Seismic Behaviour of A Multi-story Building For Soft Ground

Project Report Submitted

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Sumitted By

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CERTIFICATE

Certified that NARAYAN NARROTAM (1160444007) has carried out the research work presented in this project entitled **“**Seismic Behaviour of A Multi-story Building For Soft Ground**”** for the award of Master of Technology in Structural Engineering from Babu Banarsi Das University, Lucknow under my supervision. This project embodies result of original work and studies carried out by student and the contents of the project do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Signature

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DECLARATION

I hereby declare that the project work entitled **“Seismic Behaviour of A Multi-story Building For Soft Ground”** is a record of an original work done by me under the guidance of Department of civil Engineering, **BABU BANARSI DAS UNIVERSITY, and LUCKNOW**. This project work is done in the fulfillment of the requirements for the master’s degree. This is a bona fide work carried out by me and the results provided in this project report have not been copied from any source. The results provided in this have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The purpose of this research work is to compare the behaviour of Multi-storey building using different support conditions for example ogs building, single sturt support, double strut or x support, v support and inverted v support in ground storey for various parameters such as storey drift, stiffness, base shear, max storey displacement, etc. This will be done using ETABS 16.2 version software. In this paper analysis of G+10 Multi-storey building is done under seismic loading and the result outcomes are compared using different parameters. Subsequently goal of this investigation is to check which bolster will give better quality and security of the structure during quake and to consider the impact of infill quality and solidness in seismic examination of OGS structures. This structure is examined for time history investigation technique (a) considering infill quality and firmness (open ground story), (b) Not considering infill quality and solidness (Bare casing). The aim of this research paper is to observe the response of multi-storey building under the parameters as per new version of seismic code (IS 1893:2016). This will help us to understand the behaviour of structure as per latest design criteria..

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

In this chapter, a brief definition is given for earthquake and then the most three important characteristics of ground motion, which are stiffness, storey drift, storey stiffness, peak ground acceleration (PGA), frequency content, and duration are presented. Furthermore, the seismic design philosophy is shortly explained.

Five regular building having different support in ground storey are discussed and ground motions of high-frequency content are subjected to the corresponding models and linear time-history analysis is performed using structural analysis and design (ETABS) software.

origin of the project is also shortly represented. A brief description about the significance of the research work. The objective and scope of the current work is explained in precise. At last, the procedures, which are used to accomplish the work, is presented in sections below .

Figure 1.1 Failure of OGS Building Due to Buckling

1.2 INTRODUTION

An earthquake is the result of a rapid release of strain energy stored in the earth's crust that generates seismic waves. Structures are vulnerable to earthquake ground motion and damages the structures. In order to take precaution for the damage of structures due to the ground motion, it is important to know the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, duration, drift, stiffness, and displacement. These characteristics play predominant rule in studying the behavior of structures under the earthquake ground motion.

Severe earthquakes happen rarely. Even though it is technically conceivable to design and build structures for these earthquake events, it is for the most part considered uneconomical and redundant to do so. The seismic design is performed with the expectation that the severe earthquake would result in some destruction, and a seismic design philosophy on this premise has been created through the years. The objective of the seismic design is to constraint the damage in a structure to a worthy sum. The structures designed in such a way that should have the capacity to resist minor levels of earthquake without damage, withstand moderate levels of earthquake without structural damage, yet probability of some nonstructural damage, and withstand significant levels of ground motion without breakdown, yet with some structural and in addition nonstructural damage.

In present work, five regular RC building models are designed and different supports are given in ground storey to resist earthquake movement. The buildings are modeled as three dimension and linear time history analysis is performed using structural analysis and design (ETABS) software.

1.3 Origin of Project

A few research is carried out to study the strength and support condition. Cakir studied the evaluation of the effect of earthquake frequency content on seismic behavior of cantilever retaining wall including soil-structure interaction. Also, Nayak & Biswal studied seismic behavior of partially filled rigid rectangular tank with bottom-mounted submerged block under low, intermediate, and high-frequency content ground motions.

No work is carried out on comparision of seismic behavior of RC buildings under varying supports like v support, inverted v support, single diagonal strut, and double diagonal strut ground motions. The present study deals with seismic behavior of reinforced concrete buildings.

1.4 Research Significance

The earth shakes with the passing of earthquake waves, which discharge energy that had been confined in stressed rocks, and were radiated when a slip broke and the rocks slide to release the repressed stress. The strength of ground quaking is determined in the displacement, drift, stiffness, acceleration, duration, and frequency content of the ground motion.

The responses of RC buildings are strongly dependent on the frequency content of the ground motions. Ground motions have different frequency contents such as low, intermediate, and high. Low, mid, and high-rise reinforced concrete buildings show different response under low, intermediate, and high-frequency content ground motions.

The present work shows that how different support condition of reinforced concrete buildings behave under low, intermediate, and high-frequency content ground motions.

1.5 Objective and Scope

The purpose of this project is to study the response of regular three-dimension RC buildings high-frequency content ground motions in terms of story displacement, story drift, story acceleration and base shear performing linear time-history analysis using ETAB software.

From the three dynamic characteristics of ground motion, which are PGA, duration, and frequency content, keeping PGA and duration constant and changing only the frequency content to see how high rise reinforced concrete buildings behave under high-frequency content ground motions.

1.6 Structural Analysis by E-TABS

In this study, behaviour of building during earthquake were deliberate by the help of ETABS. ETABS stands for Extended Three-dimensional Analysis of Building System. ETABS is an analysis and design software for analyzing and designing a building. ETABS is the present day leading design software in the market. Many design use this software companies for their project design purpose. So, this paper mainly deals with the comparative analysis of the results obtained from the analysis of a multi storey building structure when analyzed comparative analysis manually and using ETABS software separately. In this case, different support condition in ground storey should be used for a G +10 storey structure is modeled using ETABS software. The height of each storey is taken as 3meter making the total height of the structure 33 meter. Analysis of the structure is done and then the results generated by this software are compared with manual analysis of the structure using IS 1893:2002

ETABS is an engineering software for analysis and design of multistory structure. ETABS is in use for 30 years and is developed by Computers and Structures, Inc. (CSI). CSI was founded in 1975, is recognized globally as the pioneering leader in software tools for structural and earthquake engineering. Software from CSI is used by thousands of engineering firms in over 160 countries for the design of major projects. CSI also provides various different products for analyzing and designing of different structures as SAP2000, CSiBridge, ETABS, SAFE and PERFORM-3D .

ETABS is a 3D object based modeling and visualization software, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide- range of materials, and provides reports, and schematic drawings that allow quick and easy understanding of analysis and design results.

ETABS integrates every aspect of the engineering design process. Creation of models in ETABS is easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. ETABS also helps in Design of steel and concrete frames (with automated optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls. Models can be rendered, and all results can be seen directly on the structure. Comprehensive and customizable report is available for all analysis and design output, and schematic construction drawings of framing plans, schedules, details, and cross-sections may be generated for concrete and steel structures.ETABS has a wide selection of templates for quickly starting a new model. At this model template stage, the user has the ability to define grid and grid spacing, the number of stories. It follow various international codes which helps user to analyze and design the structure as per their code. Various kind of different load can be applied in etabs such as Super dead load, Live load, Seismic load, Wind load, etc. ETABS provides the support of IS 1893:2002 for seismic analysis of a building & provides the analysis results for various load combinations.

1.6.1 Features of ETABS

a. One Window, Many Views: - ETABS provides a single user interface to perform: Modeling, Analysis, Design, Detailing, and Reporting.

b. Templates: - ETABS has a wide selection of templates for quickly starting a new model. The user has the ability to define grid and grid spacing, the number of stories, the default structural system sections.

c. Automated Code Based loading: - ETABS will automatically generate and apply seismic and wind loads based on various domestic and international codes.

d. Load Cases and Combinations: - ETABS allows for an unlimited number of load cases and combinations. Load combination types.

e. Mixed Units: - ETABS gives users full control of the units used with all model data and displays results in the units desired. Whether architectural units or analysis results units, you can have any combination of units throughout your model.

f. Deformed Geometry: - Users can display deformed geometry based on any load or combination of loads, as well as animations of modes.

g. Reaction Diagrams: - Support reactions can be displayed graphically on the model either as vectors or as tabular plots for selected reaction components.

h. Report Generation: - The report generator features include an indexed table of contents, model definition information, and analysis and design results in tabulated format. Reports are viewable within ETABS 2013 with live document navigation connected to the Model Explorer and directly exportable to Microsoft Word.

1.6.2 History of ETABS

Etabs is originally development of TABS over 30 year by CSI.The software is used by millions of engineers over 160 countries and is leading tool for structural and earthquake engineering. ETABS was used to create the mathematical model of the Burj Khalifa, currently world's tallest building designed by Skidmore, Owings and Merrill (SOM).ETABS was used to analyze Taipei 101 Tower in Taiwan, One World Trade Center in New York, the 2008 Olympics Birds Nest Stadium in Beijing, etc. ETABS is commonly used to analyze: Skyscrapers, parking garages, steel & concrete structures, low rise buildings, portal frame structures and high rise buildings. Other CSI software also helped in designing the cable-stayed Centenario Bridge over the Panama Canal.

1.6.3 Objectives

a) To study behavior of high-rise RC building during earthquake.

b) Effect of seismic load on structure due to plan irregularity.

c) To compute lateral force on each levels due to seismic force.

d) To check the maximum allowable response of structure.

e) To study behavior of different shaped buildings in plan during earthquake.

f) Compute the torsional movement in structure due to irregularity in mass and stiffness.

g) To study the software and provide accurate and quicker analysis results by the use of ETABS.

1.7 Methodology

The following five support condition on ground motion records are taken, high-frequency content, have been considered for the analysis:

a) Simple open ground storey building without any infill.
b) Building with single strut support diagonally in ground storey.
c) Building with double diagonal strut in ground storey.
d) Building with v support in ground storey.
e) Building with inverted v support in ground storey.

Ground motion record are selected from Pacific Earthquake Engineering Research Center (PEER) Next Generation Attenuation (NGA) database. The ground motion record is the compatible time-history of acceleration as per spectra of IS 1893 (Part1) for structural design in India. The ground motion is the 1940 El Centro east west component.

All the above five structures having different support condition in ground storey are taken for study. In order to have same PGA, the above ground motions are scaled to magnitude of 6.2 g. Ground plus ten storey RC building, which are considered high-rise reinforced building are modeled as three-dimension regular reinforced concrete buildings in ETAB software. Then the ground motions are introduced to the software and linear time history analysis is performed.

The basis of the present work is to study the behavior of reinforced concrete buildings under varying support contents. This study shows high-rise reinforced concrete buildings behave in high-frequency content ground motions.

Here, the storey displacement, storey velocity, storey acceleration, and storey stiffness of high-rise regular reinforced concrete buildings due to ground motions of high-frequency content are obtained. The methodology, which is conducted, is briefly described as below:

a. Review the existing literature and Indian design code provision for designing the OGS building.
b. Ground motion records are collected and then normalized.
c. Linear time history analysis is performed in ETABS.
d. Building response such as story displacement, story drift, story acceleration, and base shear are found due to the ground motions.
e. The results of the five regular RC buildings are compared with respect to diffrent support condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In the literature review, characteristics of ground motion, that play vital rule in the seismic analysis of structures, explained. Then behavior of RC buildings under seismic loads are represented. There are few researches concerning to the seismic behavior of structures under frequency content.

Under lateral loading the frame and the infill wall stay intact initially. As the lateral load increases the infill wall get separated from the surrounding frame at the unloaded (tension) corner, but at the compression corners the infill walls are still intact. The length over which the infill wall and the frame are intact is called the length of contact. Load transfer occurs through an imaginary diagonal which acts like a compression strut. Due to this behavior of infill wall, they can be modeled as an equivalent diagonal strut connecting the two compressive corners diagonally. The stiffness property should be such that the strut is active only when subjected to compression. Thus, under lateral loading only one diagonal will be operational at a time. This concept was first put forward by holmes (1961).

2.2 Characteristics of Ground Motion

Ground motion at a specific site because of earthquakes is influenced by source, local site conditions, and travel path. The first relates to the size and source mechanism of the earthquake. The second defines the path effect of the earth as waves travel at some depth from the source to the spot. The third describes the effects of the upper hundreds of meters of rock and soil and the surface topography at the location. Powerful ground motions cause serious damages to made-up amenities and unluckily, From time to time, induce losses of human lives. Factors that affect strong ground shaking are magnitude, distance, site, fault type, depth, repeat time, and directivity and energy pattern.

R.Suresh (January2018) [1] The present study primarily focuses on the construct of Open Ground Storey (OGS) building. The collapse mechanism of such style of building is preponderantly owing to the formation of soft- storey behavior within the ground storey of this kind of building the IS 1893 code was revised in 2002, Incorporating new recommendations to handle OGS Frame buildings. in line with this clause 7.10.3(a) of a seismic code states: "The columns and beams of the soft-storey area unit to be designed for the multiplication factor of 2.5 times the structure shears and moments calculated foer seismic loads of bare frame". The given multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, However as knowledgeable by the engineer during the design, MF of 2.5 in not realistic for low and medium rise buildings. This calls for assessment and review of the code suggested multiplication factor for low rise and medium rise Open Ground Storey buildings. The objective of the paper is to check the applicability of the multiplication factor of2.5 within the seismic Analysis of a medium rise open ground storey building. A RC framed building (G+9) with open ground strorey Placed in Bhuj (seismic Zone-V)is thought about for this study. This building is analyzed for 2 different cases by response spectrum analysis method (a) considering infill strength and stiffness (open ground storey), (b) Not considering infill strength and stiffness (Bare frame). Infill Stiffness was created in ETABS by using Equivalent Diagonal Strut approach. ETABS software is used for Structural modelling and Response spectrum analysis. Analysis is carried out for these models and results were compared.

Sayali S Takale(feb 2018)[2] Open ground storey is typical and unavoidable feature in modern multi-storey construction in many countries like India. Studies of the building failed in past Earthquake shows that, open ground storey building are most vulnerable. In industrial practice, it is common to ignore the presence of infill wall for analysis of framed building but presence of infill wall alters the behavior of structure. Flexibility of soil also affects the behavior of structure, failing of consideration of effect of soil-structure interaction under-estimates the drift and strength demand in open ground storey column, resulting in incorrect design of building. In present paper, an extensive computational study has been conducted with soil-structure interaction, to find out the behavior of open ground storey building and their seismic vulnerability. Four different models are considered and comparative study is carried out. Infill stiffness is modeled using diagonal strut approach and soil stiffness is calculated as per FEMA. The models are analyzed for earthquake loads by both linear analysis and non-linear analysis by using commercial ETABS software.

Saquib mohidin (May2018)[3] In a framed structure, the presence of Infill Walls differ the behaviour of a building under the effect of Lateral loads and Engineers ignore the Stiffness of these Infill Walls during the analysis of a framed building. And this way of analyzing a building is believed to provide a conservative design. However this may not always work especially in case of discontinuous infill walls in the building. For some of the experienced engineers, the multiplication factor of 2.5 recommended by the IS-1893 to compensate discontinuity of stiffness doesn't seem realistic for low rise buildings. Therefore this nature of assessment calls for the review of code recommended multiplication factor. Hence the aim and the objective of this thesis will remain confined to check the nature and Applicability of multiplication factor 2.5 and moreover it relies onto the study of infill strength effect and stiffness in the Ground Storey Buildings with two different support conditions by using the commercial software SAP2000. As per the resulted analysis which showed that the multiplication factor 2.5 was too high for the Beam and Column forces of the low rise Open Ground Storey Buildings. Hence it was concluded that through the elastic analysis, the stiffness in both Open Ground Storey Buildings with Infill and in the similar framed building remains the same. Although the linear analysis shows that the influence in the response is considerably shown by the support conditions and therefore can be an essential parameter to decide the force strengthening factor.

Bhatlawande Priya Vithalrao(May 2018)[4] This paper aims to analyze ten sorey high rise building with different shapes in plan, using Time history method. Several frames were modeled in ETABS software and analyzed considering El Centro earthquake 1940. Various response parameters like base shear, storey drift and lateral displacement were found. It was observed that the various parameters such as base shear, storey drift and lateral displacement varies with different shapes of building.

Akshay S. Paidalwar(June 2017)[5] Soft storey due to increase storey height is well known subject. Change in amount infill walls between stories also results in soft story. These are usually not considered as a part of load bearing system. This study investigates the soft storey behavior due to lack of infills at ground floor storey and existence of this case by means of linear static and nonlinear static analysis for midrise reinforced concrete building. Soft storey behavior due to change in infill's amount is evaluated in view of the displacement, drift demand and structural behaviour.

Ragy Jose & Restina Mathew(June2017)[6] Structural Analysis is a branch which involves in the determination of behaviour of structures in order to predict the responses of different structural components due to effect of loads. Each and every structure will be subjected to either one or the groups of loads, the various kinds of loads normally considered are dead load, live load, earth quake load and wind load. ETABS (Extended Three Dimensional Analysis of Building System) is a software which is incorporated with all the major analysis engines that is static, dynamic, Linear and non-linear, etc. and especially this Software is used to analyze and design the buildings. Our project "Analysis and Design of Commercial building using ETABS software" is an attempt to analyze and design a commercial building using ETABS. A G+3 storey building is considered for this study. Analysis is carried out by static method and design is done as per IS 456:2000 guidelines. Also an attempt has been made to design the structural elements manually. Drawing and detailing are done using Auto CAD as per SP 34.

Sadanala Shree Ram(December 2017)[7] With the increase in population and development civilization, the demand for housing is increased at peak rate. Especially in towns due to rapid industrialization, the demand is very high. Adapting the Construction of G+5 Multistoried Buildings not only matches with demand but also decreases the price of single house. In our project, a Multistoried Building is analyzed and designed for live loads, dead loads and seismic loads. The process of modeling analysis and design of Beams and Columns is carried by using ETABS package and Slabs, Footings and Staircase is done manually. One column is Designed Manually and compared with ETABS Design. Initially we started with the designing of simple 2dimensional frames and manually checked the accuracy of the software with our results. Then according to the specified criteria assigned it analyses the structure and designs the members with reinforcement details for RCC frames.The minimum requirements pertaining(Be appropriate) to the structural safety of buildings are being covered by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, and other external loads. In order to be able to prevent or to minimize occurrence of cracks, it is necessary to understand basic causes of cracking and to have knowledge about certain properties of building materials, specification for mortar and concrete, Architectural design of building, structural design, foundation design, construction practices & techniques and environments.

Bhumik R. Gajjar(December2017)[8] Today in the metropolitan cities we are rapidly constructing multi-storey building for commercial and residential purposes but proper parking space is not available everywhere. Hence the trend has been made to use ground storey for the parking purpose so that ground storey is made open for parking purpose, no infill wall is provided in ground storey. The engineers did not consider strength and stiffness of the masonry wall, they think that it is traditional design. But this design is not always acceptable, especially for vertically irregular buildings with discontinuous infill walls. Hence the behavior of infill walls in the seismic analysis of framed building is prescriptive. Indian standard IS 1893: 2002 allows analysis of open ground storey building without taking infill stiffness but with a multiplication factor 2.5 in redemption for the stiffness discontinuity. As per the code the beam and columns of the open ground storey are designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames. But as per the experienced by the engineers the multiplication factor of 2.5 is not realistic for low rise open ground storey building. Hence the assessment of the multiplication factor and the effect of strength and stiffness in the seismic analysis of low rise low rise open ground storey building should be taken into account. Infill wall can be design in commercial software using two dimensional area elements with the properties of materials for linear elastic analysis. But this type of designed may not work for non-linear analysis until the non-linear material properties for a two-dimensional orthotropic element is not very well understood. Because the problem of open ground storey cannot be identified elastic analysis as the stiffness of open ground storey and bare frame is same. As per non-linear analysis of the OGS building fails through the soft storey mechanism at a comparatively low base shear and displacement and mode of failure is looks like a brittle. Hence seismic design of an existing reinforced concrete framed building would require a non-linear analysis. Hence in this paper area recommends a linear diagonal strut approach to model infill wall for both linear (Equivalent Static Analysis and Response Spectrum Analysis) and non-linear analysis (Pushover Analysis and Time History Analysis). In this paper we analyse RC framed building (G+3) with open ground storey located in Seismic Zone- V. In this study building analyzed for two different cases: (1) considering both infill mass and infill stiffness and (2) considering infill mass but without considering infill stiffness. In this analysis support conditions of the building also affect the significant parameter for the multiplication factor.

Ashitosh C.Rajurkar (May2016)[9] Today all over the world, multistoried buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still largely practiced in the developing nations. Social and functional need to provide car parking space at ground level gives the warning against such buildings from engineering community. The building is being modeled as an 3D space frame with six degrees of freedom at each node using the software STAAD-Pro V8i. Analysis is performed for Bare Frame,Bare frame having open ground storey, Frame with infill wall, open ground story frame, frame with stiffer column size having open ground storey. Results are obtained for axial force, shear and moments for columns and are compared.

Deepak(June 2016)[10] Surveys of buildings failed in the past earthquakes show that this types of buildings are found to be one of the most vulnerable. The majority of buildings that failed during the Bhuj earthquake (2001) and Gujraat earthquake were of the open ground storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behavior in the ground storey of this type of building. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the columns of ground storey under seismic loading. In conventional design practice, the contribution of stiffness of infill walls present in upper storeys of OGS framed buildings are ignored in the structural modelling (commonly called bare frame analysis). Design based on such analysis, results in under-estimation of the bending moments and shear forces in the columns of ground storey, and hence it may be one of the reasons responsible for the failures observed. After the Bhuj earthquake took place, the IS 1893 code was revised in 2002, incorporating new design recommendations to address OGS framed buildings. According to this clause 7.10.3(a) of the same code states: “The columns and beams of the soft-sto rey are to be designed for the multiplication factor of 2.5 times the storey shears and moments calculated under seismic loads of bare frame”. The prescribed multiplication factor (MF) of 2.5, applicable for all OGS framed buildings, is proved to be fairly higher and suggests that all existing OGS framed buildings (those designed to earlier codes) are highly vulnerable under seismic loading. This MF value however does not account for number of storeys, number of bays, type and number of infill walls present, etc and hence it is independent of all of the above factors. Present study deals with various aspects related to the performance of OGS buildings. The values of magnification factor recommended in literatures vary from 1.0 to 4.8 (Kaushik, 2009).The main objective of present study is the study of comparative performance of OGS buildings designed according to various MFs using nonlinear analysis. As the more realistic performance of the OGS building requires the modelling the stiffness and strength of the infill walls, the stiffness and strength of the infill walls also considered. The variations in the type of the infill walls using in Indian constructions are significant. Depending on the modulus of elasticity and the strength, it can be classified as strong or weak. The two extreme cases of infill walls, strong and weak are considered in the study. The behavior of buildings depends on the type of foundations and soils also. Depending on the foundations resting on soft or hard soils, the displacement boundary conditions at the bottom of foundations can be considered as hinged or fixed. As the modeling of soils is not in the scope of the study, two boundary conditions, fixed and hinged, that represent two extreme conditions are considered.

Karunkanti Aparna(July2016)[11] Presence of infill walls in the frames adjusts the conduct of the working under horizontal burdens. Notwithstanding, it is regular industry practice to overlook the stiffness of infill divider for examination of confined building. Engineers trust that examination without considering infill stiffness prompts a preservationist outline. In any case, this may not be constantly valid, particularly for vertically unpredictable buildings with broken infill walls. Thus, the displaying of infill walls in the seismic examination of confined buildings is basic. Indian Standard IS 1893: 2002 permits investigation of open ground story buildings without considering infill stiffness however with a duplication element 2.5 in pay for the stiffness irregularity. According to the code the segments and light emissions open ground story are to be intended for 2.5 times the story shears and minutes computed under seismic heaps of uncovered frames (i.e., without considering the infill stiffness). Notwithstanding, as experienced by the architects at outline workplaces, the augmentation element of 2.5 is not reasonable for low ascent buildings. This requires an evaluation and audit of the code suggested duplication variable for low ascent open ground story buildings. Along these lines, the goal of this proposition is characterized as to check the material of the augmentation variable of 2.5 and to consider the impact of infill quality and stiffness in the seismic examination of low ascent open ground story building.

Ms. Kavita R. Kapadni(November 2015)[12]- The study incorporates an examination of the accordion effects such as stresses, deflection, shear limit and lateral-torsional buckling presence in regular I section simply supported gantry crane beam subjected to a consistently uniform distributed (selfweight) and an aggregated load at the intermediate section of the beam. The lateral torsional buckling and bending are the main failure mode that controls the design of a beam. Diverse states of simply supported beam is proposed in this study with distinctive cross area, web shapes and materials. Structural analysis and test study are completed on both sorts for customary and proposed beam to ascertain and approve results. An enhancement system is utilized to advance the arrangement over regular I section beam. FEA software is the most efficient tool to carry out structural analysis is done to examine the influence of the section dimension due to point load at middle span and uniformly distributed load on beam. Using the study it is observed that not only the web thickness, but also the shape of web and cross section of beam influences the resistance accordion effects.

Somani Kishangopal (Feb 2015)[13] RC framed buildings are generally designed without considering the structural action of masonry infill walls. These masonry infill walls are widely used as partitions and considered as non-structural elements. But they affect both the structural and non-structural performance of RC buildings during earthquake. RC framed building with open ground storey is known as soft storey, which performs poorly during earthquake. In order to study this total 144 RC framed buildings having bare frame, full infill frame and open ground storey frame were analyzed by seismic coefficient method and response spectrum method for various seismic hazards. The present study deals with the comparison of base shear for medium rise RC framed buildings having P+5, P+7, P+9 and P+11 storeys for various seismic zones (III, IV & V) and for various soil conditions (Hard & Medium) as per IS 1893(part 1): 2002. This work helps in understanding the effect of earthquake with increase in height of RC framed buildings on base shear for various seismic zones and soil conditions. The result shows that the effect of infill stiffness on structural response is significant under lateral loads. It is found that the presence infill walls increases the base shear by 60-65% more than bare frame by both seismic coefficient method and response spectrum method.

Piyush Tiwari(Oct 2015)[14] Open ground building (OGS) has taken its place in the Indian urban environment due to the fact that it provides much needed parking facility in the ground storey of the building. Surveys of buildings failed in past earthquakes show that this types of buildings are found to be one of the most vulnerable. Presence of infill walls in the frame alters the behavior of the building under lateral loads. However, it's common industry practice to ignore the stiffness of infill wall for analysis of framed building. Design based on such analysis results in under-estimation of building moments and shear forces in the columns of ground storey and hence it may be one of the reasons responsible for the failure observed. IS code 1893:2002 allows the analysis of open ground storey RC framed building without considering infill stiffness but with a multiplication factor of 2.5 in compensation for stiffness discontinuity. As per the code" The columns and Beams of soft storey building are to be designed for 2.5 times the storey shears and bending moments calculated under seismic loads of bare frames. However, as experienced by the engineer at design offices, MF of 2.5 in not realistic for low and mid rise buildings. This calls for assessment and review of the code recommended multiplication Factor for low rise and mid rise OGS buildings. Therefore objective of this study is to check the applicability of multiplication factor of 2.5 and to study the effect of infill strength and stiffness in seismic analysis of OGS buildings. Three Different models of existing RC framed building with open ground storey located in Seismic Zone V is considered for the study using commercial Etabs Software. Infill Stiffness with openings was modeled using a Diagonal Strut approach. Linear and NonLinear analysis is carried out for these models and results were compared.

Abhay Guleria(May2014)[15] The case study in this paper mainly emphasizes on structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I-shape. Modelling of 15- storeys R.C.C. framed building is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analyzed cases.

Saurobh Youldash(May 2014)[16] Earthquake is the result of sudden release of energy in the earth's crust that generates seismic waves. Ground shaking and rupture are the major effects generated by earthquakes. It has social as well as economic consequences such as causing death and injury of living things especially human beings and damages the built and natural environment. In order to take precaution for the loss of life and damage of structures due to the ground motion, it is important to understand the characteristics of the ground motion. The most important dynamic characteristics of earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant rule in studying the behavior of structures under seismic loads.The strength of ground motion is measured based on the PGA, frequency content and how long the shaking continues. Ground motion has different frequency contents such as low, intermediate, and high. Present work deals with study of frequency content of ground motion on reinforced concrete (RC) buildings. Linear time history analysis is performed in structural analysis and design (STAAD Pro) software. The proposed method is to study the response of low, mid, and high- rise RC buildings under low, intermediate, and high- frequency content ground motions. Both regular and irregular three-dimension two, six, and twenty-story RC buildings with six ground motions of low, intermediate, and high-frequency contents having equal duration and PGA are studied. The response of the buildings due to the ground motions in terms of story displacement, story velocity, story acceleration, and base shear are found. The responses of each ground motion for each type of building are studied. The results show that low- frequency content ground motions have significant effect on both regular as well as irregular RC buildings. However, high-frequency content ground motions have very less effect on responses of the regular as well as irregular RC buildings.

P D Kumbhar(August 2013)[17] Study of nonlinear dynamic analysis of Ten storied RCC building considering different seismic intensities is carried out and seismic responses of such building are studied. The building under consideration is modeled with the help of SAP2000-15 software. Five different time histories have been used considering seismic intensities V, VI, VII, VIII, IX and X on Modified Mercalli's Intensity scale (MMI) for establishment of relationship between seismic intensities and seismic responses. The results of the study shows similar variations pattern in Seismic responses such as base shear and storey displacements with intensities V to X. From the study it is recommended that analysis of multistoried RCC building using Time History method becomes necessary to ensure safety against earthquake force.

Jayesh. A. Dalal,(May 2013)[18] Latticed shell tube – RC core walls are new structural systems, with RC core walls in center and latticed shell tubing system on the outside. The shear rigidity of RC core wall is larger for lateral wind forces are the external latticed shell tube are more useful. The combination of these two system can achieve a powerful lateral forces resisting system. With above point of view, the model with different bracing systems such as X, Inverted V, and V with different numbers of stories are prepared in ETABS 9.7.1 software. For earthquake Time History Analysis were applied. Analytical results are compared to achieve the most suitable resisting system against the lateral forces.

C.V.R.Murty(May1997)[20] Open first storey is a typical feature in the modern multistorey constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. This paper highlights the importance of explicitly recognizing the presence of the open first storey in the analysis of the building. The error involved in modeling such buildings as complete bare frames, neglecting the presence of infills in the upper storeys, is brought out through the study of an example building with different analytical models. This paper argues for immediate measures to prevent the indiscriminate use of soft first storeys in buildings, which are designed without regard to the increased displacement, ductility and force demands in the first storey columns. Alternate measures, involving stiffness balance of the open first storey and the storey above, are proposed to reduce the irregularity introduced by the open first storey. The effect of soil flexibility on the above is also discussed in this paper.

CHAPTER 3

STRUCTURAL MODELING

3.1 Overview

Concrete is the most widely used material for construction. It is strong in compression, but weak in tension, hence steel, which is strong in tension as well as compression, is used to increase the tensile capacity of concrete forming a composite construction named reinforced cement concrete. RC buildings are made from structural members, which are constructed from reinforced concrete, which is formed from concrete and steel. Tension forces are resisted by steel and compression forces are resisted by concrete. The word structural concrete illustrates all types of concrete used in structural applications.

In this chapter, building description is presented. The plan, elevation of single strut support, double diagonal support, v support, inverted v support, and open groud storey regular reinforced concrete high rise buildings are shown . Gravity loads, dead as well as live loads, are described and elaborated. A brief description is provided for concrete and steel. Also, the concrete and steel bar properties which are used for modeling of the buildings are shown. At the end of this chapter, the size of structural elements are presented.

3.2 SEISMIC ANALYSIS

For the determination of seismic responses there is necessary to carry out seismic analysis of structure. The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as:

a) Linear Static Analysis,
b) Nonlinear Static Analysis,
c) Linear Dynamic Analysis; and
d) Nonlinear Dynamic Analysis.

3.2.1Linear static analysis or equivalent static method

It can be used for regular structure with limited height. Linear dynamic analysis can be performed by response spectrum method. The significant difference between linear static and linear dynamic analysis is the level of the forces and their distribution along the height of structure.

Nonlinear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of structure. A nonlinear dynamic analysis is the only method to describe the actual behaviour of a structure during an earthquake. The method is based on the direct numerical integration of the differential equations of motion by considering the elasto-plastic deformation of the structural element.

This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one-it requires less computational efforts and is based on formulate given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individuals lateral load resisting elements.

3.2.2Nonlinear Static Analysis

It is practical method in which analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure. Non linear static analysis is the method of seismic analysis in which behavior of the structure is characterized by capacity curve that represents the relation between the base shear force and the displacement of the roof. It is also known as Pushover Analysis.

3.2.3Linear Dynamic Analysis

Response spectrum method is the linear dynamic analysis method. In that method the peak response of structure during an earthquake is obtained directly from the earthquake response, but this is quite accurate for structural design applications .

3.2.4Nonlinear Dynamic Analysis

It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake

time history is required for a structure being evaluated. Time history analysis is a step-bystep analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake.

3.3Regular RC Buildings

The vulnerability of an element is defined as the probability that the said element will sustain a specified degree of structural damage given a certain level of ground motion severity. A large number of existing buildings in India need seismic evaluation due to various reasons such as, nonconformity with the codal requirements, revision of codes and design practice and change in the use of building. Building fragility curves are lognormal functions that describe the probability of reaching, or exceeding, structural and nonstructural damage states when it is subjected to certain ground motion intensity. These curves take into account the variability and uncertainty associated with capacity curve properties, damage states and ground shaking.

Here we a G+ 10 story regular reinforced concrete buildings, which high- rise, are considered. The beam length in (x) transverse direction is 4m and in (z) longitudinal direction 5m. Figure 3.1 shows the plan of the buildings having five bays in x-direction and five bays in y-direction. Story height of each building is assumed 3m of every RC building respectively. For simplicity, both the beam and column cross sections are assumed 350 mm x 450 mm. Throughout the study different bracing configurations were analyzed using five different types of bracings. These types of bracings include V-bracing, X-bracing, Inverted V-bracing (V-bracing), open ground storey(without bracings), and single cross bracing. To start the parametric analysis the most well-known and highly used approaches to effectively brace a building were modeled first. These include: bracing the ground bay only upon analyzing layouts, more specific differences were looked at including: different orientations of members, adding additional bracing at problem areas of the structure, bracing through multiple floors which are considered for next study.

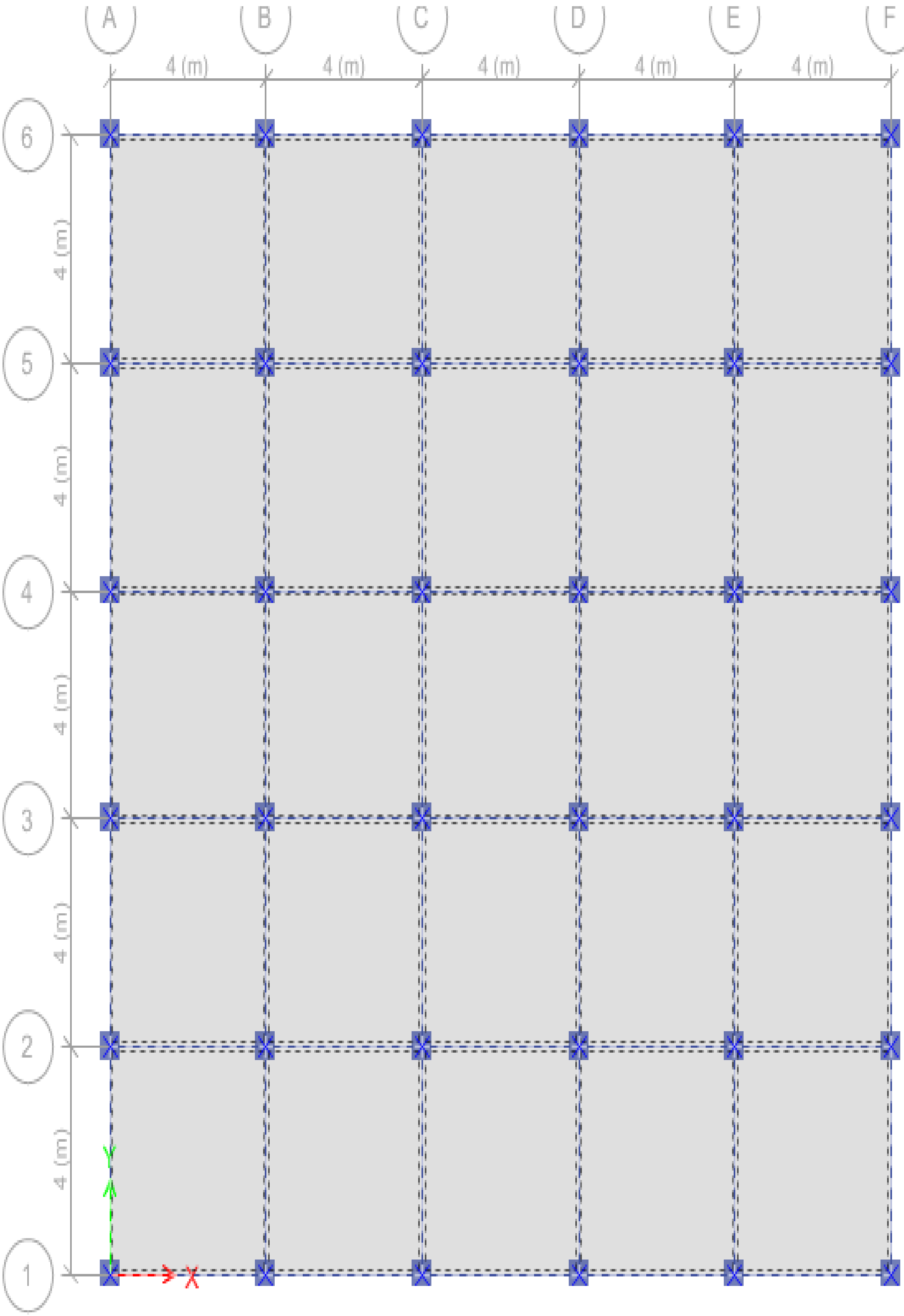


Figure 3.1 building plan of RC structure used for analysis.

3.4 Properties Of Building

Property information for materials, fram e sections, shell sections.

3.4.1 Materials

Table 3.1 - Material Properties - Summary

Name	Type	E MPa	N	Unit Weight kN/m³	Design Strengths
A416Gr270	Tendon	196500.6	0	76.9729	Fy=1689.91 MPa, Fu=1861.58 MPa
A615Gr60	Rebar	199947.98	0.3	76.9729	Fy=413.69 MPa, Fu=620.53 MPa
HYSD415	Rebar	200000	0	76.9729	Fy=415 MPa, Fu=485 MPa
M20	Concrete	22360.68	0.2	24.9926	Fc=20 MPa

3.4.2 Frame Sections

Table 3.2 - Frame Sections - Summary

Name	Material	Shape
BEAM 230 X 450	M20	Concrete Rectangular
COLUMN	M20	Concrete Rectangular

3.4.3 Shell Sections

Table 3.3 - Shell Sections - Summary

Name	Design Type	Element Type	Material	Total Thickness Mm
SLAB 150 MM	Slab	Shell-Thin	M20	150

3.5 Loads

This chapter provides loading information as applied to the model.

3.5.1 Load Patterns

Table 3.4 - Load Patterns

Name	Type	Self Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	1	
SEISMIC X	Seismic	1	IS1893 2002
SEISMIC Y	Seismic	1	IS1893 2002

3.5.2 Auto Seismic Loading

IS1893 2002 Auto Seismic Load Calculation

This calculation presents the automatically generated lateral seismic loads for load pattern SEISMIC X according to IS1893 2002, as calculated by ETABS.

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 5% for all diaphragms

Structural Period

Period Calculation Method = Program Calculated

Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2]	$Z = 0.36$
Response Reduction Factor, R [IS Table 7]	$R = 5$
Importance Factor, I [IS Table 6]	$I = 1$
Site Type [IS Table 1] = II	

Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5] $\frac{S_a}{g} = \frac{1.36}{T}$ $\frac{S_a}{g} = 0.839218$

Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

3.5.3 Load Cases

Table 3.5 - Load Cases - Summary

Name	Type
Dead	Linear Static
Live	Linear Static
SEISMIC X	Linear Static
SEISMIC Y	Linear Static
TIME HISTORY ELENCETRO	Linear Modal History

3.5.4 Load Combinations

Table 3.6 - Load Combinations

Name	Load Case/Combo	Scale Factor	Type	Auto
DCon1	Dead	1.5	Linear Add	Yes
DCon2	Dead	1.5	Linear Add	Yes
DCon2	Live	1.5		No
DCon3	Dead	1.2	Linear Add	Yes
DCon3	Live	1.2		No
DCon3	SEISMIC X	1.2		No
DCon4	Dead	1.2	Linear Add	Yes
DCon4	Live	1.2		No
DCon4	SEISMIC X	-1.2		No
DCon5	Dead	1.2	Linear Add	Yes
DCon5	Live	1.2		No
DCon5	SEISMIC Y	1.2		No
DCon6	Dead	1.2	Linear Add	Yes
DCon6	Live	1.2		No
DCon6	SEISMIC Y	-1.2		No
DCon7	Dead	1.5	Linear Add	Yes
DCon7	SEISMIC X	1.5		No
DCon8	Dead	1.5	Linear Add	Yes
DCon8	SEISMIC X	-1.5		No
DCon9	Dead	1.5	Linear Add	Yes
DCon9	SEISMIC Y	1.5		No
DCon10	Dead	1.5	Linear Add	Yes
DCon10	SEISMIC Y	-1.5		No
DCon11	Dead	0.9	Linear Add	Yes
DCon11	SEISMIC X	1.5		No
DCon12	Dead	0.9	Linear Add	Yes
DCon12	SEISMIC X	-1.5		No
DCon13	Dead	0.9	Linear Add	Yes
DCon13	SEISMIC Y	1.5		No
DCon14	Dead	0.9	Linear Add	Yes
DCon14	SEISMIC Y	-1.5		No

G+ 10 storey regular reinforced concrete buildings, which are high-rise, are considered. The beam length in (x) transverse direction is 4m and in (y) longitudinal direction 4m. Figure 3.1 shows the plan of the buildings having five bays in x-direction and five bays in y-direction. Story height of each building is assumed 3m. For simplicity, both the beam and column cross sections are assumed 230 mm x 450 mm. Now we have to apply elcentro time history data to see the displacement ,drift ,stiffness and frequency or time period of the given building.

3.6 Properties on which analysis is done

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or nonbuilding) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit (see structural engineering) in regions where earthquakes are prevalent. A building has the potential to 'wave' back and forth during an earthquake (or even a severe wind storm). This is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings, however, have higher modes of response, which are uniquely activated during earthquakes. The figure just shows the second mode, but there are higher 'shimmy' (abnormal vibration) modes. Nevertheless, the first and second modes tend to cause the most damage in most cases. Earthquake engineering has developed a lot since the early days, and some of the more complex designs now use special earthquake protective elements either just in the foundation (base isolation) or distributed throughout the structure. Analyzing these types of structures requires specialized explicit finite element computer code, which divides time into very small slices and models the actual physics, much like common video games often have "physics engines". Very large and complex buildings can be modeled in this way.

3.6.1 Storey Drift

It is defined as ratio of displacement of two consecutive floor to height of that floor. It is very important term used for research purpose in earthquake engineering.

3.6.2 Storey Displacement-

It is total displacement of ith storey with respect to ground and there is maximum permissible limit prescribed in IS codes for buildings.

3.6.3 Storey stiffness

The lateral stiffness Ks of a story is generally defined as the ratio of story shear to story drift. For frames subjected to regular lateral, load distributions, variations in the lateral stiffness of a given story for the several load cases are small enough to be neglected.

3.6.4 Time period and frequency

A time period (denoted by 'T') is the time taken for one complete cycle of vibration to pass a given point. As the frequency of a wave increases, the time period of the wave decreases. The unit for time period is 'seconds'.

Frequency is the number of times that a wave, especially a light, sound, or radio wave, is produced within a particular period, especially one second

Time period and frequency are appropriate tools for non-stationary signal analysis, synthesis, and processing. Different types of time frequency distribution have been developed for that purpose. The time-frequency distribution ideally describes how the energy is distributed, and allows us to estimate the fraction of the total energy of the signal at time t and at frequency ω . The below table statement states that the energy should be positive. In order to achieve fine simultaneous time-frequency resolution in a non-stationary time series, we must deal with the uncertainty principle. The strongest in amplitude and apparent large duration (labeled as H1) is located at the lowest frequency contained in the earthquake record. In this case the large duration is in relative comparison with the other observed frequency components.

3.7 Models And Its Properties

3.7.1 Basic Model of RC Buildings Having No Infill in Ground Storey

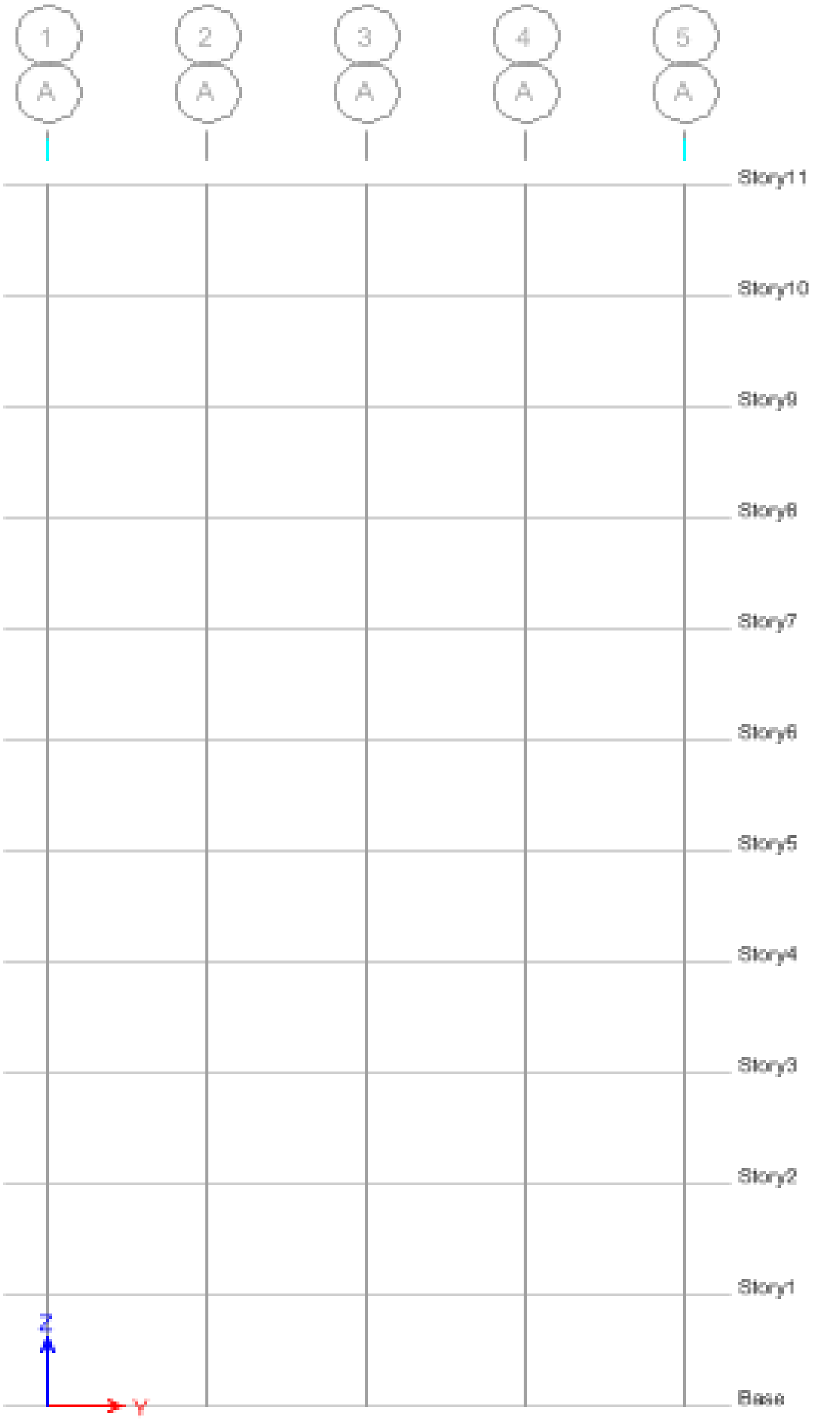


Figure 3.2 Elevation of OGS Building Having No Support in Ground

Maximum Storey Displacement of OGS Bilding

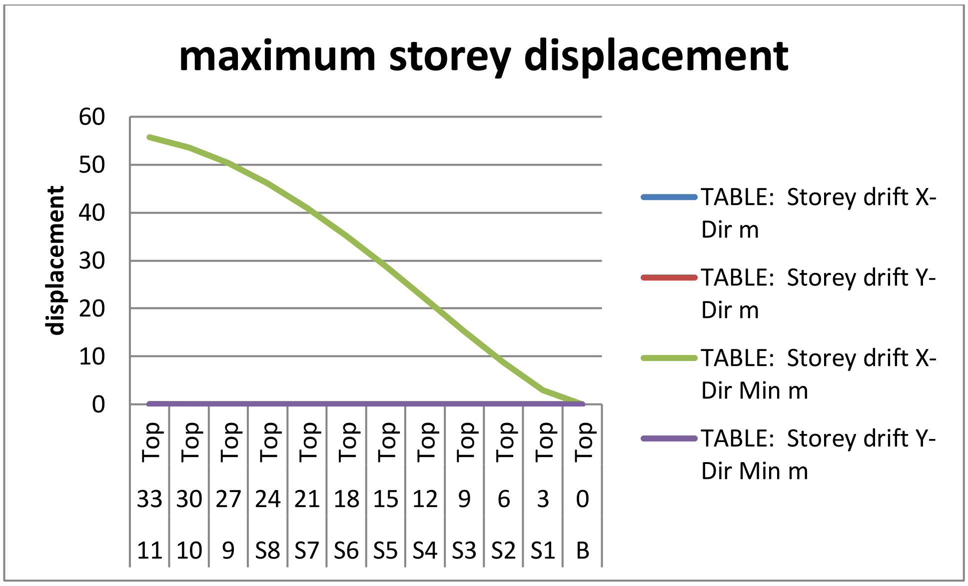


Figure 3.3 Maximum Storey Displacement of OGS Building

TABLE3.7: Maximum Storey Displacement of OGS Building						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	m		mm	mm	Mm	Mm
Story11	33	Top	55.734	0.071	55.734	0.071
Story10	30	Top	53.581	0.029	53.581	0.029
Story9	27	Top	50.388	0.004	50.388	0.004
Story8	24	Top	46.154	0.002	46.154	0.002
Story7	21	Top	41.019	0.002	41.019	0.002
Story6	18	Top	35.178	0.002	35.178	0.002
Story5	15	Top	28.819	0.002	28.819	0.002
Story4	12	Top	22.127	0.002	22.127	0.002
Story3	9	Top	15.306	0.003	15.306	0.003
Story2	6	Top	8.668	0.003	8.668	0.003
Story1	3	Top	2.932	0.02	2.932	0.02
Base	0	Top	0	0	0	0

Maximum Storey Drift of OGS Building

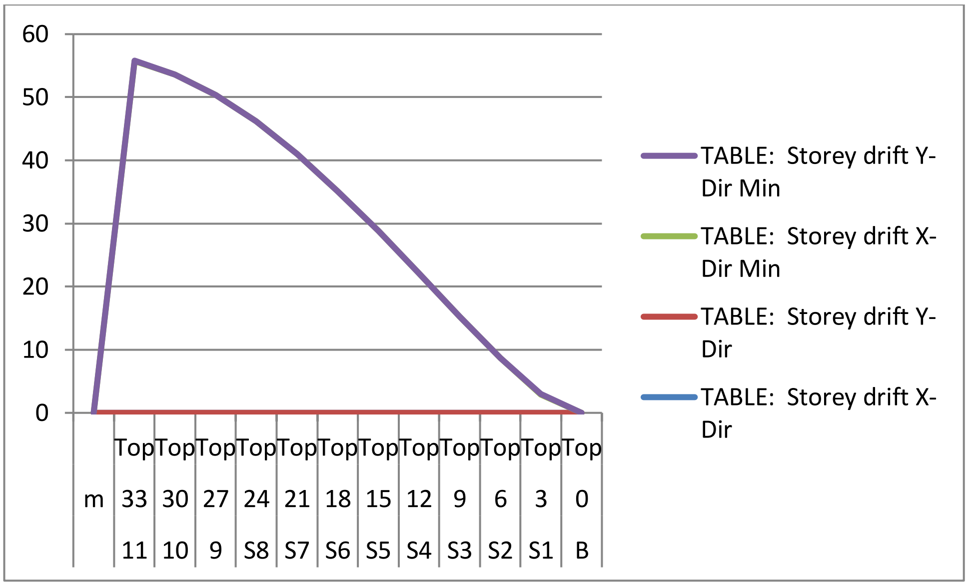


Figure 3.4 Storey Drift Of OGS Building

TABLE3.8: Storey Drift of OGS Building						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	m					
Story11	33	Top	0.000017	0.000017	55.733587	0.070625
Story10	30	Top	0.000005	0.000005	53.580854	0.028934
Story9	27	Top	0.000001	0.000001	50.387614	0.004074
Story8	24	Top	9.365E-08	9.365E-08	46.153621	0.002041
Story7	21	Top	7.625E-08	7.625E-08	41.019257	0.001528
Story6	18	Top	5.238E-08	5.238E-08	35.177768	0.00182
Story5	15	Top	4.358E-08	4.358E-08	28.819006	0.00208
Story4	12	Top	1.324E-07	1.324E-07	22.127169	0.002408
Story3	9	Top	4.071E-07	4.071E-07	15.306137	0.003391
Story2	6	Top	0.000003	0.000003	8.667621	0.002778
Story1	3	Top	0.000003	0.000003	2.931811	0.01995
Base	0	Top	0	0	0	0

Storey Stiffness of OGS Building

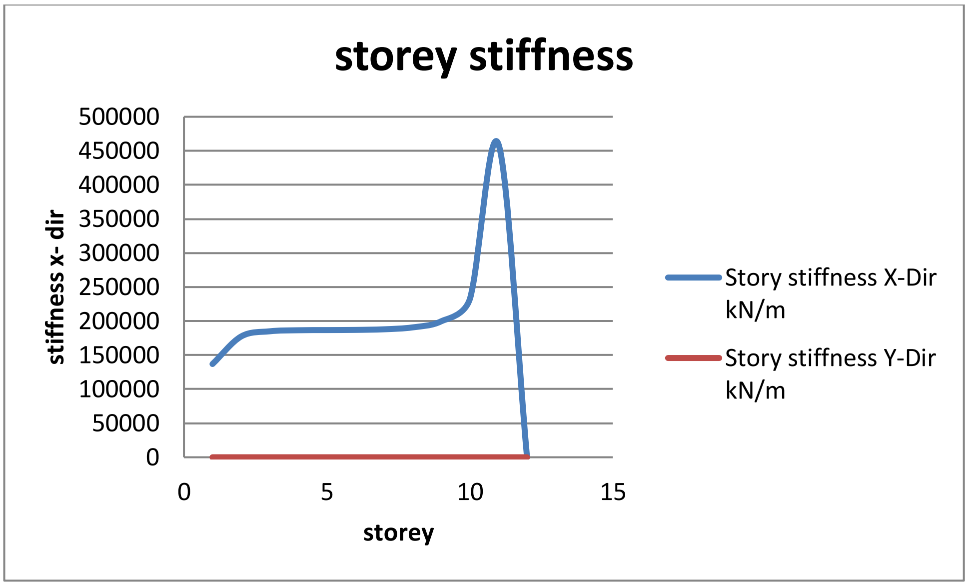


Figure 3.5 Storey Stiffness of OGS Building

Table 3.9 Story Stiffness of OGS Building				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	M		**kN/m**	**kN/m**
Story11	33	Top	136937.66z	0
Story10	30	Top	177337.43	0
Story9	27	Top	184996.81	0
Story8	24	Top	186507.86	0
Story7	21	Top	186782.43	0
Story6	18	Top	187036.21	0
Story5	15	Top	187917.72	0
Story4	12	Top	190738.34	0
Story3	9	Top	199709.75	0
Story2	6	Top	232386.79	0
Story1	3	Top	459867.92	0
Base	0	Top	0	0

Time Period And Frequency of OGS Building

Table 3.10 Time Period or Frequency of OGS Building

Case	Mode	Period Sec	Frequency cyc/sec	Circular Frequency rad/sec	Eigenvalue rad²/sec²
Modal	1	1.621	0.617	3.8772	15.0325
Modal	2	1.621	0.617	3.8772	15.0325
Modal	3	1.494	0.669	4.2044	17.677
Modal	4	0.514	1.944	12.2152	149.2101
Modal	5	0.514	1.944	12.2152	149.2101
Modal	6	0.474	2.108	13.248	175.509
Modal	7	0.283	3.531	22.1849	492.1696
Modal	8	0.283	3.531	22.1849	492.1696
Modal	9	0.261	3.826	24.0395	577.8976
Modal	10	0.183	5.455	34.277	1174.9128
Modal	11	0.183	5.455	34.277	1174.9128
Modal	12	0.169	5.929	37.2506	1387.6081

3.7.2. Model Having Single Cross Bracing In Ground Storey

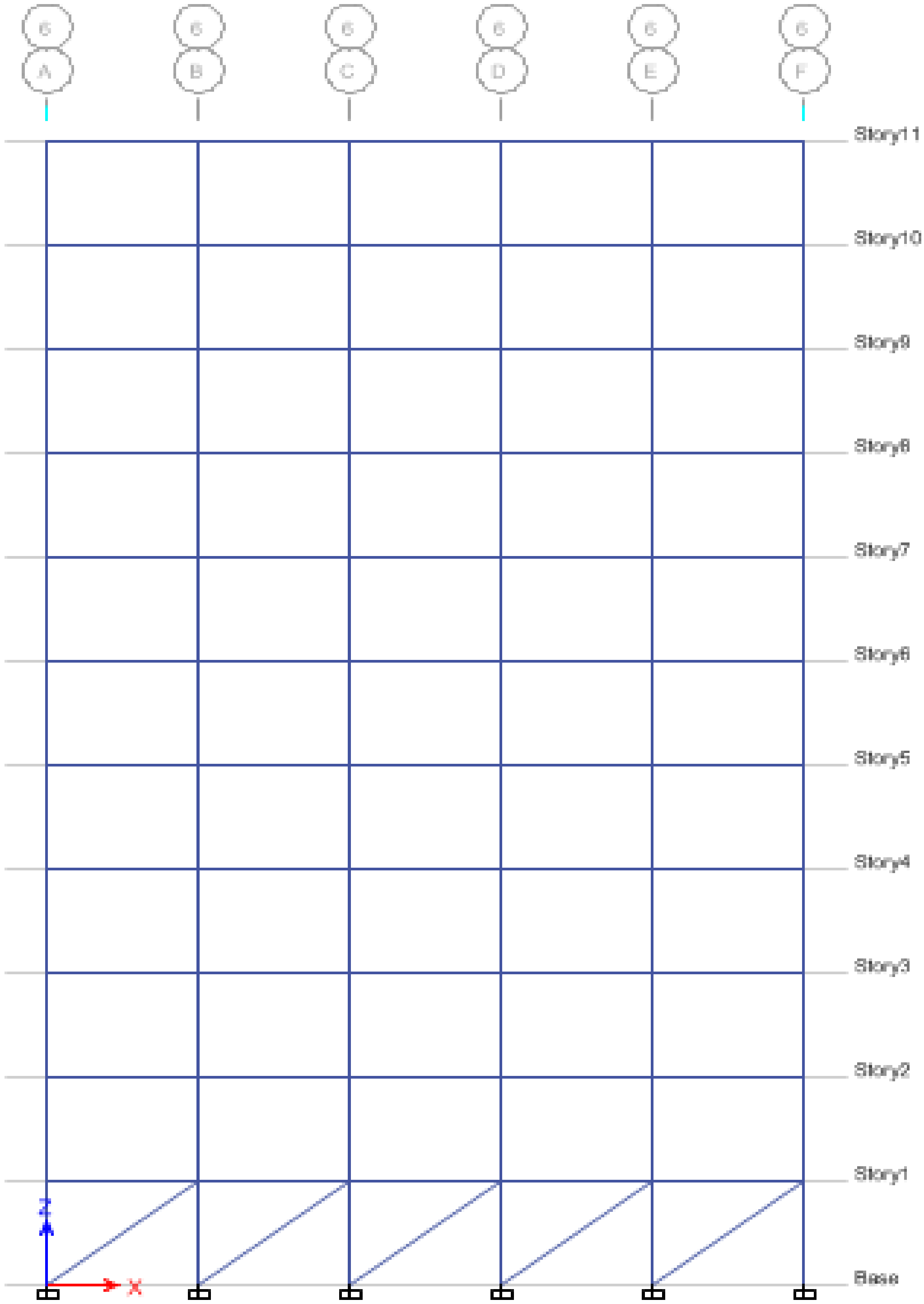


Figure 3.6 Elevation of Building Having Single Bracing in Ground

Maximum Storey Displacement of Building Having Single Bracing in Gound

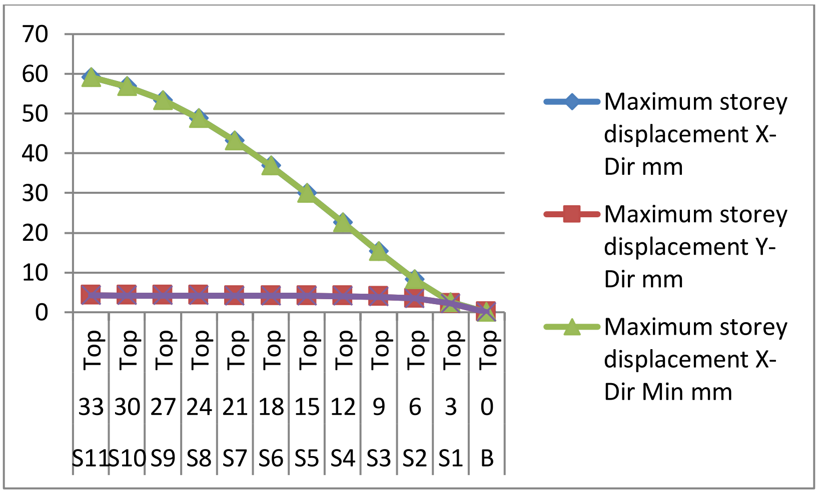


Figure 3.7 Maximum Storey Displacement of Building Having Single Bracing In Ground

Table 3.11 Maximum Storey Displacement of Building Having Single Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		Mm	mm	Mm	Mm
Story11	33	Top	59.178	4.263	59.178	4.263
Story10	30	Top	56.833	4.214	56.833	4.214
Story9	27	Top	53.365	4.178	53.365	4.178
Story8	24	Top	48.76	4.167	48.76	4.167
Story7	21	Top	43.179	4.156	43.179	4.156
Story6	18	Top	36.83	4.141	36.83	4.141
Story5	15	Top	29.923	4.116	29.923	4.116
Story4	12	Top	22.665	4.059	22.665	4.059
Story3	9	Top	15.307	3.905	15.307	3.905
Story2	6	Top	8.231	3.455	8.231	3.455
Story1	3	Top	2.513	2.171	2.513	2.171
Base	0	Top	0	0	0	0

Storey Drift of Building Having Single Bracing in Ground

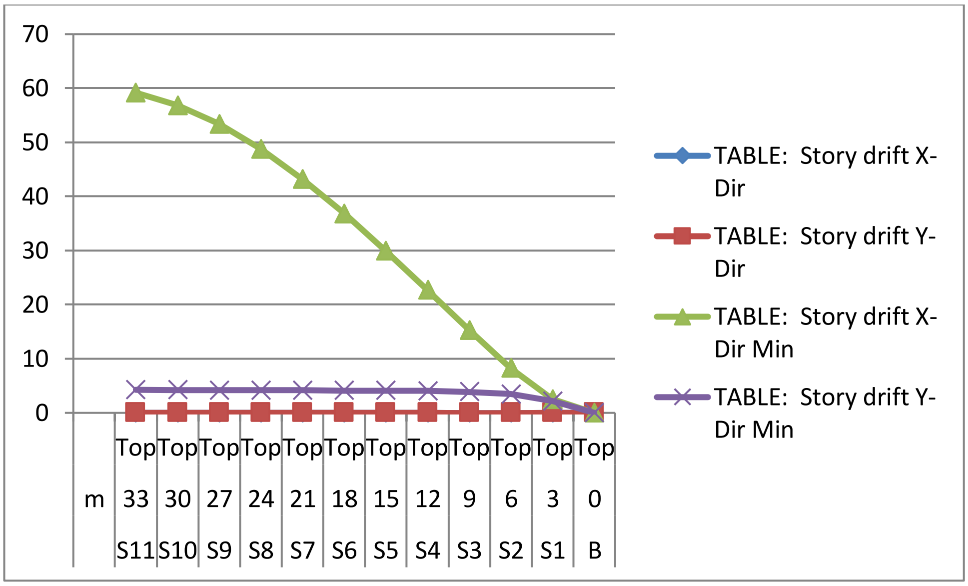


Figure 3.8 Maximum Storey Drift of Building Having Single Bracing in Ground

TABLE 3.12: Story Drift of Building Having Single Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M					
Story11	33	Top	0.000006	0.000006	59.177841	4.2628
Story10	30	Top	0.000003	0.000002	56.832849	4.213879
Story9	27	Top	0.000001	0.000001	53.364501	4.178013
Story8	24	Top	0.000001	0.000001	48.760415	4.167469
Story7	21	Top	0.000001	0.000001	43.178774	4.15581
Story6	18	Top	0.000002	0.000002	36.830009	4.141376
Story5	15	Top	0.000003	0.000003	29.923084	4.116277
Story4	12	Top	0.000009	0.000009	22.664535	4.058684
Story3	9	Top	0.000028	0.000028	15.307318	3.904684
Story2	6	Top	0.000093	0.000091	8.230956	3.454674
Story1	3	Top	0.000127	0.000125	2.513456	2.171396
Base	0	Top	0	0	0	0

Storey Stiffness of Building Having Single Bracing in Ground

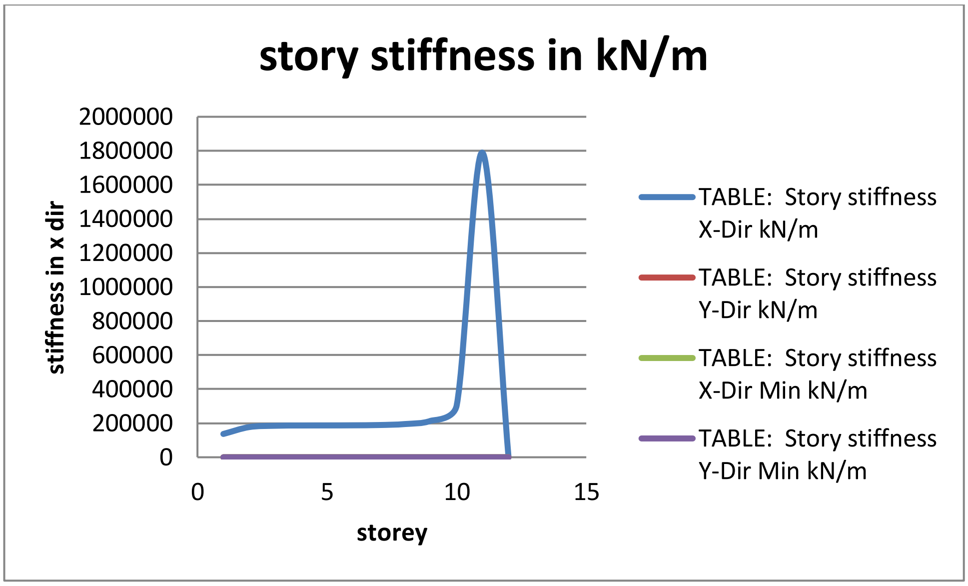


Figure 3.9 Maximum Storey Stiffness of Building Having Single Bracing in Ground

TABLE 3.13: Maximum Storey Stiffness of Building Having Single Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		kN/m	kN/m	kN/m	kN/m
Story11	33	Top	136977.285	0	59.178	4.263
Story10	30	Top	177393.884	0	56.833	4.214
Story9	27	Top	185057.196	0	53.365	4.178
Story8	24	Top	186602.388	0	48.76	4.167
Story7	21	Top	186981.977	0	43.179	4.156
Story6	18	Top	187542.431	0	36.83	4.141
Story5	15	Top	189341.464	0	29.923	4.116
Story4	12	Top	195042.464	0	22.665	4.059
Story3	9	Top	214219.866	0	15.307	3.905
Story2	6	Top	304285.863	0	8.231	3.455
Story1	3	Top	1788067.092	0	2.513	2.171
Base	0	Top	0	0	0	0

Time period and frequency of building having single bracing in ground

Table 3.14 Time period or frequencies of building having single bracing in ground

Mode	Period	Frequency	Circular Frequency	Eigenvalue
	sec	cyc/sec	rad/sec	rad^2/sec^2
1	1.512	0.661	4.1543	17.2586
2	1.511	0.662	4.1578	17.2877
3	1.392	0.718	4.514	20.376
4	0.476	2.099	13.1868	173.8918
5	0.476	2.101	13.2016	174.2822
6	0.439	2.277	14.3095	204.7629
7	0.261	3.837	24.1059	581.0938
8	0.26	3.842	24.1375	582.6204
9	0.24	4.164	26.1609	684.3918
10	0.167	5.974	37.5343	1408.826
11	0.167	5.983	37.5941	1413.314
12	0.154	6.503	40.8568	1669.275

3.7.3 Model having double cross bracings in ground

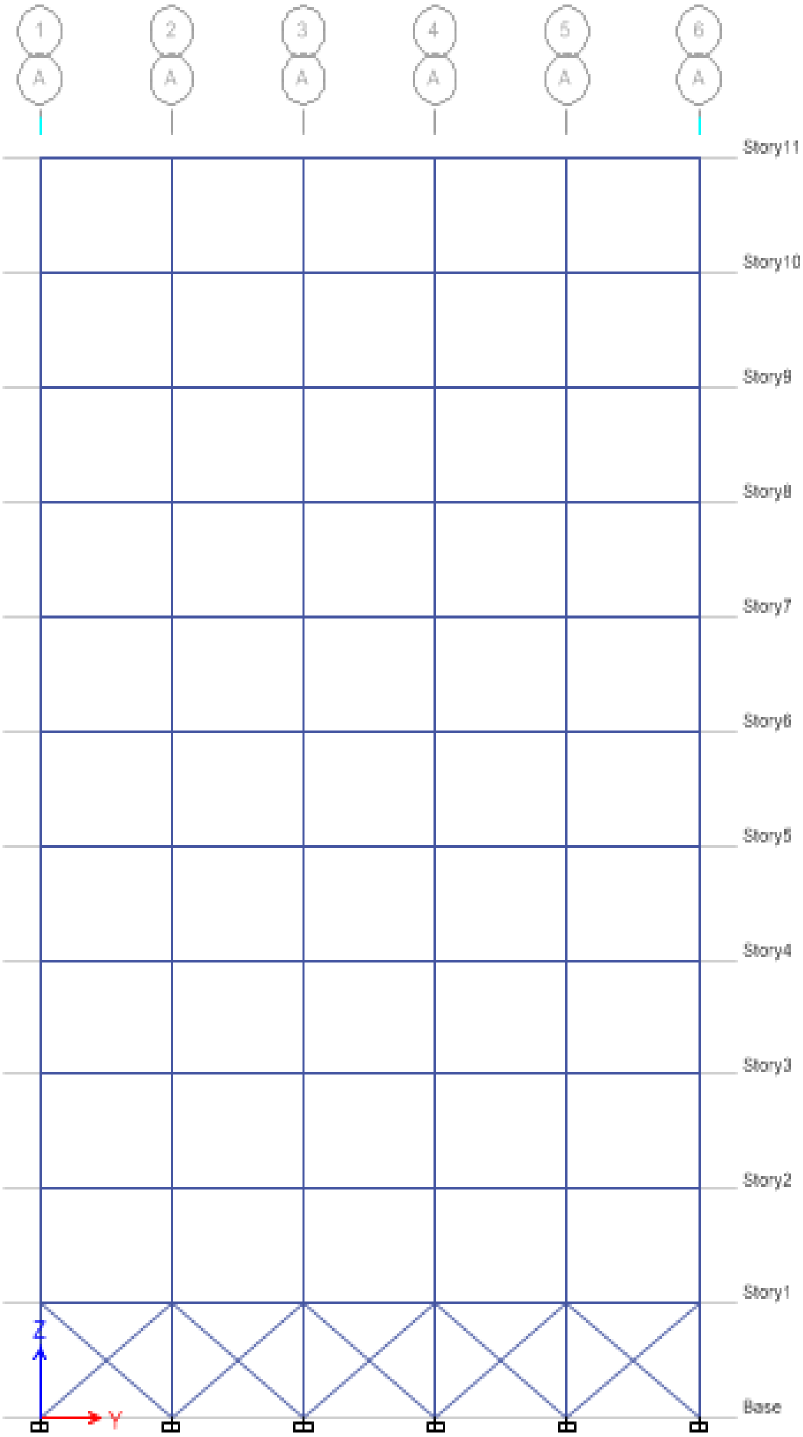


Figure 3.**10** Elevation of building having double bracing in ground

Maximum storey displacement of building having double bracing in ground

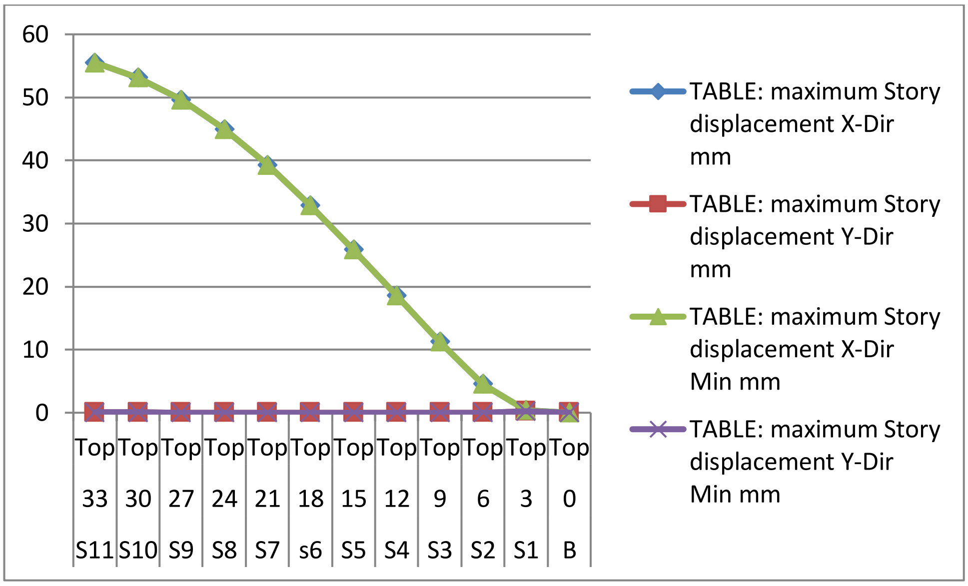


Figure 3.11 Maximum Storey Displacement of Building Having Double Bracing in Ground

TABLE3.15:Maximum Storey Displacement of Building Having Double Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		Mm	mm	Mm	Mm
Story11	33	Top	55.53	0.069	55.53	0.069
Story10	30	Top	53.165	0.029	53.165	0.029
Story9	27	Top	49.648	0.004	49.648	0.004
Story8	24	Top	44.978	0.002	44.978	0.002
Story7	21	Top	39.315	0.002	39.315	0.002
Story6	18	Top	32.876	0.002	32.876	0.002
Story5	15	Top	25.88	0.002	25.88	0.002
Story4	12	Top	18.564	0.003	18.564	0.003
Story3	9	Top	11.246	0.002	11.246	0.002
Story2	6	Top	4.574	0.016	4.574	0.016
Story1	3	Top	0.418	0.227	0.418	0.227
Base	0	Top	0	0	0	0

Maximum storey drift of building having double cross bracings in ground

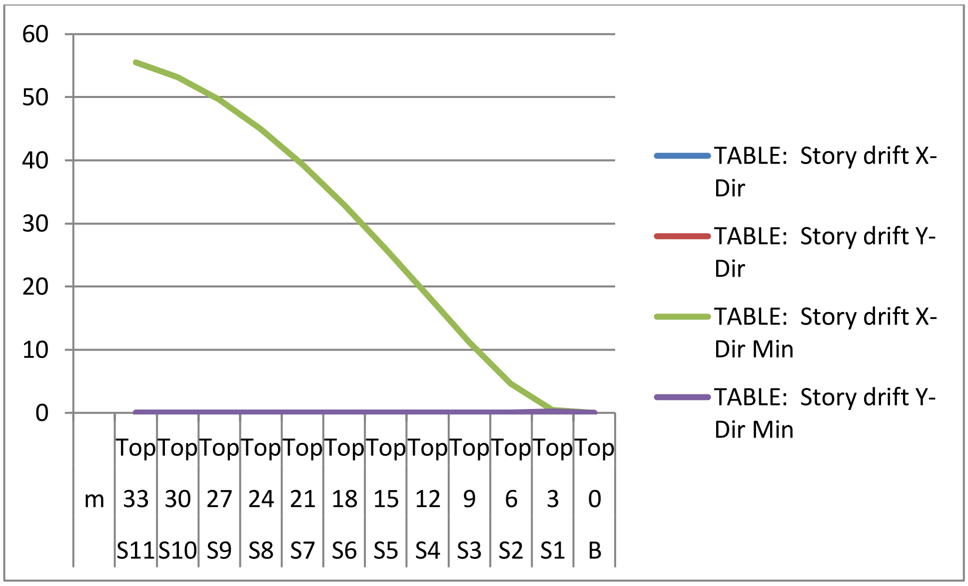


Figure 3.12 Maximum Storey Drift of Building Having Double Bracing in Ground

TABLE3.16 Maximum Storey Drift of Building Having Double Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M					
Story11	33	Top	0.000017	0.000017	55.530244	0.069189
Story10	30	Top	0.000005	0.000005	53.165137	0.028703
Story9	27	Top	0.000001	0.000001	49.647703	0.004064
Story8	24	Top	9.073E-08	9.073E-08	44.978145	0.002096
Story7	21	Top	7.856E-08	7.856E-08	39.315069	0.001587
Story6	18	Top	0.000000041	0.000000041	32.875634	0.001903
Story5	15	Top	1.344E-07	1.344E-07	25.880149	0.00215
Story4	12	Top	4.736E-07	4.736E-07	18.564389	0.0032
Story3	9	Top	0.000002	0.000002	11.246148	0.001665
Story2	6	Top	0.000037	0.000037	4.574459	0.016451
Story1	3	Top	0.000039	0.000039	0.417582	0.227342
Base	0	Top	0	0	0	0

Story Stiffness Of Building Having Double Cross Bracing In Ground

Figure 3.13 Maximum Storey Stifness of Building Having Double Bracing in Ground

TABLE3.17 Maximum Storey Stifness of Building Having Double Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		kN/m	kN/m	kN/m	kN/m
Story11	33	Top	137429.628	0	55.53	0.069
Story10	30	Top	177774.577	0	53.165	0.029
Story9	27	Top	185360.285	0	49.648	0.004
Story8	24	Top	186866.973	0	44.978	0.002
Story7	21	Top	187249.46	0	39.315	0.002
Story6	18	Top	187884.688	0	32.876	0.002
Story5	15	Top	189944.45	0	25.88	0.002
Story4	12	Top	196515.181	0	18.564	0.003
Story3	9	Top	219244.828	0	11.246	0.002
Story2	6	Top	337949.347	0	4.574	0.016
Story1	3	Top	7717002.119	0	0.418	0.227
Base	0	Top	0	0	0	0

Time Period And Frequencies of Building Having Double Cross Bracing in Ground

TABLE3.18: Time Period And Frequencies of Building Having Double Cross Bracing in Ground					
Case	**Mode**	**Period**	**Frequency**	**Circular Frequency**	**Eigenvalue**
		sec	cyc/sec	rad/sec	rad^2/sec^2
Modal	1	1.504	0.665	4.1775	17.4517
Modal	2	1.504	0.665	4.1775	17.4517
Modal	3	1.385	0.722	4.5355	20.5705
Modal	4	0.474	2.112	13.2671	176.0164
Modal	5	0.474	2.112	13.2671	176.0164
Modal	6	0.437	2.289	14.3844	206.9096
Modal	7	0.259	3.864	24.2763	589.339
Modal	8	0.259	3.864	24.2763	589.339
Modal	9	0.239	4.189	26.3225	692.8766
Modal	10	0.166	6.024	37.8477	1432.4481
Modal	11	0.166	6.024	37.8477	1432.4481
Modal	12	0.153	6.55	41.1555	1693.7714

3.7.4 .V Braced Structure

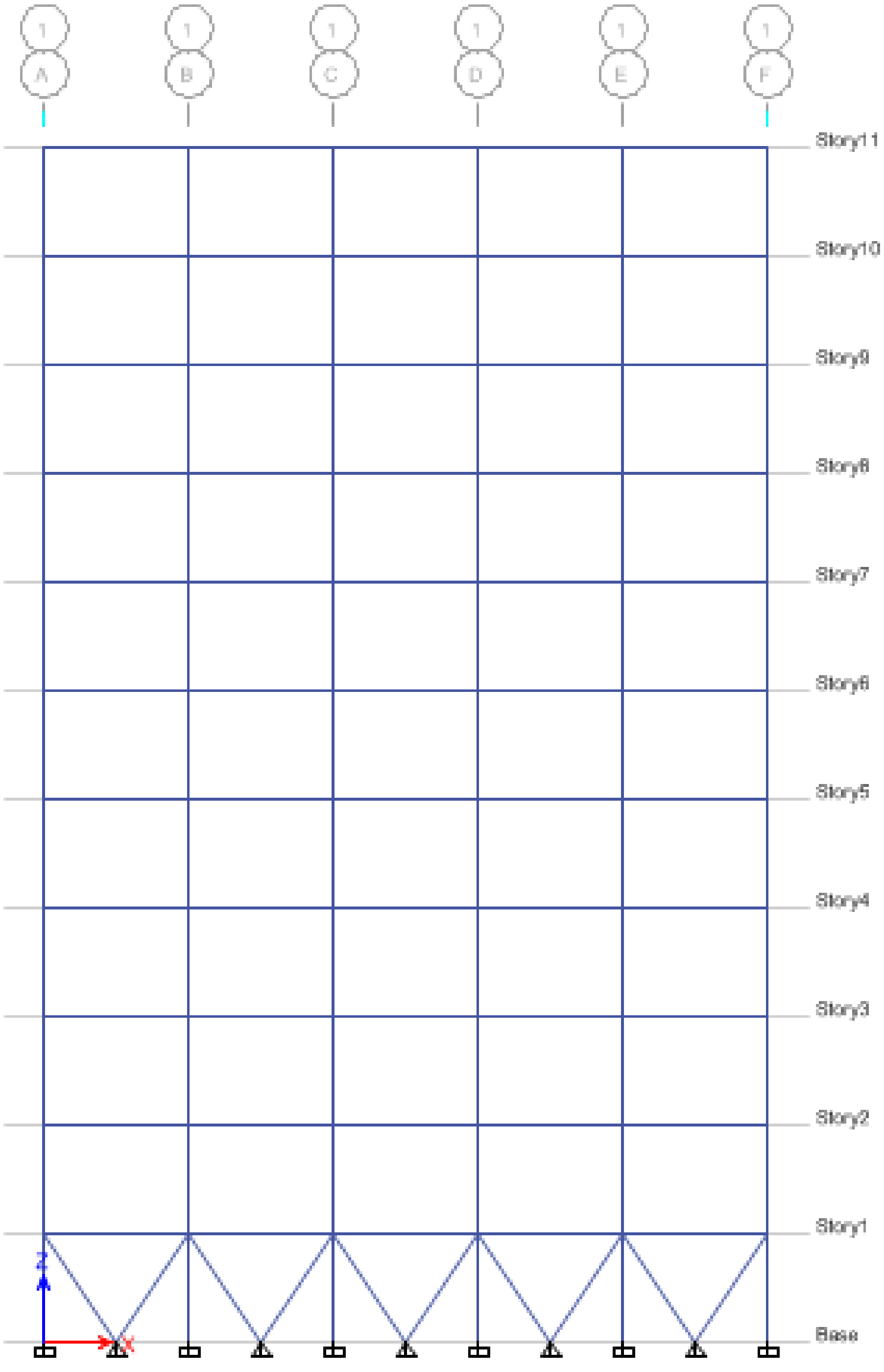


Figure 3.14 Elevation of Building Having V Bracing in Ground

Maximum Storey Displacement of Building Having V Bracing in Ground

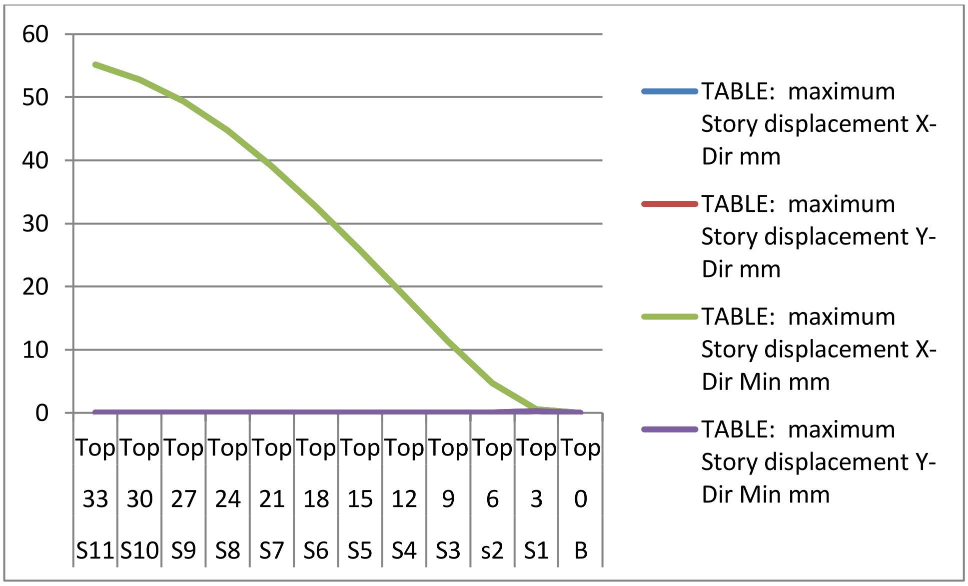


Figure 3.15 Maximum Storey Displacement of Building Having V Bracing in Ground

Table 3.19 Maximum Storey Displacement of Building Having V Bracing in Ground

Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		mm	mm	Mm	Mm
Story11	33	Top	55.169	0.068	55.169	0.068
Story10	30	Top	52.831	0.028	52.831	0.028
Story9	27	Top	49.351	0.004	49.351	0.004
Story8	24	Top	44.729	0.002	44.729	0.002
Story7	21	Top	39.123	0.002	39.123	0.002
Story6	18	Top	32.747	0.002	32.747	0.002
Story5	15	Top	25.82	0.002	25.82	0.002
Story4	12	Top	18.573	0.003	18.573	0.003
Story3	9	Top	11.318	0.002	11.318	0.002
Story2	6	Top	4.689	0.019	4.689	0.019
Story1	3	Top	0.528	0.275	0.528	0.275
Base	0	Top	0	0	0	0

Maximum Storey Drift of Building Having V Bracing in Ground

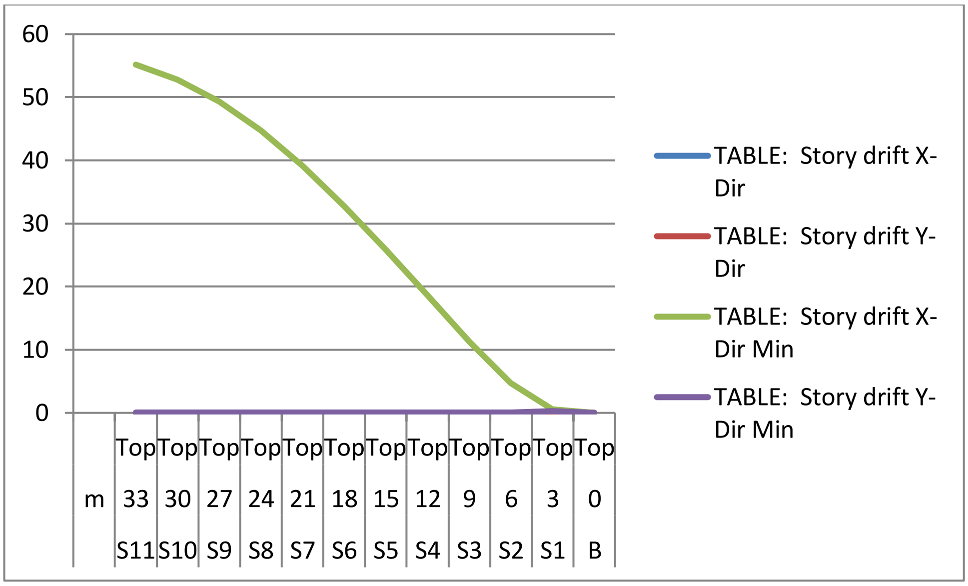


Figure 3.16 Maximum Storey Dirift of Building Having V Bracing in Ground

TABLE:3.20: Maximum Storey Dirift of Building Having V Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	m					
Story11	33	Top	0.000016	0.000016	55.16931	0.068103
Story10	30	Top	0.000005	0.000005	52.831273	0.028263
Story9	27	Top	0.000001	0.000001	49.351174	0.003995
Story8	24	Top	8.844E-08	8.844E-08	44.729385	0.002091
Story7	21	Top	7.896E-08	7.896E-08	39.123035	0.001594
Story6	18	Top	4.069E-08	4.069E-08	32.747226	0.001912
Story5	15	Top	1.509E-07	1.509E-07	25.819853	0.002144
Story4	12	Top	0.000001	0.000001	18.573385	0.0033
Story3	9	Top	0.000002	0.000002	11.318495	0.002045
Story2	6	Top	0.000041	0.000041	4.689221	0.018694
Story1	3	Top	0.000043	0.000043	0.527688	0.275059
Base	0	Top	0	0	0	0

Storey Stiffness of Building Having V Bracing in Ground

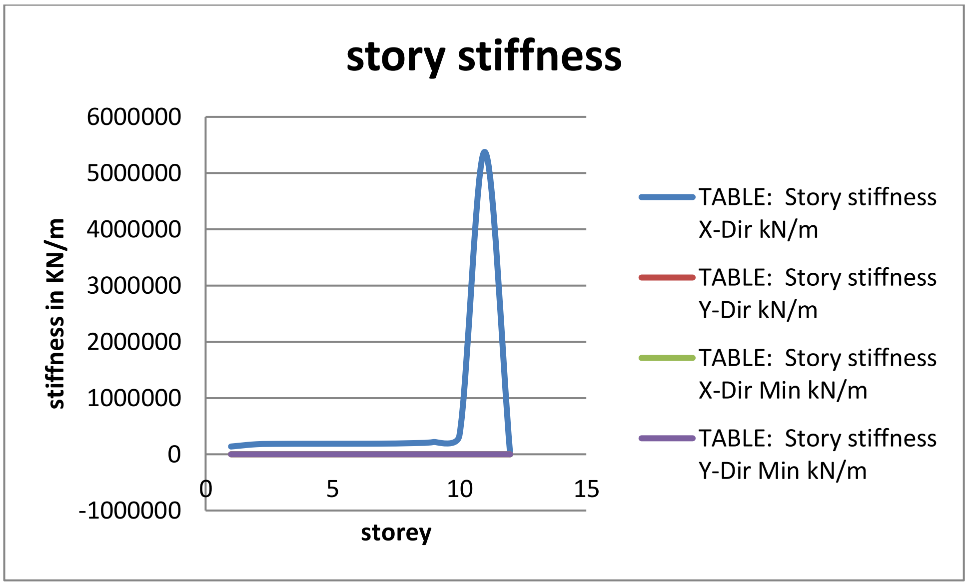


Figure 3.17 Maximum Storey Stiffness of Building Having V Bracing in Ground

TABLE:3.21 Maximum Storey Stiffness of Building Having V Bracing in Ground						
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	M		kN/m	kN/m	kN/m	kN/m
Story11	33	Top	137743.68	0	55.169	0.068
Story10	30	Top	178041.83	0	52.831	0.028
Story9	27	Top	185568.881	0	49.351	0.004
Story8	24	Top	187038.817	0	44.729	0.002
Story7	21	Top	187395.928	0	39.123	0.002
Story6	18	Top	188004.635	0	32.747	0.002
Story5	15	Top	190012.945	0	25.82	0.002
Story4	12	Top	196434.397	0	18.573	0.003
Story3	9	Top	218580.831	0	11.318	0.002
Story2	6	Top	332740.491	0	4.689	0.019
Story1	3	Top	5377063.244	0	0.528	0.275
Base	0	Top	0	0	0	0

Time Period And Frequencies of Building Having V Bracing in Ground

TABLE:3.22 Time Period And Frequencies of Building Having V Bracing in Ground					
Case	**Mode**	**Period**	**Frequency**	**Circular Frequency**	**Eigenvalue**
		sec	cyc/sec	rad/sec	rad^2/sec^2
Modal	1	1.507	0.663	4.1686	17.3769
Modal	2	1.507	0.663	4.1686	17.3769
Modal	3	1.388	0.72	4.5261	20.4851
Modal	4	0.475	2.106	13.2343	175.1476
Modal	5	0.475	2.106	13.2343	175.1476
Modal	6	0.438	2.284	14.3499	205.9194
Modal	7	0.26	3.852	24.2007	585.6723
Modal	8	0.26	3.852	24.2007	585.6723
Modal	9	0.239	4.177	26.2473	688.9197
Modal	10	0.167	6.003	37.7166	1422.5385
Modal	11	0.167	6.003	37.7166	1422.5385
Modal	12	0.153	6.528	41.0193	1682.5798

3.7.5 Inverted V Bracing

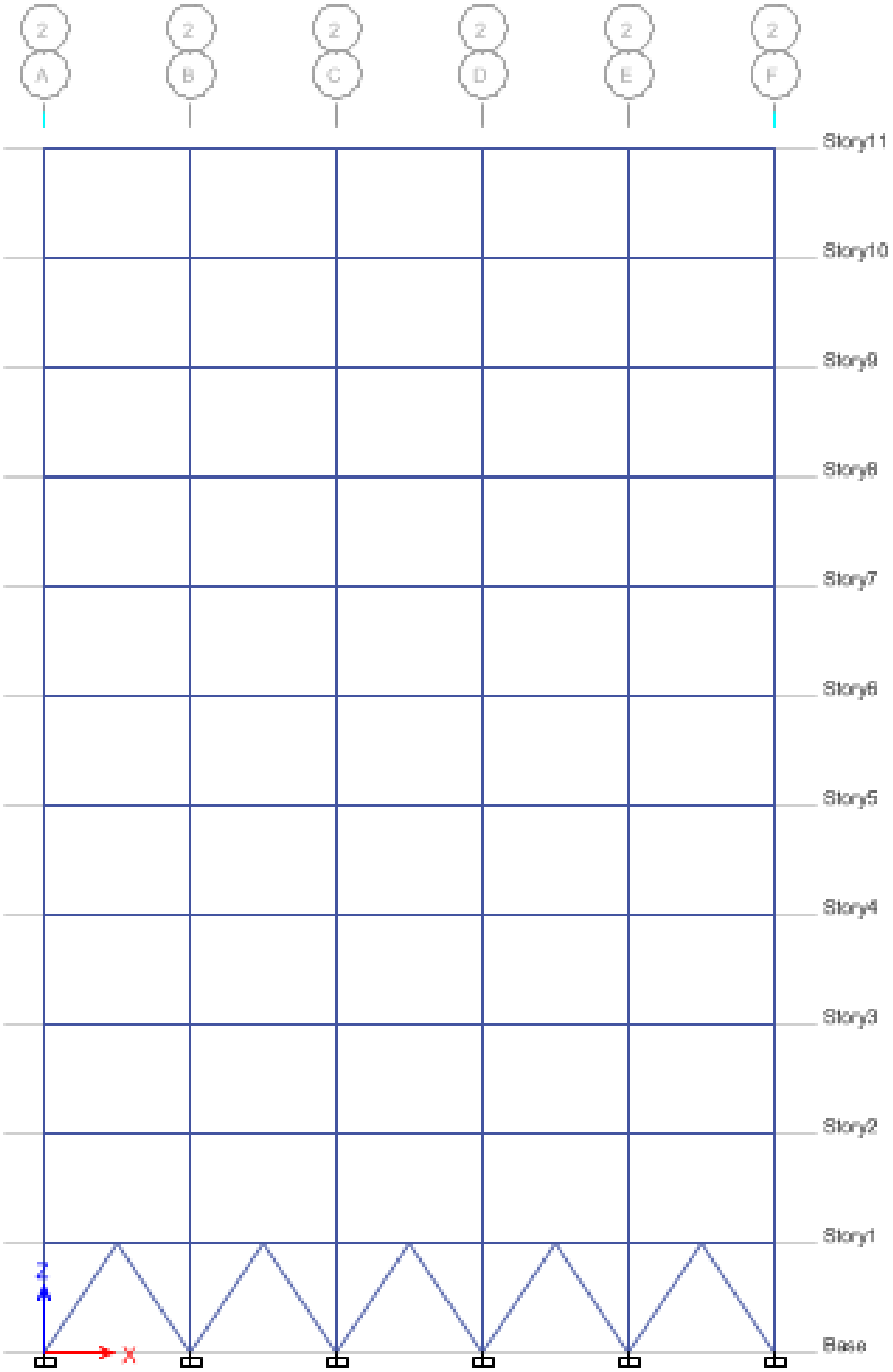


Figure 3.18 Elevation of Building Having Inverted V Bracing in Ground

Maximum Storey Displacement of Building Having Inverted V Bracing in Ground

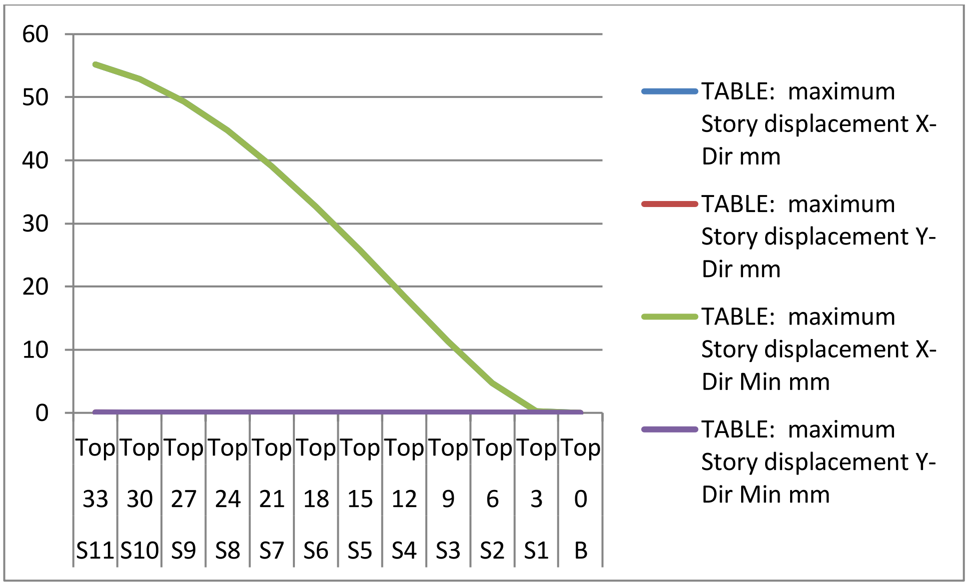


Figure 3.19 Maximum Storey Displacement of Building Having Inverted V Bracing in Ground

TABLE 3.23: Maximum Storey Displacement of Building Having Inverted V Bracing in Ground

Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**	**X-Dir Min**	**Y-Dir Min**
	m		Mm	mm	Mm	Mm
Story11	33	Top	55.201	0.07	55.201	0.07
Story10	30	Top	52.855	0.029	52.855	0.029
Story9	27	Top	49.368	0.004	49.368	0.004
Story8	24	Top	44.74	0.002	44.74	0.002
Story7	21	Top	39.127	0.002	39.127	0.002
Story6	18	Top	32.745	0.002	32.745	0.002
Story5	15	Top	25.812	0.002	25.812	0.002
Story4	12	Top	18.56	0.003	18.56	0.003
Story3	9	Top	11.301	0.003	11.301	0.003
Story2	6	Top	4.683	0.027	4.683	0.027
Story1	3	Top	0.275	0.021	0.275	0.021
Base	0	Top	0	0	0	0

Maximum Storey Drift of Building Having Inverted V Bracing in Ground

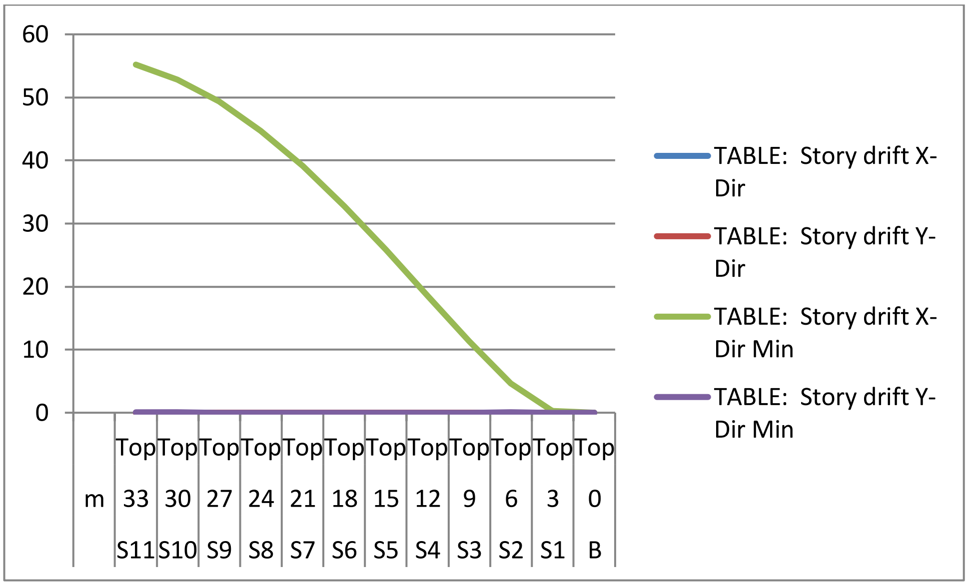


Figure 3.20 Maximum Storey Drift of Building Having Inverted V Bracing in Ground

TABLE 3.24:Maximum Storey Drift of Building Having Inverted V Bracing in Ground

Story	Elevation	Location	X-Dir	Y-Dir	X-Dir Min	Y-Dir Min
	m					
Story11	33	Top	0.000017	0.000017	55.200599	0.070087
Story10	30	Top	0.000005	0.000005	52.85475	0.029014
Story9	27	Top	0.000001	0.000001	49.367725	0.004108
Story8	24	Top	9.313E-08	9.313E-08	44.739614	0.002091
Story7	21	Top	8.055E-08	8.055E-08	39.127179	0.001574
Story6	18	Top	3.507E-08	3.507E-08	32.745425	0.001892
Story5	15	Top	1.883E-07	1.883E-07	25.812154	0.002117
Story4	12	Top	0.000001	0.000001	18.560426	0.003247
Story3	9	Top	0.000004	0.000004	11.301205	0.002761
Story2	6	Top	0.000001	0.000001	4.68268	0.027307
Story1	3	Top	0.000003	0.000003	0.274914	0.021415
Base	0	Top	0	0	0	0

Maximum Storey Stiffness of Building Having Inverted V Bracing in Ground

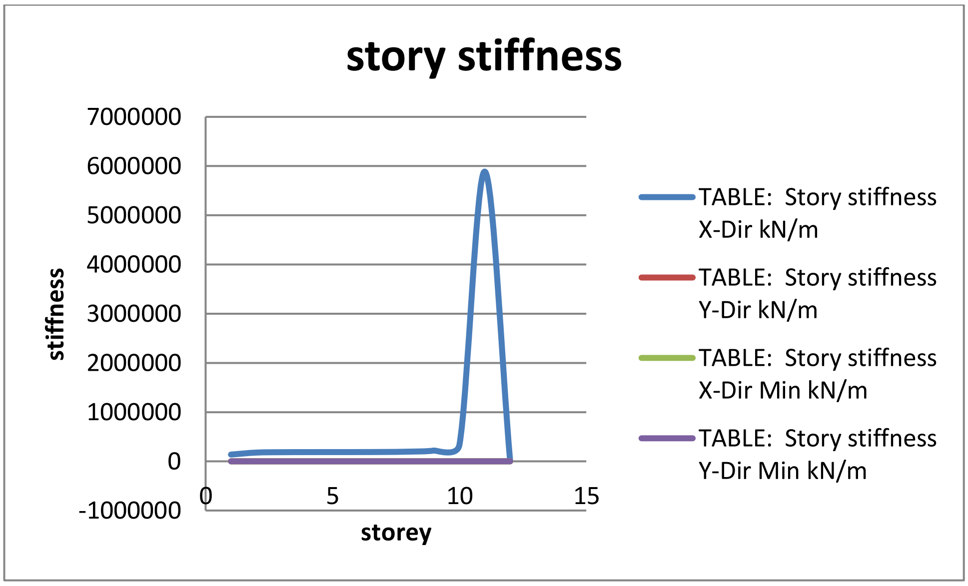


Figure 3.21 Maximum Storey Stiffness of Building Having Inverted V Bracing in Ground

TABLE 3.25 Maximum Storey Stiffness of Building Having Inverted V Bracing in Ground

Story	Elevation	Location	X-Dir	Y-Dir	X-Dir Min	Y-Dir Min
	m		kN/m	kN/m	kN/m	kN/m
Story11	33	Top	137329.649	0	55.201	0.07
Story10	30	Top	177687.691	0	52.855	0.029
Story9	27	Top	185291.488	0	49.368	0.004
Story8	24	Top	186807.597	0	44.74	0.002
Story7	21	Top	187191.691	0	39.127	0.002
Story6	18	Top	187817.101	0	32.745	0.002
Story5	15	Top	189837.629	0	25.812	0.002
Story4	12	Top	196278.759	0	18.56	0.003
Story3	9	Top	218489.501	0	11.301	0.003
Story2	6	Top	332060.869	0	4.683	0.027
Story1	3	Top	5887818.98	0	0.275	0.021
Base	0	Top	0	0	0	0

Time Period And Frequencies of Building Having Inverted V Bracing in Ground

TABLE 3.26 Time Period And Frequencies of Building Having Inverted V Bracing in Ground					
Case	**Mode**	**Period**	**Frequency**	**Circular Frequency**	**Eigenvalue**
		sec	cyc/sec	rad/sec	rad^2/sec^2
Modal	1	1.508	0.663	4.1679	17.3715
Modal	2	1.508	0.663	4.1679	17.3715
Modal	3	1.389	0.72	4.5235	20.4619
Modal	4	0.475	2.105	13.2239	174.8713
Modal	5	0.475	2.105	13.2239	174.8713
Modal	6	0.438	2.282	14.3396	205.6252
Modal	7	0.26	3.851	24.1977	585.5274
Modal	8	0.26	3.851	24.1977	585.5274
Modal	9	0.24	4.175	26.2309	688.059
Modal	10	0.167	5.999	37.6926	1420.7313
Modal	11	0.167	5.999	37.6926	1420.7313
Modal	12	0.153	6.523	40.9838	1679.674

CHAPTER 4
LINEAR TIME HISTORY ANALYSIS

4.1 Overview

In this chapter, the characteristics of the ground motions, which are used for the time-history analysis of the RC buildings, are explained and a brief description is given for linear time-history analysis. An introduction to the definition, sources, causes, characteristics, magnitude, intensity, instrument, and classification of earthquake.

It also gives a detail explanation about the ground motion records, which are considered for the current work. The acceleration, velocity, and displacement versus time for each ground motion record are shown.

A brief definition is given for the linear time-history analysis in section 4.4. The dynamic characteristics of eleven-story regular RC buildings are also presented.

4.2 Introduction

An earthquake is a hysteria of ground quaking caused by a sudden discharge of energy in the earth's lithosphere. This energy may come mainly from stresses formed during tectonic processes, which involves interaction between the crust and the inner side of the earth's crust. Strain energy stored inside the earth will be released and maximum of it changes to heat, sound and remaining as seismic waves. The science of the earthquake is called seismology. The source and nature of earthquakes is the science of seismology.

Sources of earthquake are tectonic, volcanic, rock fall or collapse of cavity which are natural source and mining induced earthquake, reservoir induced earthquake, and controlled source (explosive) which are man-made source. In fact, 90 percent of the earthquakes are due to plate tectonics. There are six continental sized plates which are African, American, Antarctic, Australia-Indian, Euro-Asian, and pacific plate.

There are mainly four principle plate boundaries such as divergent boundary (inner side of the earth adds new plate material), subduction boundary (plates converge and the beneath thrust one is consumed), collision boundary (previous subduction zone where continents resting on plates are smashing), and transform boundary (two plates are sliding one another).Geologists are interested in the nature and properties of the earthquake; they use seismograph to record the seismic waves (seismogram), while engineers are interested in the nature and properties of ground motion; they use accelerograph to measure the ground acceleration record (accelerogram). Seismic waves are classified as P-waves, S-waves, Love wave, and Rayleigh wave. The motion of sufficient strength that effects people and environment is called strong ground motion. It is described by three transitions and three rotations. The effect of the three rotations is very small which may be neglected. The maximum absolute value of the ground acceleration is peak ground acceleration (PGA). PGA, frequency content and duration are the most important characteristics of earthquake. The rock site experiences higher acceleration, soil site undergoes higher velocity, and higher displacement.

The smallest natural frequency of a structure is the fundamental frequency and the dominating frequency of earthquake is the excitation frequency. Resonance occurs when the dominating frequency of the earthquake ground motion matches with the fundamental frequency of the structure. Earthquake ground motion is dynamic load, which can be classified as deterministic non-periodic transient load as well as probabilistic load. Earthquake is classified based on location, focal depth, causes, magnitude, and epicentral distance.

Earthquake is specified regarding magnitude and intensity. The magnitude of earthquake is a measure of energy discharged. It is characterized as logarithm to the base 10 of the maximum trace amplitude, represented in microns, which the standard short-period torsion seismometer (with a time period of 0.8 s, magnification 2,800 and damping almost critical) would register because of the earthquake at an epicentral distance of 100 km.

The intensity of an earthquake at a location is a measure of the strength of a shaking during an earthquake and is designated by roman numbers I to XII in accordance to the modified Mercalli Scale or M.S.K Scale of seismic intensities. For a particular earthquake magnitude is constant, however, intensity varies from place to place. Magnitude is quantitative measurement; intensity is qualitative measure of the severity of earthquake at a particular site. Quantitative instrumental measures of intensity include engineering parameters such as peak ground acceleration, peak ground velocity, the Housner spectral intensity, and response spectra in general. Magnitude is a quantitative measure of the size of an earthquake, which is the amount of energy released, which is independent of the place of inspection. It is measured by Richter Scale (Dr. Charles Richter, he observed that “at same distance magnitude is directly proportional to amplitude of earthquake”). Earthquake has social as well as economic consequences such as fatality and injury to human beings, and damage to the built and natural environment. For every one unit increase in magnitude, there is 10 times increase in amplitude and times increase in energy.

Measurement of ground motion during an earthquake gives fundamental data for earthquake analysis. The records of the motions of structures give understanding how structures behave during earthquakes. The basic element of ground shaking measuring instruments is some form of transducer. A transducer is a mass-spring-damper system mounted inside a rigid frame that is attached to the surface whose motion is to be measured. Three separate transducers are required to measure three components of ground motion. When subjected to motion of support point, the transducer mass moves relative to the frame, and this relative displacement is recorded after suitable magnification.

The basic instrument to record three components of ground shaking during earthquakes is the strong-motion accelerograph as shown in Figure 4.1, which does not record continuously but is triggered into motion by the first waves of the earthquake to arrive.Table 4.1 shows the direct and indirect effects of earthquake.

Figure 4.1: Accelerograph, Courtesy of Museum of Geoastrophysics National Observatory of Athens

4.1 Direct And Indirect Effects of Earthquake

Direct Effects	Indirect Effects
Ground shaking, ground cracking, ground lunching, differential ground settlement, Soil liquefaction, lateral spreading, landslide, rock falls, vibration of structures, falling objects, structural damage, and structural collapse	Landslides, tsunamis, seiches, avalanches, rock falls, floods, fires, and toxic contamination

Table 4.1 Direct And Indirect Effects of Earthquake

Ground motions are taken for the study purpose. The ground motion is the 1979 Imperial Valley-06 (Holtville Post Office) H-HVP225 component ground motion is explained above and the corresponding velocity and displacement versus time are obtained.

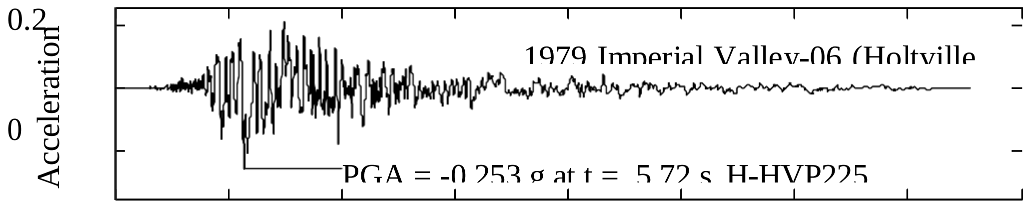
4.4 Ground Motion Records

Buildings are subjected to ground motions. The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration. Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories

High-frequency content PGA/PGV > 1.2

Intermediate-frequency content 0.8< PGA/PGV< 1.2

Low-frequency content PGA/PGV < 0.8



-0.2 Figure 4.2: Electro Time History Data

4.5 Ground motion characteristics and classification of its frequency-content

Records (Station)	Component	Magnitude	Epicentral Distance	Duration (s)	Time step for response	PGA (g)	PGV (m/s)	PGA/PGV	Frequency Content Classification
1979 Imperial Valley-06 (Holtville Post Office)	H-HVP225	6.5 3	19.81	37.74		0.252 6	0.487 5	0.518 2	Low
IS 1893 (Part1) : 2002*	-	-	-	38.01	0.01	1	1.040 7	0.960 9	Intermediate
1957 San Francisco (Golden Gate Park)	GGP010	5.2 8	11.13	39.72	0.00 5	0.095 3	0.039 1	2.440 5	High
1940 Imperial Valley (El Centro)	elcentro_EW	7.1		53.46	0.02	0.214 1	0.487 9	0.438 9	Low
1992 Landers (Fort Irwin)	FTI000	7.2 8	120.9 9	39.98	0.02	0.113 6	0.095 7	1.186 8	Intermediate
1983 Coalinga-06 (CDMG46617)	E-CHP000	4.8 9	9.27	39.99 5	0.00 5	0.147 9	0.057 3	2.581	High

Table 4.2. Ground Motion And Frequency Characteristics

4.6 Linear Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed.

In linear dynamic method, the structures is modeled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled utilizing time history analysis, the displacements and internal forces are found using linear elastic analysis. The playing point of linear dynamic procedure as for linear static procedure is that higher modes could be taken into account.

In linear dynamic analysis, the response of the building to the ground motion is computed in the time domain, and all phase information is thus preserved. Just linear properties are considered. Analytical result of the equation of motion for a one degree of freedom system is normally not conceivable if the external force or ground acceleration changes randomly with time, or if the system is not linear. Such issues could be handled by numerical time-stepping techniques to integrate differential equations.

In order to study the seismic behavior of structures subjected to low, intermediate, and high- frequency content ground motions, dynamic analysis is required. The ETAB software is used to perform linear time history analysis.

eleven-story regular RC buildings are modeled as three- dimension. Material properties, beam and column sections, gravity loads, and ground motions listed in are assigned to the corresponding RC buildings and then linear time history analysis is performed. The linear time-history analysis results for regular RC buildings.

In the analysis of structures, the number of modes to be considered should have at least 90 percent of the total seismic mass.

CHAPTER 5

REGULAR RC BUILDINGS RESULTS AND DISCUSSION

5.1Overview

In this chapter, the results of eleven-story regular reinforced concrete buildings in terms of story displacement, story drift, story acceleration, and stifness are presented in (x) transverse and (y) longitudinal direction. Also the roof displacement, roof velocity, and roof acceleration for each building due to each ground motion is illustrated in (x) transverse and (y) longitudinal direction. The responses of the structures due to the ground motions are found.

5.2 Eleven story Regular RC Building

G+10 storey regular rc building selected for study having different supports in ground storey like single strut support, double diagonal support, v shape support, inverted v support are applied and compared to show the most stable structure under seismic loading , for this time history elcentro data was taken and applied on structure with the help to ETABS software used for designing of structure, load analysis and all structure related works.It was developed by CSI in 1975.

5.3 Maximum Storey Displacement

S no.	Model name	Maximum value	Minimum value
1	OGS building without support	55.734(11storey)	2.932(1storey)
2	Single Diagonal strut support	55.678(11storey)	2.513(1storey)
3	Double diagonal strut support	55.53(11storey)	0.418(1storey)
4	V support in ground storey	55.169(11storey)	0.528(1storey)
5	Inverted v support in ground storey	55.201(11storey)	0.275(1storey)

Table 5.1. Maximum Storey Displacement Comparision

As we saw here in the above table that maximum displacement at the top of the storey is in the structure which are open ground storey having no support in base, after that single diagonal supported structure ,double diagonal strut support, inverted v support and in last v support respectively will show minimum displacement and hence maximum stable base according to storey displacement.

5.4 Maximum Storey Drift

s.no	Model name	Maximum value	Minimum value
1	OGS building without support	55.733587(storey11)	2.931811(storey1)
2	Single Diagonal strut support	59.177841(storey11)	2.513456(storey1)
3	Double diagonal strut support	55.530244(storey11)	0.417582(storey1)
4	V support in ground storey	55.16931(storey11)	0.527688(storey1)
5	Inverted v support in ground storey	55.200599(storey11)	0.274914(storey1)

Table 5.2. Maximum Storey Drift Comparision

As we saw here in the above table that maximum storey drift at the top of the storey is maximum and minimum in bottom stories, story drift decreases as storey decreases storey drift is maximum in single diagonal supported structure , after that open ground storey having no support in base, double diagonal strut support, inverted v support and in last v support respectively will show minimum storey drift and hence maximum stable base according to storey drift. More drift will show less stable structure, or have less stability.

5.5 Storey Stiffness

s.no	Model name	Maximum value in kN/m	Minimum value in kN/m
1	OGS building without support	459867.92(storey1)	136937.66(storey11)
2	Single Diagonal strut support	1788067.092(storey1)	136977.285(storey11)
3	Double diagonal strut support	7717002.119(storey1)	137429.628(storey11)
4	V support in ground storey	5377063.244(storey1)	137743.68(storey11)
5	Inverted v support in ground storey	5887818.98(storey1)	137329.649(storey11)

Table 5.3. Maximum Storey Stiffness Comparision

As stiffness is the ratio of storey shear and storey drift , having negligible values for many loads, stiffness of the structure will be maximum on first storey and minimum on top storey here for five different models having different support it will be maximum for double diagonal strut support and minimum for OGS building having no support in ground storey.

5.6 Time Period And Frequency

Time period and frequency are appropriate tools for non-stationary signal analysis, synthesis, and processing. Different types of timefrequency distribution have been developed for that purpose. The time-frequency distribution ideally describes how the energy is distributed, and allows us to estimate the fraction of the total energy of the signal at time t and at frequency ω . The below table statement states that the energy should be positive. In order to achieve fine simultaneous time-frequency resolution in a non-stationary time series, we must deal with the uncertainty principle. The strongest in amplitude and apparent large duration (labeled as H1) is located at the lowest frequency contained in the earthquake record. In this case the large duration is in relative comparison with the other observed frequency components.

S.no	Model name	Period sec	Frequency Cyc/sec	Circular frequency rad/sec	Eigenvalue Rad2/sec2
1	OGS building without support	1.621	0.617	3.8772	15.0325
2	Single Diagonal strut support	1.512	0.662	4.1578	17.2586
3	Double Diagonal strut support	1.504	0.665	4.1775	17.4517
4	V support in ground storey	1.507	0.663	4.1686	17.3769
5	Inverted V support in ground storey	1.508	0.663	4.1679	17.3715

Table 5.4. Frequency And Time Period Comparision

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1Summary

Ground motion causes earthquake. Structures are vulnerable to ground motion. It damages the structures. In order to take precaution for the damage of structures due to the ground motion, it is important to know the characteristics of the ground motion. The characteristics of ground motion are peak ground acceleration, peak ground velocity, peak ground displacement, period, and frequency content etc.

Here, low, mid, and high-rise regular as well as irregular RC buildings are studied under low, intermediate, and high-frequency content ground motions. Six ground motions of low, intermediate, and high-frequency content are introduced to the corresponding buildings. Linear time history analysis is performed in ETABS. The outputs of the buildings are given in terms of story displacement, story velocity, story acceleration, and base shear. The responses of each ground motion for each type of building is studied and compared.

6.2 Conclusions

Following conclusions can be drawn for the five differently supported structures having eleven-story regular RC buildings from the results obtained.

Time history analysis was introduced, on five structures having different support in ground storey only, namely OGS building (having no support in ground storey)single strut support(in this type of support a diagonally support was provided), double stut support in ground storey(it will be supported diagonally from both sides), v support in ground storey, and inverted v support. In this study the performance of all the five buildings are examined. Based on the research performed in this study, the following conclusions were drawn;

- ***a)*** The seismic responses namely storey stiffness,storey displacements and storey drifts in both the directions are found to vary in similar pattern with intensities for all the Time Histories and all the models considered for the study.
- ***b)*** The most stable structure is the one which has v support in the ground storey provides better strength against earthquake.

c) Comparision of maximum storey displacement gives maximum displacement at top storey in OGS building and minimum displacement in the building which have v support in ground storey.

d) Maximum story drift will increase with increase in the story height and minimum at the bottom story.here maximum storey drift was found in the structure which have single strut support in ground storey and minimum in structure which have v support in ground storey.

e) Storey Stiffness was antoher point of comparision where we found stiffness is maximum in structure which is x supporting or double diagonal support in ground storey and minimum in OGS building having no support in ground storey.

f) Maximum lateral displacement and lateral increases when storey height increases.

g) As Time History is realistic method, used for seismic analysis, it provides a better check to the safety of structures analyzed and designed by method specified by IS code.

6.3 Recommendations

The present work is carried out to study the behavior of eleven-story regular three-dimension reinforced concrete buildings high-frequency content ground motions. The structure responses such as story displacement, story velocity, story acceleration, and base shear are found and the results are compared. The study of frequency content of ground motion has wide range; one can study the behavior of structures such as steel building, bridge, reservoir etc. under low, intermediate, and high- frequency content ground motion.

Future researches and works may be recommended as detailed below:

a) It is expected that this study will be a point of reference to other RC multi story buildings around the world.

b) The similar approach can be taken for regular and irregular buildings having different height at different storey , it will increase the stiffness and drift of the building.

c) The proposed results need to be validated by further case studies. Building models considered in this study are high rise and therefore influence of period-shift here. For low-rise buildings shift-in-period can be an additional parameter.

d) Another field of wide research could be the design of the infill walls considering the door and the window openings which has not been considered in this case.

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