25480.45 kN

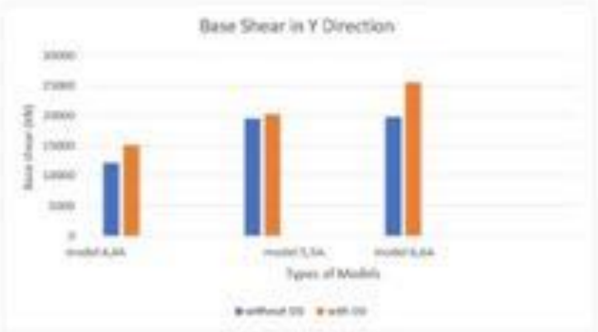


Fig. Base Shear in Y Direction

From the above fig 5.3.2 the base shear in Y direction is maximum for Model 6A with of 25480.45 kN when soil structure interaction is considered and minimum is for Model 4 without soil structure interaction.

5.4 Roof Displacement for Single Basement Floor Models

5.4.1 Roof Displacement Along X Direction

Roof Displacement along X direction for all Models

Model	Roof Displacement of All Models (mm)
Model 1	138.92 mm Storey 8
Model 1A	148.92 mm Storey 8
Model 2	116.39 mm Storey 12
Model 2A	152.38 mm Storey 12
Model 3	117.48 mm Storey 16
Model 3A	164.65 mm Storey 16

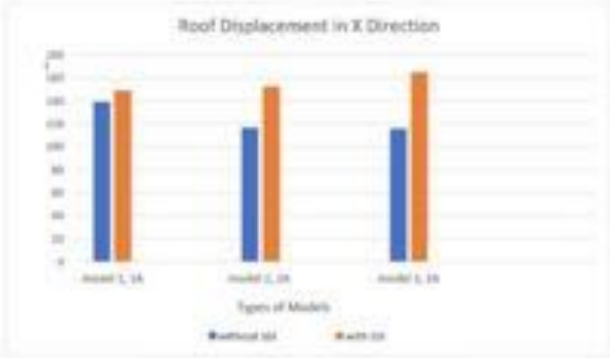


Fig: 5.4.1 Roof Displacement Along X Direction

From the above fig. the maximum roof displacement occurs at top storey. The model 3 show maximum displacement with soil structure interaction is164.65mm.

5.4.2 Roof Displacement along Y Direction

Roof Displacement along Y direction of all Models

Model	Roof Displacement of All Models (mm)
Model 1	140.02 mm Storey 8
Model 1A	152.42 mm Storey 8
Model 2	116.11 mm Storey 12
Model 2A	152.20 mm Storey 12
Model 3	115.34 mm Storey 16
Model 3A	171.78 mm Storey 16

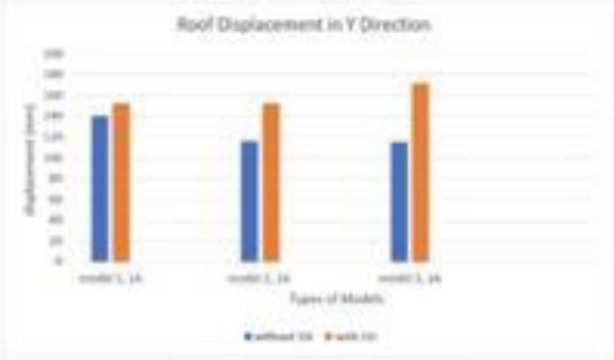


Fig: Roof Displacement along Y Direction

As is evident from the above charts showing the lateral displacement in top storeys since the analytical models are symmetrical lateral displacements are exhibited in one directions only as the ground motion is applied in a single direction at a time. For a regular perfectly symmetrical building where the lateral displacement occurs only along the axis along which the force (load or acceleration) is applied and there is a little to no displacement in the transverse direction as observed from the above models.This observation is significant in the sense that it demonstrates that the lateral force resisting elements must be well oriented along both the orthogonal directions.

In Model 1, Model 2 and Model 3 which are analysed without soil interaction the maximum displacement is in Model 3 for both the ground motion applied in X and Y direction. The model 3A is having displacement in X direction is greater than the displacement in Y direction. From the fig Model 1A, Model 2A and Model 3A which are analysed with soil interaction the maximum displacement is in Model 3A for both the ground motion applied in X and Y direction. The Model 3A is having displacement in Y direction is greater than the displacement in X direction.

5.5 Roof Displacement for Double Basement Floor Models

5.5.1 Roof Displacement along X direction

Roof Displacement along X direction for all Models

Model	Roof Displacement of all Models (mm)
Model 4	129 mm Storey 8
Model 4A	149 mm Storey 8
Model 5	92.72 mm Storey 12
Model 5A	149 mm Storey 12
Model 6	115.46 mm Storey 16
Model 6A	191.46 mm Storey 16

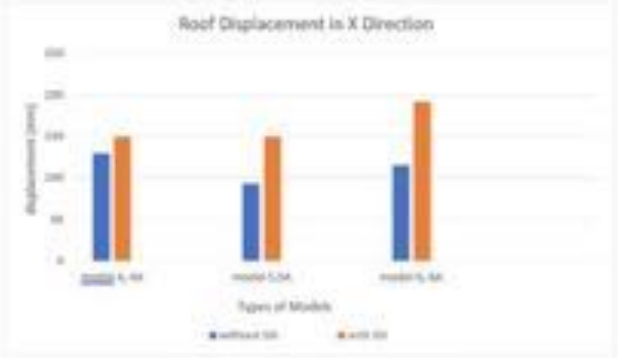


Fig: Roof Displacement Along X Direction

From the Fig., it is observed that the roof displacement is increasing when soil structure interaction considered. The roof displacement is maximum for model 6 with 115.46mm and minimum for model 4 with 129mm.

5.5.2 Roof displacement along Y direction

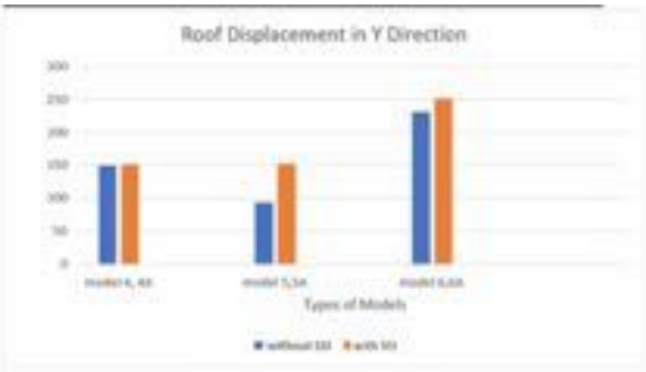


Fig: Roof Displacement along Y Direction

From the above fig., the maximum roof displacement is observed for Model 4, with and without structure interaction.

5.6 Story Drifts for Single Basement Floor

Story drift may be defined as the drift of one level of multi-storey building relative to level below. It is a unitless quantity. The greater the drift the greater is likelihood of damage.

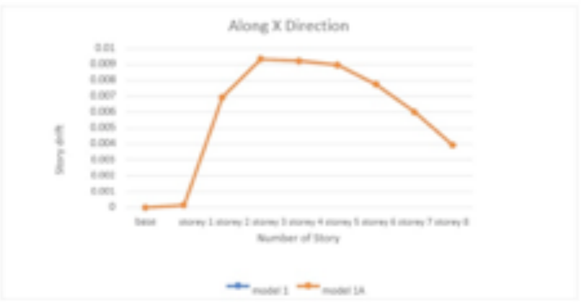


Fig 5.6.1 Story Drift for Model 1 in X Direction

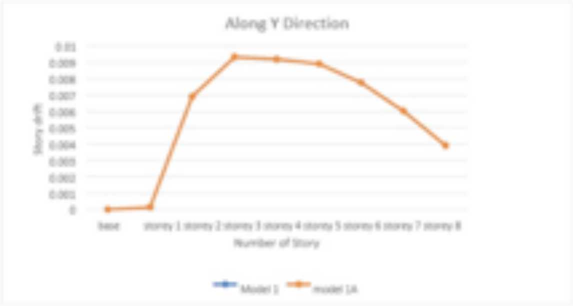


Fig 5.6.2 Story Drift for Model 1 in Y Direction

5.7 Story Drifts for Double Basement Floor

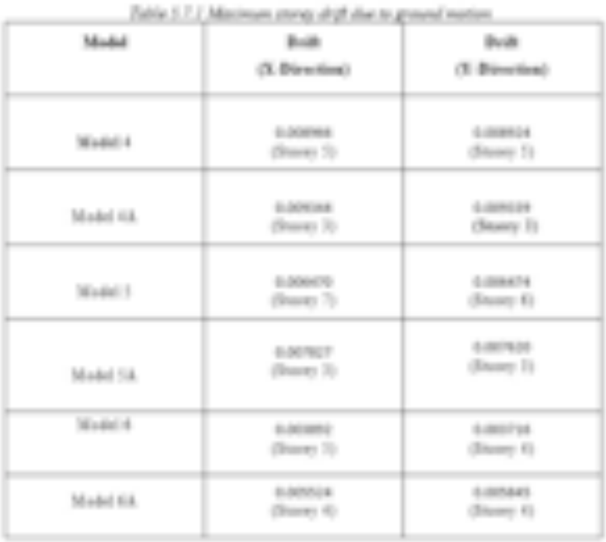
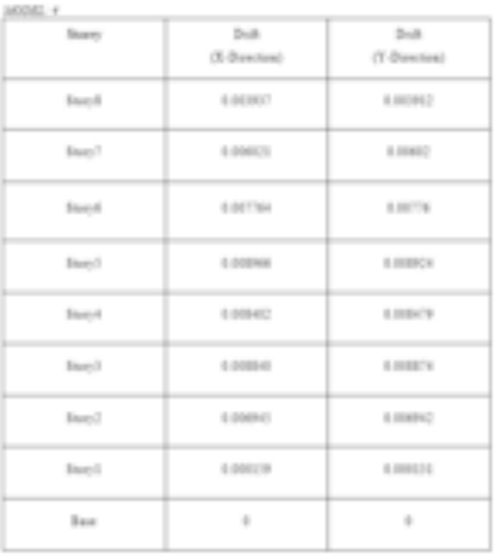


Table 5.7.1 Maximum storey drift due to ground motion



MODEL 4

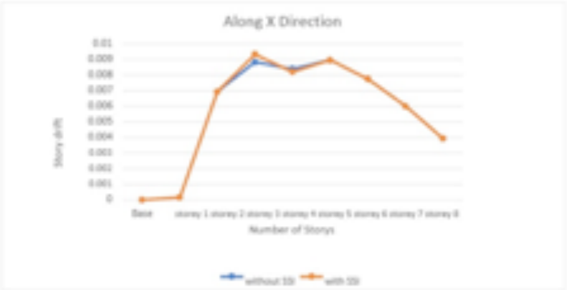


Fig 5.7.1 Story Drift for Model 4 in X Direction

Fig 5.7.2 Story Drift for Model 4 in Y Direction

From the above Fig 5.7.1 and Fig 5.7.2 the model 4 and model 4A is showing same value of storey drift for the ground motion applied in X and Y direction is 0.008964.

VI. SUMMARY AND CONCLUSION

6.1 Summary

Direct-integration time-history solves equations for the entire structure at each time step in linear time history analysis as compared to a modal time-history load case using the mode superposition method. Newmark's technique is the most commonly used numerical approach to solving dynamic issues. It is a system of numerical time integration step-by-step. During each small time interval the acceleration remains constant in this method, and this constant is assumed to be the average of the accelerations at the time ti and ti+1 in the two instants.

For 3 models with distinct story height, the seismic analysis is performed. Using linear time history study in ETABS, the models are given with single basement floor and double basement floor with lateral earth pressure acting on the retention wall. In relation to soil structure interaction, they are all 12 models with single cellar and double basement floor.

The effect of soil interaction on retaining walls was compared with selected few parameters. From the outcomes it is noted that, in relation to earthquake forces, the lateral pressure acting on the retaining wall shows that the displacement for model 1 is maximum. And when interaction with the soil structure is regarded as the basis and peak displacement is noted in Model 2. It is observed from the results that the models with interaction of the soil structure show the maximum earthquake response with lateral earth pressure acting on the retaining wall.

6.2 Conclusions

- The model with retaining wall considering lateral earth pressure acting on the retaining wall show that the effect of earthquake on the building is more compared to building without retaining wall.
- The models with single storey basement floor and double story basement floor show the maximum effect of lateral earth pressure acting on retaining wall is at the base of retaining wall and minimum at top surface of the retaining wall.
- From the graphs of single basement floor, the base shears is observed that for models with soil interaction on retaining walls is increasing compared to the models without soil interaction. The percentage increase is 34-40% and 10-15% for model 3 along X and Y direction respectively.
- From the graphs of double basement floor, the base shears it can be observed that for models with soil interaction on retaining walls is increasing compared to the models without soil interaction. The percentage increase is 8-11% and 28-30% along X and Y direction.
- The maximum story displacement occurs at top story and minimum at base. The maximum story displacement for single basement floor is observed in model 3 without soil interaction and when soil interaction is considered the maximum value is observed in model 3A. The percentage increase is 30-42% and is 30-48% along X and Y direction respectively for models with and without soil structure interaction. For double basement floor models the maximum roof displacement is increased by 15-30% and 60% along X and Y direction respectively.
- For single basement floor, the maximum storey drift in X-direction and Y direction is shown in model 1. For double basement floor the maximum story drift is observed in model4.

- Comparing the models with single basement and double basement the model 3 i.e 16 storey model have shown maximum effect of earthquake as compared to models with single basement floor models.
- From the results it is observed that the effect of soil structure interaction acting on the structure in addition to earthquake forces the displacement is increased.

Scope for Further Study

The further study can be carried out using different method of analysis for irregular buildings with different floor levels or different heights. It can be studied with mass irregularities and stiffness irregularities considering soil structure interaction

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