Dynamic Analysis on Conventional Structure and Geo-polymer Concrete Structure Using Response Spectrum Method

S. Ravi Teja Venkata Sai Kumar[1], P. N. B. Raj Kiran Nanduri[2]

Mtech Scholar[1], Assistant Professor[2]
Samskruti College of Engineering and Technology, Kondapur (V), Ghatkesar (M)
Medchal Dist (Old R.R. Dist), Hyderabad 501301, TELANGANA, INDIA[1,2]

ABSTRACT: - This project describes seismic analysis of high raised using E-tabs, the model of residential G+11 building is prepared and analysis is done using response spectra method considering building location in zone III, this analysis will produce the effect of higher modes of vibration and actual distribution of forces in elastic range in a better way. Test results include lateral loads on diaphragm, lateral loads on story, diaphragm center of mass displacement, diaphragm drifts, maximum story displacements, maximum story drifts, story shears, overturning moments, and story stiffness and get effective lateral load resisting system and helps in finding out whether geo-polymer concrete can be used in the construction of high raised building as we include the dynamic loads in the high raised structure's.

I. INTRODUCTION

These days earthquakes has become very frequent in the nature due to several reasons, here we don't discuss about the reasons of earthquake rather our subject is how to with stand the earthquake loads on the structures or buildings. This becomes the major criteria for us, as the earthquakes are becoming quite common to us designing the building or analysing the buildings in general regular format using the static loads such as live load, dead load etc., we can't design a safer building especially in the case of high raised building it is because in high raised building there will be wind pressure on the building at greater magnitude which varies time to time depending upon the intensity, velocity and direction of wind i.e., dynamic in nature similarly to earth quake loads so as to withstand these type of loads, static methods are not enough and hence we go for dynamic analysis and we model the required structure using ETABS software and analyse the structure in the ETABS using the response spectra method.

Dynamic Analysis

Structures on the earth are generally subjected to two types of loads i.e. static and dynamic. Static loads are constant with time while dynamic loads are time varying. In general, the majority of the civil structures we design assuming only the static loads. The effect of dynamic load is not actually considered in many cases it is because, in India the structures are rarely effected by the earthquake and more over its considerations in the analysis makes the solution more complicated and time consuming. This negligence is the reason for the cause of disaster in most of the cases, particularly, in case of earthquake the negligence of dynamic forces are only the reason for the disaster. Nowadays, there is a growing interest in the process of designing civil engineering structures capable to withstand dynamic loads, particularly, earth quake induced load. The present project is the analysis of a multi-storey structure by considering the dynamic loads on the structure depending up on the zone as per IS code.

India is divided into multiple zones based upon the intensity of the earthquakes depending upon the local circumstances and this division is shown in the Indian map below.

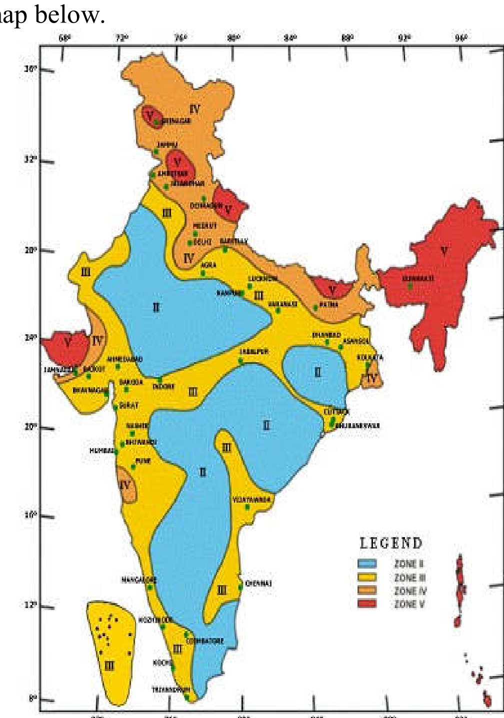

Figure 1-Zones in India

The above map explains how the zones are distributed in india and this will be the basic information which we use to design the multi-storey building or structures by considering the dynamic loads.

The goal of seismic zoning is to delineate regions of similar probable intensity of ground motion in a country, for providing a guideline for provision of an adequate earthquake resistance in constructing facilities, as a step of disaster mitigation. Various social, economical and political considerations govern the prescription if minimum standard of safeguard against earth quake in the design of a structure. These are

i. Economic concept of acceptable risk and
ii. Answer to social question 'how safe is safe enough'

The strongest intensity of likely ground motion is based on the answer to the above two posers/ in terms of pure economic theory, earthquake causes two types of losses namely primary loss and secondary loss.

A primary loss is irrecoverable loss, which results in the loss of human life in the earth quake. All other losses which occur in the earthquake can be placed under the term secondary losses. Thus the minimum standard in a code is prescribed such that complete collapse of the structure is prevented which ensures that no human life is lost. This requires a forecast of the strongest intensity of likely ground motion at a particular site during the service life of structure. Thus estimate acceleration, velocity, displacement, frequency content and duration of expected maximum strong motion is required for a site. Seismic zoning map of a country segregates country in various areas of similar probable maximum intensity of ground motion. The maximum intensity is fixed in such a way that the lifeline/critical structures will remain functional and there is low possibility of collapse of the structure designed with the provision provided in the code even for the occurrence of the earthquake with higher intensity. Thus a structure designed with the provision of code can suffer dame of both structural and non-structural type. The damage is repairable but its economic viability is not warranted.

Response Spectra

It is defined as the plot between the peak state response i.e., displacement, velocity and acceleration to a series of oscillators of varying natural frequency, which are forced into motion by the same base vibrations.

OR

It is the representation of a spectrum of maximum response during a given earthquake ground motion of idealized single degree freedom system having different natural periods and given damping.

This is the most useful concept inthe earthquake engineering and in applying the concepts in the seismological knowledge of strong earthquake to the design of the structure. In the case of response spectrum we don't consider the time variation of the response spectrum rather it is there extreme value that convey the crucial information they relate to maximum forces, maximum displacement and maximum deformation that must be able to endure.

We calculate the maximum response for a range of values of frequency and damping and portray the results graphically, we then have a spectrum chart that shows maximum response of all possible single degree of freedom system to that component of the earthquake. We develop such response spectrum for the area where the structure is to be designed, then we must calculate natural period of the structure and put them on x – axis, and then check the maximum displacement. In this case the response will be displacement, velocity or acceleration and if these three responses are plotted on the single plot then this plot is called as tripartite plot.

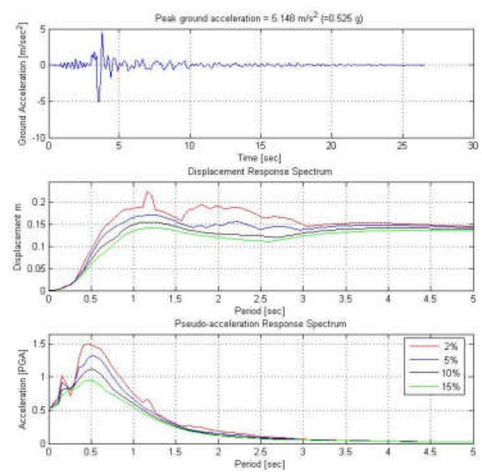

Figure 2- Model graphs of Response Spectrum

In general earthquake engineers prefer to report interaction between ground acceleration and structural systems through response spectrum as popularised by Housner. It reflects frequency content, amplitude of ground motion and effect of subsequent filtering by the structure. Acceleration spectrum is a plot of natural period of vibration of a single degree of freedom oscillator with a specific value of damping versus peak absolute acceleration of oscillator mass when subjected to a base acceleration equal to the earthquake accelerogram. The value of the spectral acceleration at zero periods, known as zero period acceleration (ZPA), is the PGA because oscillator is composed of infinitely stiff linear spring. The relative displacement response spectrum asymptotically approaches maximum ground displacement for highly flexible structure. This implies that the mass remains stationary for all practical purposes and only the ground moves as the linear elastic SDOF system is composed of spring with negligible stiffness. In between the two extremes period, the value of spectral acceleration at a particular period is a constant multiplier, known as amplification factor, of peak ground acceleration. The amplification factor at short period increases with increase in the period and reaches maximum at the sub-soil period and then it decreases with the increase in the period in general. The amplification factor for the rocky site conditions is higher than the alluvial soil conditions at short periods and vice versa at long periods. The amplification factor reduces with increase of hypocentral distance from the site and peak amplification occurs at longer period.

Geo- Polymer Concrete

Geopolymer concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Use of geopolymer reduces the demand of Portland cement which is responsible for high CO_2 emission. Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules.Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.The main constituent of geopolymers source of silicon and aluminium which are provided by thermally activated natural materials (e.g. kaolinite) or industrial byproducts (e.g. fly ash or slab) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.

Recent research works have studied the properties of heat-cured fly ash based geopolymer concrete. The results of these studies have shown potential use of geopolymer concrete as a construction material. The studies have shown that geopolymer concrete has the properties of high compressive strength, very little drying shrinkage, low creep, good bond with reinforcing steel, good resistance to acid, sulphate and fire. It was also found from the experimental and analytical works that the performance of geopolymer concrete structural members such as beams and columns was similar to that of OPC concrete members. Other recent studies have also reported similar engineering properties of geopolymer concrete which are favourable for its use as a construction material.

Need for the work

Tall building developments have been rapidly increasing worldwide. The growth of multi-storey building in the last several decades is seen as the part of necessity for vertical expansion for business as well as residence in major cities. As the height of the building increases the lateral resisting system becomes more important than the structural system that resists the gravitational loads.

From the research papers it is observed the response of the structures subjected to Earthquake excitation. They are found to be incresing in the Natural time period, reduction in lateral displacement and reduction in story drift of the building. In this present study, it is proposed to compare between the performances of conventional structure and geo-polymer concrete structure in the high rise buildings. The performance index includes displacement, base shear, storey drifts and relative performance should be investigated. Two buildings, one with conventional structure and other with geo-polymer concrete structure considering the earthquake zone as per IS 1893:2002(part 1) is being analyzed by using finite element software package ETABS 2016. For analysis various IS codes have been referred, for Gravity load combination IS 456:2000 and for seismic load combinations as per IS 1893:2002(part 1) code is referred. To analyze the structures, the static and dynamic analysis method is adopted. The response spectrum functions are defined to carry out dynamic analysis.

Objective of the work

1. To study the concept of two lateral resisting systems conventional and geo-polymer concrete structural system in earthquake zones and wind conditions.
2. To Model of two buildings, one with conventional system and other with geo-polymer concrete are done by using ETABS 2016 software.
3. Analyzing the modeled structures considering earthquake zone using response spectrum analysis.
4. Study of results in terms of storey displacements, storey drifts, storey shear and time periods.

Scope of the work

The study focuses on comparison of seismic analysis of conventional concrete structure and geo-polymer concrete structure. For the analysis, the model of RC building G+11 storey with 10.5m x 14.5m plan area is considered. The performance of the building is analyzed in Zone III. Modeling and analyzation of the structure is done in ETABS 2016 software. The model of the building with conventional concrete structure and geo-polymer concrete will be implemented in the software and it would be analyzed for response spectrum. Time period of the structures are retrieve from the software and as per IS 1893(part 1):2002 seismic analysis has undergone and storey displacements, storey drifts, storey shear will be compared.

II. LITERATURE REVIEW

.**Dynamic Analysis on Multistoried Regular Building – Dr. Savita Maru, Mohit Sharma**

In this paper the results are obtained using STADD PRO for the structure in zone II and zone III for both static and dynamic analysis

- There is no much difference in the values of axial forces between the values obtained by static and dynamic analysis.
- The values for torsion at different points in the beam are negative and for dynamic analysis the torsion values are positive.
- The values for moment at different points in the beam 10-15% higher for dynamic analysis than the values obtained for static analysis for the moment at the same points.
- The values for displacements at different points in the beam are 17 – 28% higher for dynamic analysis than the values obtained for static analysis at the same point.

Dynamic Analysis on Multistorey RCC Building – Alhamd Farqaleet

In this case we can observe that storey drift increases from base to top floor. Maximum storey drift is found to be within the permissible storey drift range as per IS 1893:2002. The max drift obtained at 10^{th} storey is 0.106m while permissible drift is approximately 0.124m. The max base shear in x and y direction are 2528.2 KN and 184.59 KN hence we can conclude that time history analysis should be performed as it predicts the structural response more accurately than response spectrum analysis.

Dynamic Analysis on Multistorey Building For Different Shapes – D. Gouse Peera, Mohammed Rizwan Sultan

In this journal he gives importance to the shape.

- Irregular shaped are severely affected during earthquakes especially in high seismic zones.
- Base shear is calculated for different kinds of structures we get lowest base shear for L shaped building and highest for rectangular shaped.
- Irregular shape building undergo more deformation than the regular shape building.
- C shape building is more vulnerable than other shaped building

Dynamic Analysis on Multistorey Steel Structures – Meghashree T N, P. Sudheer Kumar, T. Pranay Kumar

- There is no much difference in the magnitude of axial forces in the static and dynamic analysis of the steel structures.
- Magnitude of moments are higher in the case of static analysis when compared with the dynamic analysis.
- We can observe the values of torsion in the static analysis are negative and the values are positive in the case of dynamic analysis.
- The values of displacements at the different points in the beam are higher for static analysis and lesser for dynamic analysis.
- The values of seismic namely base shear, storey displacement and storey drifts for all the time histories are found to be of the increased order for seismic intensities varying from floor to floor.

III. METHODS OF ANALYSIS

All the structures are designed for the combined effects of gravity loads and seismic loads to verify that adequate vertical and lateral strength and stiffness are achieved to satisfy the structural performance and acceptance deformation levels prescribed in the governing building code. Because of the inherent factor of safety used in the design specification, most structures tend to adequately protected against vertical shaking. Vertical acceleration should also be considered in structures with large spans, those in which stability for design, or for overall stability analysis of structures.

In general, most earthquake code provisions implicitly require the structures be able to resist:-

- Minor earthquake without any damage.

- Moderate earthquake with negligible structural damage and some non-structural damage.
- Major earthquake with some structural damage and non-structural damage without collapse.
- The structure is expected to undergo fairly large deformation by yielding in some structural members.

Seismic codes are unique to a particular region or country. In India, IS 1893:2002 (part-1) is the main code that provided outline for calculation of seismic design force. This force depends on the mass and seismic coefficient of the structure and later in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests and ductility. IS 1893:2002 (part-1) deals with assessment of seismic loads on various structures and buildings.

The whole centers on the calculation of base shear and its distribution over height. The analysis can be performed on the basis of external action, the behavior of the structure or structural materials and the type of structural mode selected. In all that treated as discrete system having concentrated mass at floor levels, which include half the column and walls above and below the floor. In addition, appropriate of live load at this floor is also lumped with it.

For the determination of seismic responses, there is necessary to carry out seismic analysis of structure. Based on the type of external action and behavior of structure, the analysis can be further classified as:

- Linear Static Analysis
- Equivalent Static Analysis
- Linear Dynamic Analysis
- Response Spectrum
- Linear Time History Analysis
- Non linear Static Analysis
- Push Over Analysis
- Non linear Dynamic Analysis
- Non-Linear Time History Analysis

Linear static analysis or equivalent static method 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 behavior 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.

Linear static analysis

This method of finding lateral force is also known as the static method or equivalent static method or seismic coefficient method. The static method is the simplest one and it required less computational effort and it is based on formula given in the code of practice IS 1893:2002 (part-1). The design against seismic loads must consider the equivalent linear static methods. It is to be done with an estimation of base shear load and its distribution on each story calculated by using formula given in the code.

Linear 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.

In **linear time history analysis** overcomes all the disadvantages of modal response spectrum analysis, provide non-linear behavior is not involved, the support points of the model are oscillated back and forth in accordance to a recoded ground motion of an actually occurred earthquake (as recorded by a seismograph and available in tabular form of time vs acceleration).

Response spectrum method

The response spectrum method (RSM) was introduced in 1932 in the doctoral dissertation of Maurice Anthony Biot at Caltech. It is an approach to finding earthquake response of structures using waves or vibrational mode shapes. The mathematical principles of oscillations in n-degree-of-freedom systems were taken largely from the theories of acoustics developed by Rayleigh. Biot stated "…[a] building…has a certain number of so called normal modes of vibration, and to each of them corresponds a certain frequency." Biot utilized the Fourier amplitude spectrum to find the maximum amplitude of motion of asystem: the sum of amplitudes for each separate mode of oscillation (Trifunac and Todorovska, 2008).

The concept of the "response spectrum" was applied in design requirements in the mid-20th Century, for example in building codes in the state of California (Hudson, 1956; Trifunac and Todorovska, 2008). It came into widespread use as the primary theoretical tool in earthquake engineering in the 1970s when strong-motion accelero graph data became widely available (Trifunac and Todorovska, 2008).

The seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. The response of a building can be defined as a combination of many special modes that in a vibrating string corresponding to the harmonic. A response spectrum is simply a plot of the peak or steady state response of a series of accelerator of varying natural frequency that are forced into motion by same base vibration or shake. If the input used in calculating a response spectrum is stead state periodic, then the steady state result it recorded. Damping must be present or else the response will be infinite some level if damping is generally assumed, but a value will be obtained even with no damping.

Dynamic analysis using the response spectrum method shall calculate peak modal response for sufficient modes to capture at least 90% of the participating mass of the building in each of two orthogonal principal horizontal directions of the buildings. Modal damping ratios shall reflect the damping in the building at deformation levels that the yield deforms. The response spectrum method uses peak modal response calculated from dynamic analysis of a mathematical model. Only those modes contributing using rational methods to estimate total building response quantifies. Response spectra also can be used in assessing the response of linear systems with multiple modes of oscillation (multi degree of freedom systems), although they are only accurate for low levels of damping. Modal analysis is performed to identify the modes and response in that mode can be picked from response spectrum. The peak response is then combined to estimate a total response the result is typically different from that which would be calculated directly from an input, since phase information is lost in the process of generating the response spectrum.

The response spectrum are very useful tools of earthquake engineering for analyzing the performance of buildings and equipment in earthquake, since many behave principally as simple oscillators (also known as single degree freedom system). Thus if we can find out the natural frequency of the building, then the peak response of the building can be estimated by reading the value from the ground response spectrum for appropriate frequency. In most building codes in seismic regions, this value from the basis for calculating the forces that a building must be designed to resist to earthquake motion. Significant seismic damage may occur if the building response is in tune with components of the ground motion (resonance), which may be identified from the response spectrum. For regular low rise buildings the structural response to earthquake is characterized by the fundamental mode (a waving back and forth), and must building codes permit design forces to be calculated from the design spectrum on the basis of that frequency, but for more complex buildings, combination of the results for many modes (calculate through modal analysis) is often required.

Computer analysis can be used to be determining these modes for a building. For each mode a response is read from the design spectrum, based on the modal frequency and the modal mass and they are combined to provide an estimate of the total response of the building. In this we have to calculate the magnitude of forces in all direction i.e. X, Y and Z and then see the effects on the building. Combined methods include the following:

- Absolute peak values are added together
- Square root of the sum of the squares (SRSS)
- Complete quadratic combination (CQC), a method that is an improvement on SRSS closely spaced modes

The main limitation of response spectrum is that they are only universally applicable for linear systems. Response spectra can be generated for nonlinear systems, but are only applicable to systems with the same nonlinearity, although attempts have been made to develop nonlinear seismic design spectra with wider structural application. The results of this cannot be directly combined for multi-mode response. The representation of maximum response of idealized single degree freedom system having certain time period and damping, during past earthquake ground motions. The maximum response plotted against the un-damped natural period and for various damping factors and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement. For this purpose response spectrum case of analysis have been performed based on IS 1893:2002 (part-1). The modal analysis leads to the response history of the structure to the specified ground motion: however this method is used in conjunction with a response of spectrum.

Errors in evaluation of response spectrum

The following errors are introduced in evaluation of response spectrum

- Straight line approximation:- In the digital computation of spectra, the actual earthquake record is replaced by linear segments between the points of digitization. This is a minor approximation provided that the length of the time intervals is much shorter than the periods of interest.
- Truncation error:- In general, a truncation error exists in numerical methods for integrating differential equations. For example, in third-order Runge- Kutta methods the error is proportional to $(\Delta ti)^4$.

- Error due to rounding the time record: - For earthquake records digitized at irregular time intervals, the integration technique proposed in this report requires rounding of the time record and the attendant error depends on the way the rounding is done. For round-off to 0.005 sec, the average error in spectrum values is expected to be less than 2 percent.
- Error due to discretization: - In any numerical method of computing the spectra, the response is obtained at a set of discrete points. Since spectral values represent maximum values of response parameters which may not occur at these discrete points, discretization introduces an error which gives spectrum values lower than the true values. The error will be a maximum if the maximum response occurs exactly midway between two discrete points. An estimate for the upper bound of this error is noted that at the time of maximum displacement or velocity, the response of the oscillator is nearly sinusoidal at a frequency equal to its natural frequency. Under this assumption the error can be related to the maximum interval of integration, Δt_i and the period of the oscillator.

Time history analysis

It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion in order to examine the exact non-linear behavior of building structures, non-linear time history analysis has to be carried out. In this method, the structure is subjected to real ground motion records. This makes this analysis of masonry infill in a multi-storied building analysis method quite different from all the other approximate analysis methods as the inertial forces are directly determined from these ground motions and the response of the building either in deformation or in forces are calculated as a function of time considering the dynamic properties of the building structure time history. Time history is a step by step analysis of the dynamic response of structure of a specified loading that may vary with time.

Linear time history analysis

The linear time history method involves a time-step-by-step evaluation of the building response, using discretized record or synthetic earthquake records as base motion input. Pair of ground motion records for simultaneous analysis along each horizontal axis of the building should be consistent. Consistent pairs are the orthogonal motions expected at a given site based on the same earthquake. The damping matrix associated with the mathematical model shall reflect the damping in the building a deformation levels near the yield. The seismic input is modeled using either modal spectral analysis or time history analysis but in both case, the corresponding internal forces and displacement are determined using linear elastic analysis. The advantage of these linear dynamic procedures with respect to linear static procedures is the higher modes can be considered. However, they are based on linear elastic response and hence the applicable decreases with increasing behavior, which is approximated by global force reduction factors.

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a time history analysis using ground directly, since phase information is lost in the process of generating the response spectrum. In linear time history analysis, the response of the building to ground motion is calculated in the time domain, and all phase information is therefore maintained. In case where building are either too irregular, too tall or of significance to all community in disaster response, the response spectrum approach is no longer appropriate and more complex analysis is often required. The results (BM, SF, etc.) are usually taken as the maximum enveloped over time (i.e. the maximum bending moment on the mid span of a particular beam in the maximum among all the BM's each corresponding to each time point over the duration of earthquake).

Non linear 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.**

Non linear dynamic analysis

It is known as **Non-Linear 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-by-step 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.

- **Non linear time history analysis**

This is as same as the linear time history analysis, but here since the structure has nonlinear hinges inserted, the members can undergo stiffness degradation, strength deterioration in general damage, as a real building would, during the process of an earthquake. A seismically deficient building will be subjected to inelastic action during earthquake motion. Non-linear time history analysis of the building under strong ground motion brings out the regions of weakness and ductility demand of the structure. This is the most rational method available for assessing building performance. Nonlinear time history analysis utilize the combination of ground motion records with a detailed structural model, therefore capable of producing result with relative low uncertainty. In nonlinear time history analysis the detailed structural model subjected to a ground motion record produces estimates of component deformation for each degree of freedom in the model and the model response are combined using schemes such as the square root of sum of squares (SRSS).

In nonlinear time history analysis the nonlinear properties of the building are considered as part of a time domain analysis. This approach is the most rigorous and is required by some buildings codes for buildings of unusual configuration or of special importance. However the calculated response can be very sensitive to the characteristics of the individual ground motion used as seismic input, therefore several analyses are required using ground motion records to achieve a reliable estimation of the probabilistic distribution of structural response. Since the properties of the seismic response depend on the intensity or severity of the seismic shaking, a comprehensive assessment calls for numerous nonlinear dynamic analyses at various levels of intensity to represent different possible earthquake scenarios.

IV. MODELING AND ANALYSIS

This chapter deals with the modeling and analysis of the structure under various loads. The finite element package ETABS V16.2.1.0 has been used for the analysis. A three dimensional model of the structure have been created to undertake static and dynamic analysis. The model ideally represents the complete three dimensions (3D) characterizes of the building, including its mass distribution, strength, stiffness deformability. Modeling of the material properties, structural elements, load patterns, load cases and combinations and response spectrum and time history functions are discussed in this chapter.

ETABS Software

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. For a sophisticated assessment of seismic performance, modal and direct-integration time-history analyses may couple with P-Delta and Large Displacement effects. Nonlinear links and concentrated PMM or fiber hinges may capture material nonlinearity under monotonic or hysteretic behavior. Intuitive and integrated features make applications of any complexity practical to implement. Interoperability with a series of design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises.

The step wise procedure that is followed in ETABS Software is

- Modeling of structural elements
- Loading, analysis and design
- Output

ETABS also features interoperability with related software products, providing for the import of architectural models from various technical drawing software, or export to various platforms and file formats. SAFE, the floor and foundation slab design software with post-tensioning (PT) capability, is one such option for export. CSI coordinated SAFE to be used in conjunction with ETABS such that engineers could more thoroughly detail, analyze, and design the individual levels of an ETABS model. While ETABS features a variety of sophisticated capabilities, the software is equally useful for designing basic systems. ETABS is the practical choice for all grid-like applications ranging from simple 2D frames to the most complex high rises.

Modal analysis

Modal analysis is used to determine the vibration modes of a structure. These modes are useful to understand the behavior of the structure. They can also be used as the basis for modal superposition in response-spectrum and modal time-history Load Cases. They are

- Eigen vector analysis
- Ritz-vector analysis

Eigenvector analysis determines the undamped free vibration mode shapes and frequencies of the system. These natural modes provide an excellent insight into the behavior of the structure.

Ritz-vector analysis: Research has indicated that the natural free- vibration mode shapes are not the best basis for a mode- superposition analysis of structures subjected to dynamic loads. It has been demonstrated that dynamic analyses based on a special set of load-dependent Ritz vectors yield more accurate results than the use of the same number of natural mode shapes. Ritz-vectors are generated by taking into account the spatial distribution of the dynamic loading, whereas the direct use of the natural mode shapes neglects this very important information.

The spatial distribution of the dynamic load vector serves as a starting load vector to initiate the procedure. The first Ritz vector is the static displacement vector corresponding to the starting load vector. The remaining vectors are generated from a recurrence relationship in which the mass matrix is multiplied by the previously obtained Ritz vector and used as the load vector for the next static solution. Each static solution is called a generation cycle. When the dynamic load is made up of several in de pendent spatial distributions, each of these may serve as a starting load vector to generate a set of Ritz vectors. Each generation cycle creates as many Ritz vectors as there are starting load vectors. If a generated Ritz vector is redundant or does not excite any mass degrees of freedom, it is discarded and the corresponding starting load vector is re moved from all subsequent generation cycles.

Standard eigen-solution techniques are used to orthogonalize the set of generated Ritz vectors, resulting in a final set of Ritz-vector Modes. Each Ritz-vector Mode consists of a mode shape and frequency. The full set of Ritz-vector Modes can be used as a basis to represent the dynamic displacement of the structure. When a sufficient number of Ritz-vector Modes have been found, some of them may closely approximate natural mode shapes and frequencies. In general, however, Ritz- vector Modes do not rep re sent the intrinsic character is tics of the structure in the same way the natural modes do. The Ritz- vector modes are biased by the starting load vectors.

Problem Formulation

Two tall buildings of 10 storey's with plan area 10.5 mx14.5 m is analyzed in ETABS V16.2.1.0 package to determine dynamic control of the those buildings. Wind and Earthquake parameters for analysis are taken and dynamic analysis is performed as per IS: 1893-2002 code. Analysis is performed to find Time History, Time Period, Storey Displacement, Storey Drift and base shear for the two structures. General description of the Building is tabulated in table 5.1

Table 4.1 Description of the Building data

1	**Details of the building**			
i)	Structure	OMRF		
ii)	Number of stories	G+10		
iii)	Type of building	Regular and Symmetrical in plan		
iv)	Plan area	10.5 m x 14.5 m		
v)	Height of the building	33 m		
vii)	Support	Fixed		
viii)	Seismic zones	III		
2	**Material properties**			
i)	Grade of concrete	M30		
ii)	Grade of steel	Fe415		
iii)	Density of reinforced concrete	25 kN/m^3		
iv)	Young's modulus of M30 concrete, E_c	27386.13 kN/m^2		
v)	Young's modulus of M30 concrete, E_G	247800 kN/m^2		
vi)	Poissions ration, μ_c	0.2		
vii)	Poissions ration, μ_G	0.15		
viii)	Young's modulus steel, E_s	2×10^8 kN/m^2		
3	**Type of Loads & their intensities**			
i)	Floor finish	1.5 kN/m^2		
ii)	Live load on floors	2 kN/m^2		
iii)	External wall load on beams	11.5 kN/m^2		
iv)	Internal wall load on beams	5.27 kN/m^2		
4	**Seismic Properties**			
i)	Zones	III	0.16	
ii)	Importance factor (I)	1		
iii)	Response reduction factor (R)	5%		
iv)	Soil type	II		
v)	Damping ratio	0.05		
vi)	Wind Speed - Zone III	39 m/sec		
vii)	Wind coefficients Terrain category Risk coefficient Topography	 2 1 1		
5	**Member Properties**	**No. of stories**	**Grade**	**Section sizes (mm)**
i)	Column	ALL	M30	450 x 450
ii)	Beam	ALL	M30	500 x 230
iii)	Slab	ALL	M 30	175

Earthquake Data Description

During the past earthquakes in India many structures have been severely damaged or collapsed, like in bhuj earthquake in Gujarat buildings and structures severely damaged, this indicated the need of evaluating the seismic adequacy of existing structures and alternative new method for design of new structures. In particular, the seismic rehabilitation of older concrete structures in high seismicity area, is matter of growing concern, since structures vulnerable to damage must be determined to make such assessment, simplified linear elastic methods are not adequate and structural engineers must use more complex nonlinear inelastic technique such as nonlinear dynamic analysis.

Bhuj/Kachchh 2001-01-26 03:16:40 Utc

The powerful earthquake that struck the Kutch area in Gujarat at 8:46 am on 26th January 2001 has been the most damaging earthquake in last five decades in India. The M7.9 quake caused a large loss of life and property. Over 18,600 persons are reported to be dead and over 167,000 were injured. The entire Kutch region of Gujarat, enclosed on three sides by the Great Runn of Kutch, the little Runn of Kutch and the Arabian Sea, sustained highest damage with maximum intensity of shaking as high as X on the MSK intensity scale. The most common way of describing a ground motion is through the time history.

- Acceleration time history
- Velocity time history
- Displacement time history

Figure 5.1 Location of bhuj earthquake

Acceleration data

Station: Ahmedabad, India

Station Owner: Dept. of Earthquake Engineering, IITR, India

Station Latitude & Longitude: 23.0300, 72.6300

Earthquake: BHUJ/KACHCHH 2001-01-26 03:16:40 UTC

Hypo central Distance: 239 km

Peak Acceleration: -0.78236 m/s/s at 34.945 sec

26706 acceleration data points (in m/s/s) were recorded at 0.005 sec time interval.

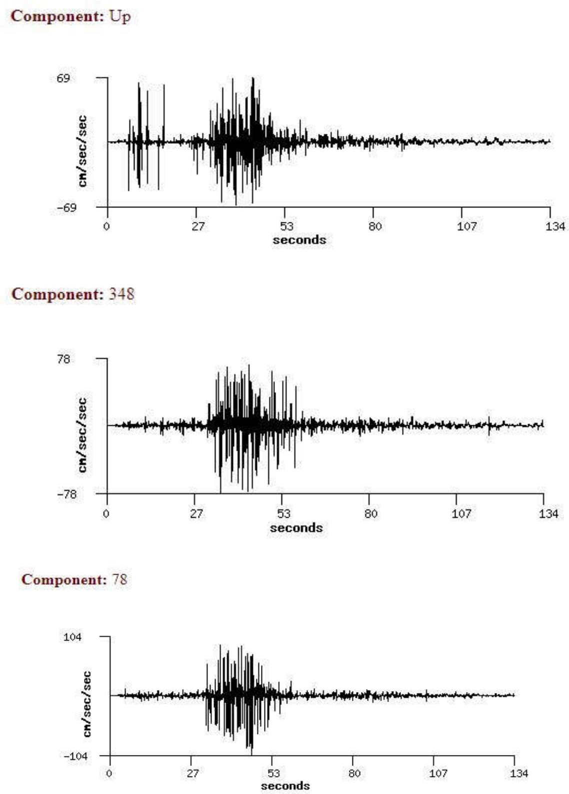

Figure 5.2 Peak accelerations of bhuj earthquake

In the present study, 10 storied reinforced concrete structures IS considered. The 1st model is for RC building with conventional concrete and 2nd model is with geo polymer concrete. The modeled structures are situated in earthquake zone III of India having medium stiff soil is considered. Plan and 3D view of the structures is shown in Figure 5.3 Figure 5.4

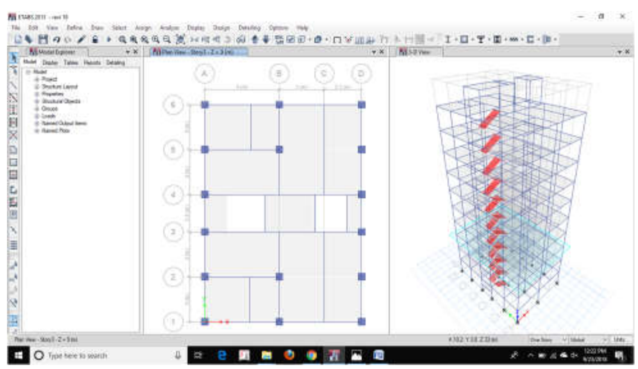

Figure 5.3 Plan and 3D view of the structure

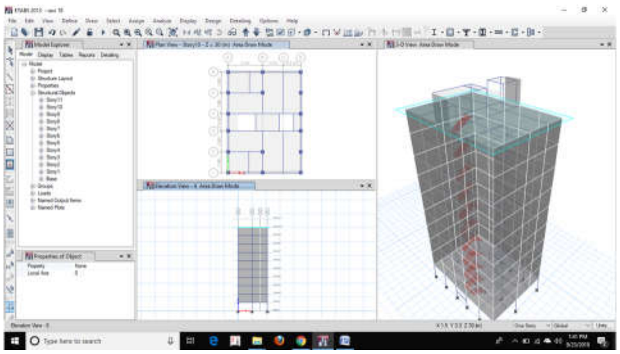

Figure 4.4 Plan, Elevation and 3D view of the structure

After completing the modeling we need to define materials such as concrete, steel etc. which are required in defining the structural members such as beams, columns, stair case etc., when we define the type of material we are also allowed to choose the grade of the material at the same time, after this selection we will define the structural members such as beams, columns along with this we also define shape of the structure such as rectangle, circle etc., along with this we also define the design parameters of the structural, we can observe these things in the followed figures.

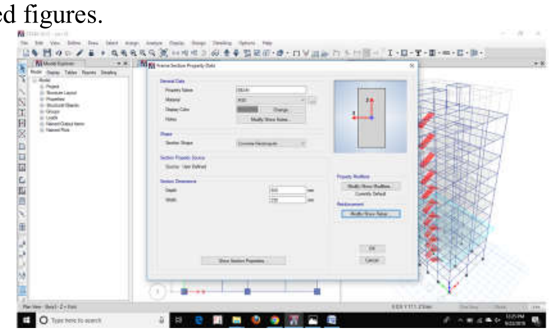

Figure 4.5 Defining of beam

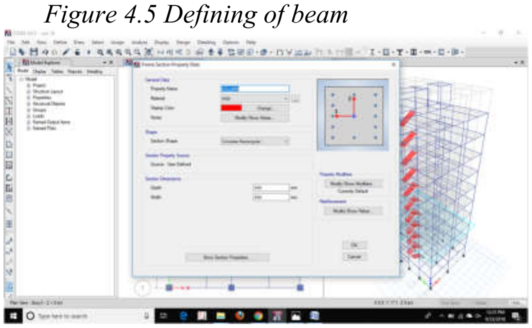

Figure 4.6 Defining of column

After we complete defining beams and columns we then assign them to the model as per our requirements, we shall assign the properties carefully such that there should not be any flaw in the assignment and after this is done we shall define the dead load,
live load, earth quake load, wind load as per our requirements and then we assign these loads on the beams and columns of the structure, these are shown in the following figures.

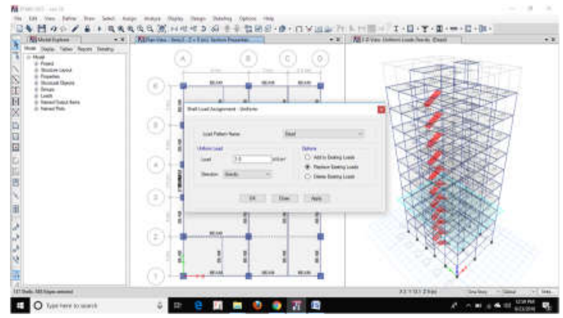

Figure 4.7 Defining Floor Finish load(DEAD LOAD)

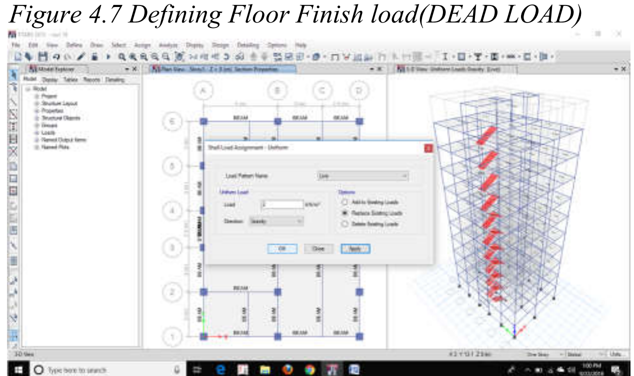

Figure 4.8 Defining Live Load

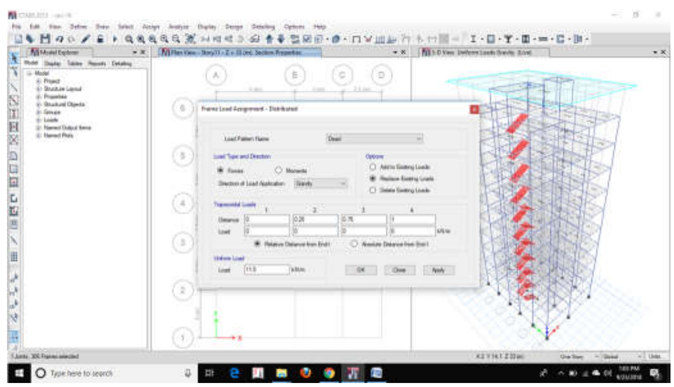

Figure 4.9 Defining Outer Wall Load

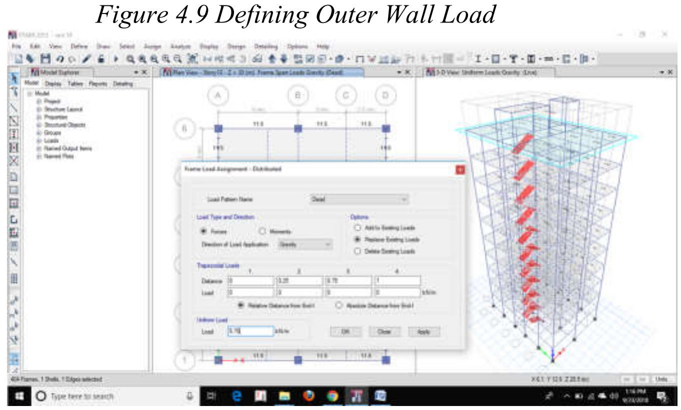

Figure 4.10 Defining Inner Wall Load

After assigning the loads which are defined above, we also define the earth quake loads, wind loads as per our requirements, the figures below will explain the way we define the lateral loads such as both earth quake and wind loads and in the below figures we can observe the structure after we apply all the loads.

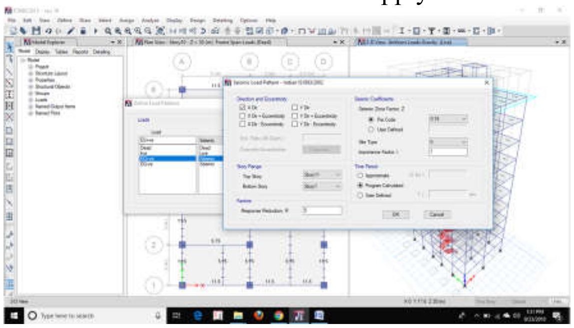

Figure 4.11 Defining the Earth Quake Load

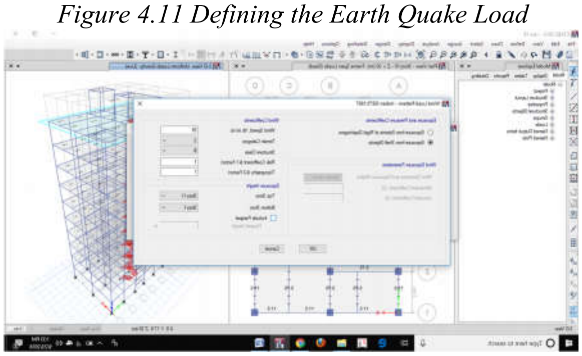

Figure 4.12 Defining the Wind Load

Wind loads are defined as above but we can assign then only if walls are there on the structure, but as we have already assigned wall load on the beam, now we need to select none in the wall and then we have to assign the wind loads and this can be observed in the figure below.

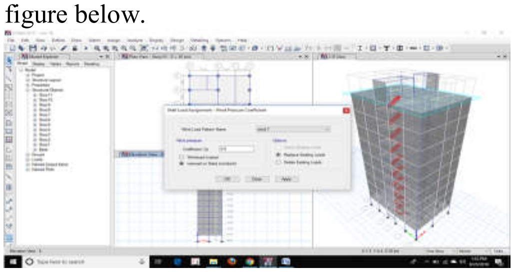

Figure 4.13 Assigning the Wind Load

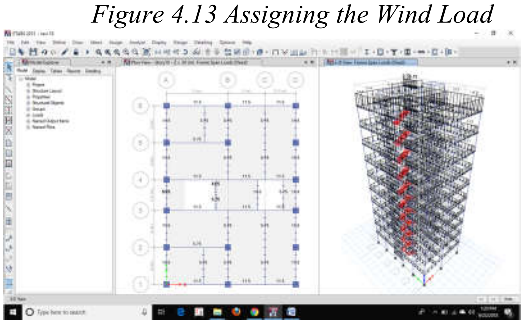

Figure 4.14 Assigning of loads

In the following Fig.5.14, definitions of loading are shown. Several loads are applied on both the structure such as dead load which is self-weight, super dead load which is applied dead load, live load which is imposed load, wind load at two directions X and Y which is imposed load, earthquake load at two directions applied X and Y direction which is imposed load, Load combination is done as per IS: 1893-2002.

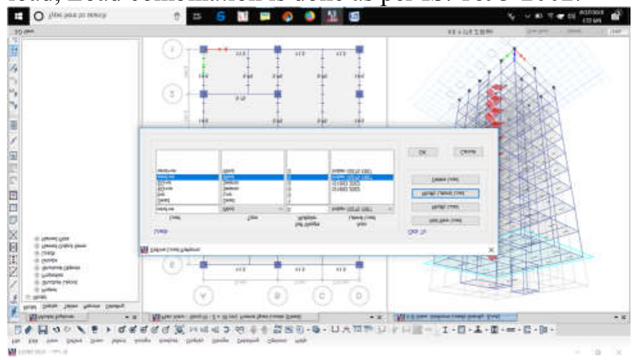

Figure 4.15 Loading patterns

Defining the response spectrum function and time history data in different zones in the software for analyzing structures are shown in Fig.5.15

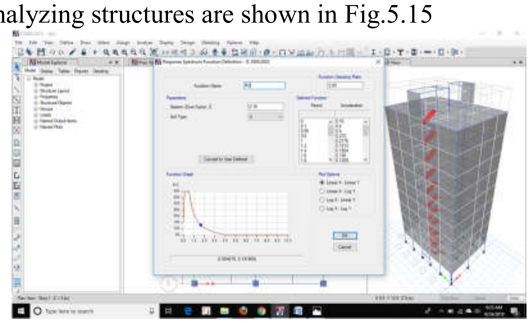

Figure 4.16 Defining Response spectrum data

Load combinations as per IS codes

When earthquake forces are considered on a structure, load combinations shall be combined of partial safety factors for limit state design of reinforced concrete structures where terms like DL, LL, EQX and EQY, RSX and RSY, THX and THY stands for response quantities due to dead load, live load, earthquake loads in X and Y direction, response spectrum in X and Y direction and time history in X and Y direction respectively. Load combinations are considered according to IS 1893-2002 part 1 is tabulated in Table 5.2

Table 4.2 Load combination as per Indian standards

Load Combination	Load Factors
Gravity Analysis	1.5(DL + LL)
Equivalent Static Analysis	1.2(DL + LL ± EQX)
	1.2(DL + LL ± EQY)
	1.5(DL ± EQX)
	1.5(DL ± EQY)
	0.9(DL ± EQX)
	0.9(DL ± EQY)
	0.9DL ± 1.5EQX
	0.9DL ± 1.5EQY

Response Spectrum Analysis	1.2(DL + LL ± RSX)
	1.2(DL + LL ± RSY)
	1.5(DL ± RSX)
	1.5(DL ± RSY)
	0.9(DL ± RSX)
	0.9(DL ± RSY)
	0.9DL ± 1.5RSX
	0.9DL ± 1.5RSY

V. RESULTS AND DISCUSSIONS

The seismic analysis of the modeled structures with shear walls and diagrids spanning in two directions are carried out by using ETABS software and the results are given in the following sections. The parameters studied are story displacement, story drifts, base shear and storey stiffness in seismic zones III. Comparison of seismic behavior is made between the structures with conventional concrete and geo-polymer concrete . The comparison has done in Response Spectrum method.

Story displacement

It is the total displacement of i[th] story with respect to ground. The story displacements of the modeled structures located in zone III using response spectrum method and time history analysis in X – direction are shown in Table

Table 5.1 Story displacements of the structures in zone III in X-direction

Displacements(mm) in Zone III in X-direction							
		X			Y		
Story	**Elevation**	**Conventio**	**Geo-Polyme**	**%**	**Conventiona**	**Geo-Polyme**	**%**
Stor	33	5.6	5.6	0	0.8	0.9	-12.5
Stor	30	5.9	6	-	0.9	0.9	0
Stor	27	5.7	5.8	-	0.8	0.8	0
Stor	24	5.4	5.5	-	0.8	0.8	0
Stor	21	5	5	0	0.8	0.8	0
Stor	18	4.5	4.5	0	0.7	0.7	0
Stor	15	3.9	3.9	0	0.6	0.6	0
Stor	12	3.1	3.2	-	0.5	0.5	0
Stor	9	2.4	2.4	0	0.4	0.4	0
Stor	6	1.5	1.5	0	0.3	0.3	0
Stor	3	0.7	0.7	0	0.2	0.2	0
Bas	0	0	0	0	0	0	-12.5

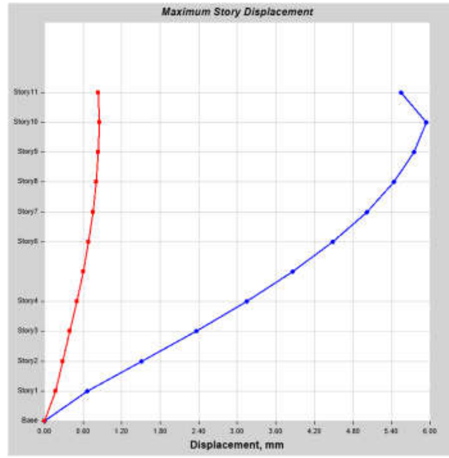

Figure 5.1 Story displacement of conventional concrete in zone III in X- direction using Response Spectrum method

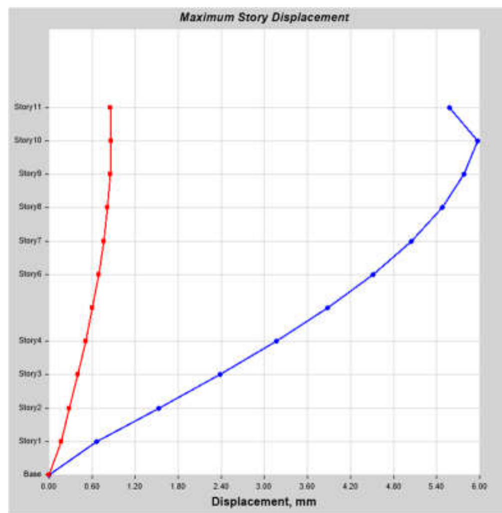

Figure 5.2 Story displacement of geo-polymer concrete in zone III in X- direction using Response Spectrum method

Table 5.2 Story displacements of the structures in zone III in Y-direction

Displacements(mm) in Zone III in Y-direction							
		X			Y		
Story	**Elevation**	**Conventi**	**Geo-Polym**	**%**	**Conventio**	**Geo-Poly**	**%**
Sto	33	8.2	8.3	-	16.8	16.9	-
Sto	30	13.4	13.5	-	17.9	18	-
Sto	27	12.9	13	-	17.3	17.4	-
Sto	24	12.2	12.3	-	16.2	16.4	-
Sto	21	11.1	11.2	-	14.9	15	-
Sto	18	9.9	10	-	13.2	13.3	-

Sto	15	8.4	8.5	-	11.2	11.3	-
Sto	12	6.8	6.8	0	9	9.1	-
Sto	9	5	5	0	6.6	6.7	-
Sto	6	3.1	3.1	0	4.1	4.1	0
Sto	3	1.2	1.2	0	1.6	1.6	0
Ba	0	0	0	-	0	0	-

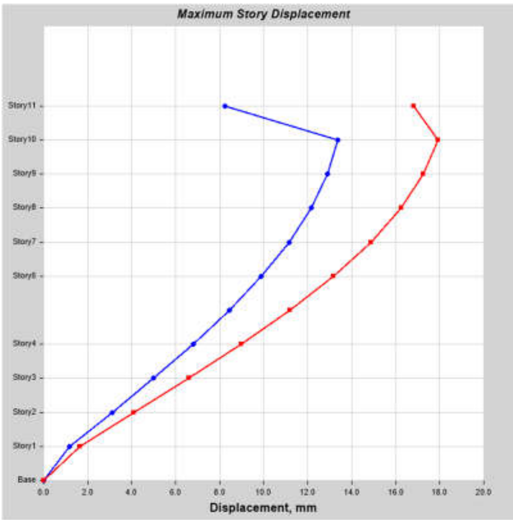

Figure 5.3 Story displacement of conventional concrete in zone III in Y- direction using Response Spectrum method

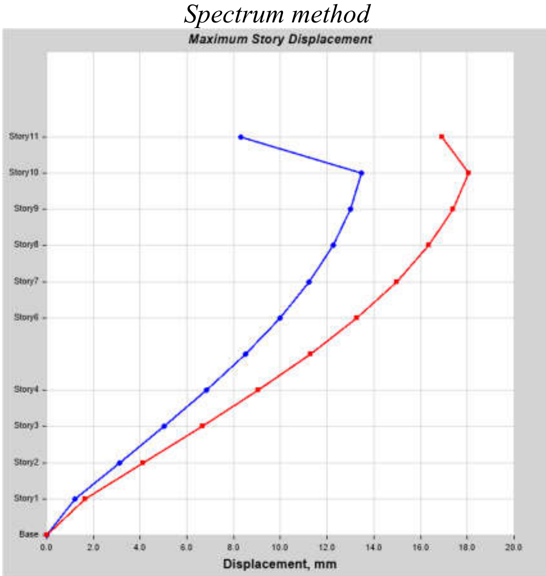

Figure 5.4 Story displacement of geo-polymer concrete in zone III in Y- direction using Response Spectrum method

Story drifts

Story Drift is defined as ratio of displacement of two consecutive floors to the height of that floor. Drifts in frame structure are due to the result of flexure and shear mode contributions. In high rise structures, higher axial forces and deformations in columns and accumulations of their effects over greater heights cause flexure component displacement to become dominant.

The story drifts of the modeled structures in Zone III using response spectrum method and time history analysis in X – direction is shown in Table

Table 5.3 Story drifts of the structures in zone III in X-direction

Drift(mm) in Zone III in X-direction							
		X			**Y**		
Story	**Elevation**	**Conventio**	**Geo-Polym**	**%**	**Conventiona**	**Geo-Polym**	**%**
Sto	33	0.001	0.0018	-	0.000	0.0001	-
Sto	30	0.000	0.0000	0	0.000	0.0000	0
Sto	27	0.000	0.0001	0	0.000	0.0000	0
Sto	24	0.000	0.0001	-	0.000	0.0000	0
Sto	21	0.000	0.0001	-	0.000	0.0000	0
Sto	18	0.000	0.0002	-	0.000	0.0000	0
Sto	15	0.000	0.0002	-	0.000	0.0000	0
Sto	12	0.000	0.0002	-	0.000	0.0000	-
Sto	9	0.000	0.0002	-	0.000	0.0000	-
Sto	6	0.000	0.0003	-	0.000	0.0000	-
Sto	3	0.000	0.0002	-	0.000	0.0000	0
Bas	0	0	0	0	0	0	0

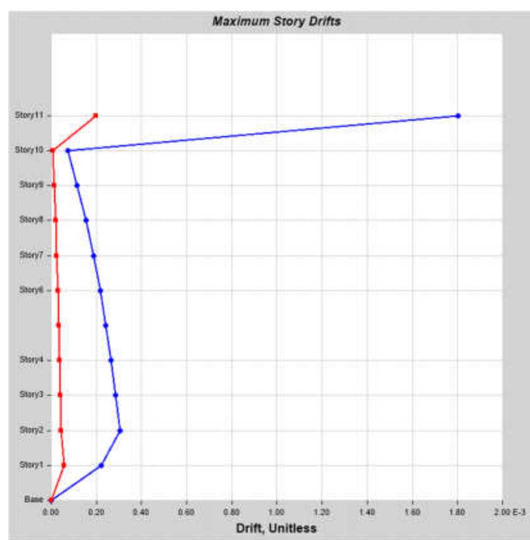

Figure 5.5 Story drift of conventional concrete in zone III in X- direction using Response Spectrum method

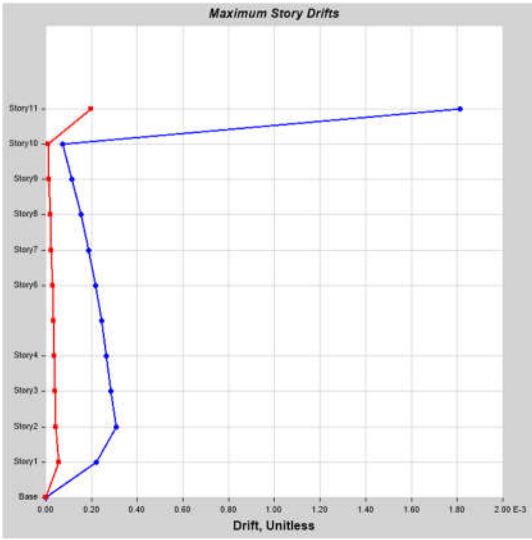

Figure 5.6 Story drift of geo-polymer concrete in zone III in X- direction using Response Spectrum method

Table 5.4 Story drifts of the structures in zone III in Y-direction

Drift(mm) in Zone III in Y-direction							
		X			**Y**		
Story	**Elevation**	**Conventio**	**Geo-Polym**	**%**	**Conventio**	**Geo-Polym**	**%**
Sto	33	0.000	0.0009	-	0.005	0.0060	-
Sto	30	0.000	0.0001	-	0.000	0.0002	-
Sto	27	0.000	0.0002	-	0.000	0.0003	-
Sto	24	0.000	0.0003	-	0.000	0.0004	-
Sto	21	0.000	0.0004	-	0.000	0.0005	-
Sto	18	0.000	0.0004	-	0.000	0.0006	-
Sto	15	0.000	0.0005	-	0.000	0.0007	-
Sto	12	0.000	0.0006	-	0.000	0.0008	-
Sto	9	0.000	0.0006	-	0.000	0.0008	-
Sto	6	0.000	0.0006	-	0.000	0.0008	-
Sto	3	0.000	0.0003	-	0.000	0.0005	-
Bas	0	0	0	0	0	0	0

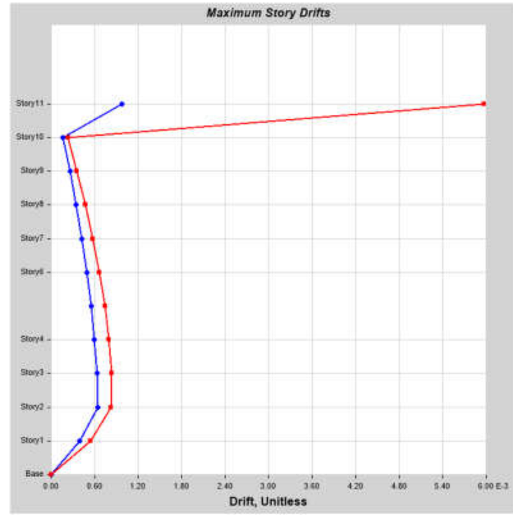

Figure 5.7 Story drift of conventional concrete in zone III in X- direction using Response Spectrum method

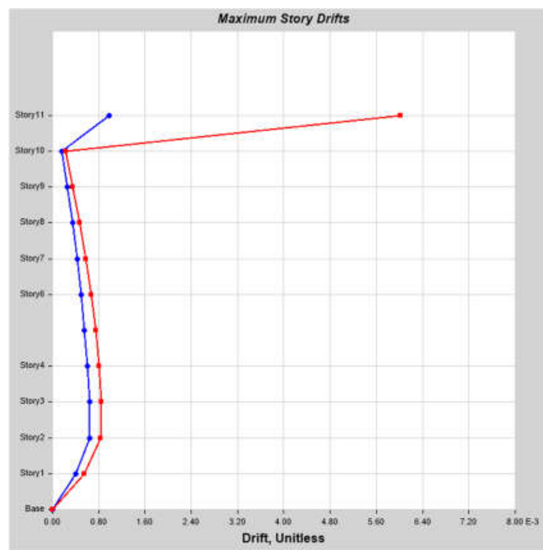

Figure 5.8 Story drift of geo-polymer concrete in zone III in X- direction using Response Spectrum method

Story shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Storey shear factor is the ratio of the story shear force when story collapse occurs to the story shear force when total collapse occurs.

Table 5.5 Story shear of the structures in zone III in X-direction

			Storey Shear in Zone III in X-					
			X			Y		
Story	Elevatio		Conventi	Geo-Poly	%	Conventi	Geo-Poly	%
Sto	33	Top	13.1	13.3	-	1.52	1.556	-
		Botto	13.1	13.3	-	1.52	1.556	-
Sto	30	Top	46.1	46.5	-	11.5	11.64	-
		Botto	89.3	90.1	-	8.55	8.698	-
Sto	27	Top	84.3	85.2	-	16.9	17.24	-
		Botto	146.	148.	-	14.3	14.62	-
Sto	24	Top	117.	119.	-	22.2	22.57	-
		Botto	197.	199.	-	19.6	20.05	-
Sto	21	Top	148.	150.	-	27.0	27.48	-
		Botto	241.	243.	-	24.4	24.89	-
Sto	18	Top	175.	177.	-	31.2	31.78	-
		Botto	280.	282.	-	28.6	29.17	-
Sto	15	Top	199.	201.	-	34.9	35.52	-
		Botto	314.	317.	-	32.2	32.87	-
Sto	12	Top	219.	222.	-	38.0	38.70	-
		Botto	343.	346.	-	35.3	35.99	-
Sto	9	Top	240.	243.	-	40.4	41.13	-
		Botto	367.	371.	-	37.8	38.56	-
Sto	6	Top	226.	229.	-	41.2	41.92	-
		Botto	385.	388.	-	39.7	40.50	-
Sto	3	Top	178.	181.	-	19.5	20.06	-
		Botto	391.	395.	-	40.5	41.34	-
Ba	0	Top	0	0	0	0	0	0
		Botto	0	0	0	0	0	0

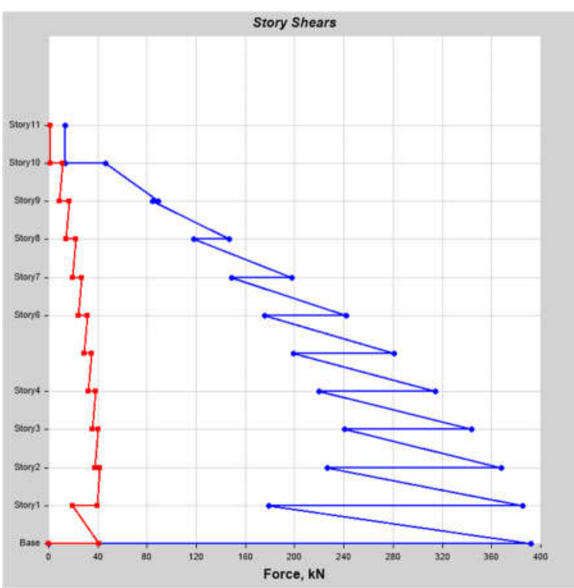

Figure 6.9 Story shear of conventional concrete in zone III in X- direction using Response Spectrum method

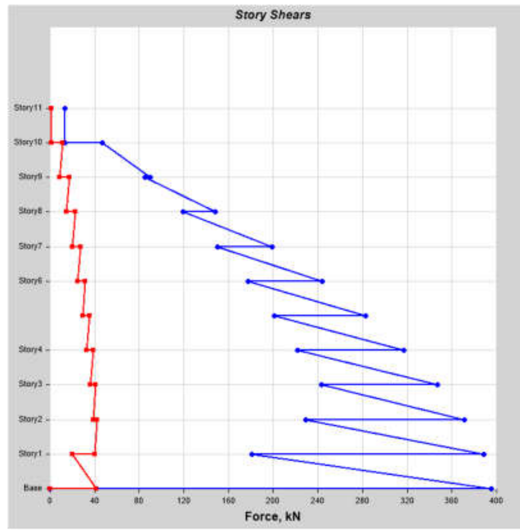

Figure 5.10 Story shear of geo-polymer concrete in zone III in X- direction using Response Spectrum method

Table 5.5 Story shear of the structures in zone III in Y-direction

			Storey Shear in Zone III in Y-					
			X			Y		
Story	Elevation (m)		Conventional	Geo-Polymer	%	Conventional	Geo-Polymer	%
Sto	33	Top	3.625	3.646	-	15.08	15.27	-
		Botto	3.625	3.646	-	15.08	15.27	-
Sto	30	Top	10.35	10.50	-	41.11	41.30	-
		Botto	13.80	14.00	-	100.5	101.1	-
Sto	27	Top	15.00	15.27	-	79.64	80.22	-
		Botto	22.27	22.64	-	170.5	171.8	-
Sto	24	Top	20.34	20.74	-	115.8	116.7	-
		Botto	30.16	30.69	-	235.5	237.4	-
Sto	21	Top	25.44	25.96	-	148.6	149.9	-
		Botto	37.36	38.04	-	294.2	296.7	-
Sto	18	Top	30.02	30.64	-	178.3	179.9	-
		Botto	43.83	44.64	-	345.6	348.5	-
Sto	15	Top	34.05	34.77	-	204.9	206.8	-
		Botto	49.50	50.43	-	389.2	392.5	-
Sto	12	Top	37.79	38.58	-	227.5	229.7	-
		Botto	54.24	55.27	-	425.2	428.8	-
Sto	9	Top	42.47	43.36	-	246.9	249.3	-

		Botto	57.94	59.04	-	453.5	457.5	-
Sto	6	Top	36.69	37.52	-	253.3	255.8	-
		Botto	60.40	61.56	-	473.4	477.5	-
Sto	3	Top	34.93	35.63	-	239.8	242.0	-
		Botto	60.49	61.67	-	480.7	484.9	-
Bas	0	Top	0	0	0	0	0	0
		Botto	0	0	0	0	0	0

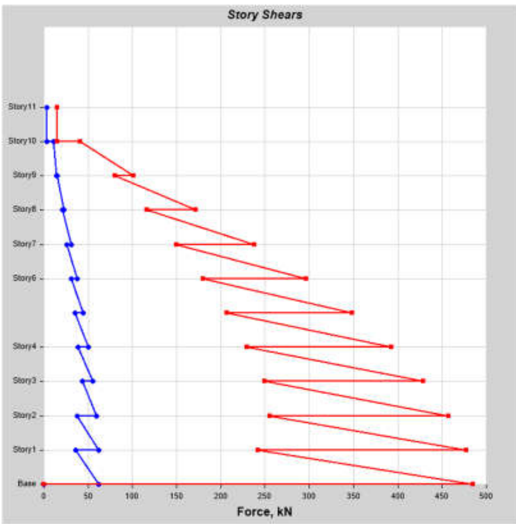

Figure 5.11 Story shear of conventional concrete in zone III in Y- direction using Response Spectrum method

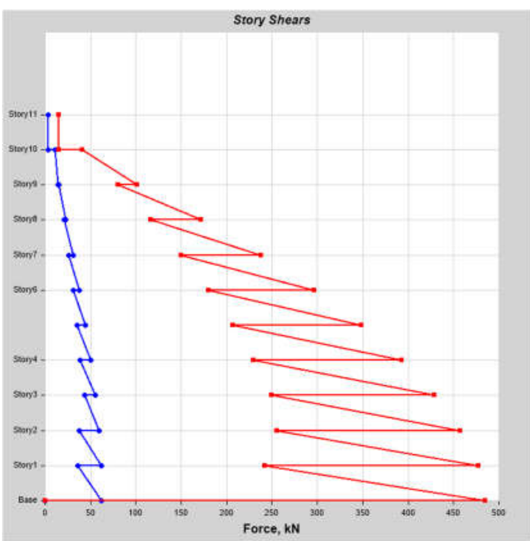

Figure 5.12 Story shear of geo-polymer concrete in zone III in Y- direction using Response Spectrum method

Story 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,variat-ions in the lateral stiffness of a given story for the several load cases are small enough to be neglected

Table 5.7 Story stiffness of the structures in zone III in Y-direction

STOREY STIFFNESS IN RS X							
		X			Y		
Story	Elevation	Conventiona	Geo-Polyme	%	Conventional	Geo-Polyme	%
Stor	33	4710.3	4754.67	-	4894.1	4974.89	-
Stor	30	43767	438816.	-	0	0	0
Stor	27	47179	473215.	-	0	0	0
Stor	24	47637	477844.	-	0	440971.	0
Stor	21	47994	481445.	-	434239	435917.	-
Stor	18	48297	484508.	-	430311	431986.	-
Stor	15	48566	487231.	-	427951	429632.	-
Stor	12	48823	489830.	-	426604	428706.	-
Stor	9	48022	481711.	-	430710	433413.	-
Stor	6	49104	492402.	-	419641	422006.	-
Stor	3	71606	716862.	-	378092	381338.	-
Bas	0	0	0	0	0	0	0

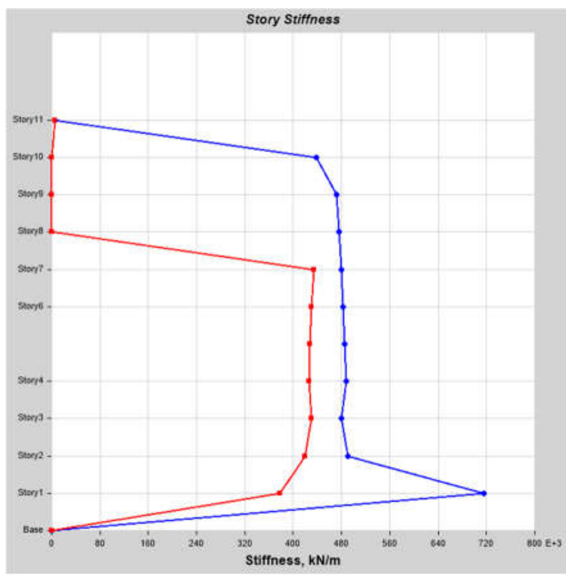

Figure 5.13 Story stiffness of conventional concrete in zone III in X- direction using Response Spectrum method

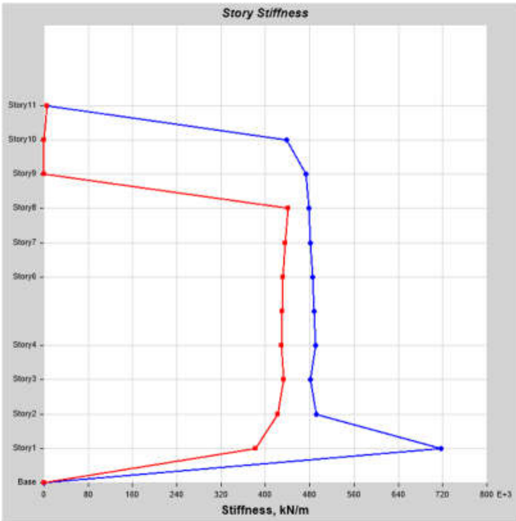

Figure 5.14 Story stiffness of geo-polymer concrete in zone III in X- direction using Response Spectrum method

Table 5.8 Story stiffness of the structures in zone III in Y-direction

STOREY STIFFNESS IN RS Y							
		X			Y		
Story	Elevation	Conventio	Geo-Polym	%	Conventiona	Geo-Polym	%
Sto	33	2452.	2446.9	0.23	1665.	1674.1	-
Sto	30	5189	52385.	-	22469	225121	-
Sto	27	5375	54314.	-	24572	246226	-
Sto	24	5455	55142.	-	25410	254602	-
Sto	21	5522	55829.	-	25923	259740	-
Sto	18	5583	56455.	-	26252	263023	-
Sto	15	5644	57077.	-	26532	265802	-
Sto	12	5712	57761.	-	26820	268687	-
Sto	9	5742	58063.	-	27206	272535	-
Sto	6	5890	59521.	-	28691	287372	-
Sto	3	9502	96036.	-	42643	426856	-
Bas	0	0	0	0	0	0	0

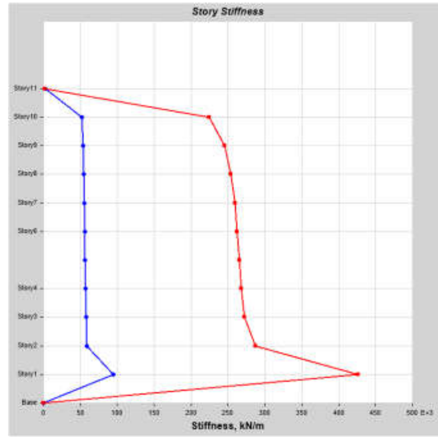

Figure 5.15 Story stiffness of conventional concrete in zone III in Y- direction using Response Spectrum method

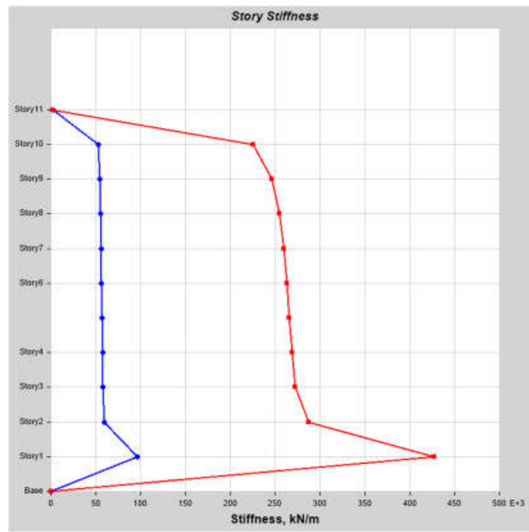

Figure 5.16 Story stiffness of geo-polymer concrete in zone III in Y- direction using Response Spectrum method

VI. CONCLUSIONS

In the previous chapter, the seismic behavior of the modeled structures i.e. story displacement, story drifts, base shear and natural time period in seismic zones are discussed and comparison of seismic behavior is made between structure with conventional concrete and geo-polymer concrete structure in response spectrum method. In this chapter, the conclusions of the obtained results are discussed in detail.

- The maximum story displacement between conventional concrete structure and the geo-polymer concrete structure is 3.22% but we can observe that even the displacement is higher when compared with conventional concrete the displacement is with the limits as per is code.

- The maximum story drift between conventional concrete structure and the geo-polymer concrete structure is 2.7% .
- The maximum story shear between conventional concrete structure and the geo-polymer concrete structure is 2.2%, the storey shear is also increasing in the structure when compared with conventional concrete this resembles the resistance towards the seismic loads is higher for concrete when compared with geo-polymer concrete, but we can observe we can also use the geo-polymer concrete but the only thing is the structure becomes little uneconomical but we can use this in the low seismic prone area, so as to be environmental friendly.
- The maximum story stiffness between conventional concrete structure and the geo-polymer concrete structure is 1.64%.
- With the above observations we conclude that both conventional concrete and geo-polymer concrete can be used in the high-raised structure even when the seismic loads and wind loads play major role in the design, but by using the geo-polymer concrete the structure may become uneconomical but at the same time by encouraging these types of constructions we can make the environmental friendly structures.

REFERENCES

1. Kirtan T and Jayaramappa N, "Comparative study of multi-storey RC frame with shear wall and hexagrid system", *Indian Journal of Research*, Volume: 06, Issue: 01, January 2017, pp. 814-817, ISSN 2250-1991.
2. Jayesh Venkolath and Rahul Krishnan K, "Optimal diagrid angle of high-rise buildings subjected to lateral loads", *International Research Journal of Engineering and Technology (IRJET),* Volume: 03 Issue: 09, September 2016, (pp. 841-846).
3. Abhinav V, Sreenatha Reddy, Vasudeva Naidu and Madan Mohan, "Seismic analysis of multi-story RC building with shear wall using STAAD.Pro", *International Journal of Innovative Technology and Research (IJITR),* Volume: 4, Issue: 5, August 2016, pp. 3776-3779, ISSN 2320 –5547.
4. Nandeesh K C and Geetha K, " Comparative study of hyperbolic circular diagrid steel structure rehabilitated at core with shear wall and steel braced frames", *International Journal of research in Engineering and technology (IJRET),* Volume: 05, Issue: 07, July 2016, pp. 317- 323, eISSN: 2319-1163, p-ISSN: 2321-7308.
5. Md. Samdani Azad and Syed Hazni Abd Gani, "Comparative study of seismic analysis of multi-story buildings with shear walls and bracing systems", *International Journal of Advanced Structures and Geotechnical Engineering (IJASGE),* Volume: 05, Issue: 03, July 2016 pp. 72-77, ISSN 2319-5347.
6. Harshita Tripathi and Sarita Singla, "Diagrid structural system for RC framed multi-storey building", *International Journal of Scientific & Engineering Research (IJSER),* Volume: 7, Issue: 6, June 2016, pp. 356-362, ISSN 2229-5518.
7. Priyanka Soni, Purushottam Lal Tamarkar and Vikky Kumhar, "Structural analysis of multi-storey building of different shear walls location and heights", *International Journal of Engineering Trends and Technology (IJETT),* Volume: 32, February 2016.
8. Shubham R Kasat, Sanket R Patil, Akshay S Raut and Shrikant R Bhuskade, "Comparative study of multi- storey building under the action of shear wall using ETAB software", *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT),* 2016.
9. Alkuntel C V, Dhimate M V, Mahajan M B, Shevale S Y, Shinde S K and Raskar A, "Seismic analysis of multi-storey building having infill wall, shear wall and bracing", *Imperial Journal of Interdisciplinary Research (IJIR),* Volume: 02, Issue: 06, 2016, pp. 1522-1524, ISSN: 2454-1362.
10. Saket Yadav and Vivek Garg, "Advantage of steel diagrid building over conventional building," *International Journal of Civil and Structural Engineering Research (ISSN),* Volume: 03, Issue: 01, September 2015, pp. 394-406.
11. Anil Baral and Yajdani S K, "Seismic analysis of rc framed building for different positions for shear wall", *International Journal of Innovative Research in Science (IJIRSET),* volume: 04, Issue: 05, May 2015, pp. 3346-3353, e- ISSN: 2319-8753, p-ISSN: 2347-6710.
12. Suchita Tuppad and Fernades R J, "Optimum location of shear wall in a multi-storey building subjected to seismic behaviour using genetic algorithm", *International Research Journal of Engineering and Technology (IRJET),* Volume: 02, Issue: 04, 2015, pp. 236- 240, e-ISSN: 295-0056, p-ISSN: 2395-0072.
13. Mohd Atif, Laxmikant Vairagade and Vikrant Nair, "Comparative study on seismic analysis of multi-storey building stiffened with bracing and shear wall", *International Research Journal of Engineering and Technology (IRJET),* Volume: 02, Issue: 05, 2015, pp. 1158- 1170, e-ISSN: 2395-0056, p-ISSN: 2395-0072.
14. Rohit Kumar Singh, Vivek Garg, Abhay Sharma, "Analysis and design of concrete diagrid building and its comparison", *International Journal of Science, Engineering and Technology (IJSET),* Volume: 02, Issue; 06, August 2014, pp. 1330-1337, ISSN: 2348-4098.
15. Sanjay Sengupta "Study of shear walls in multi-storied buildings with different thickness and reinforcement percentage for all seismic zones in India", *International Journal of Research in Engineering and Technology (IJRET),* Volume: 03, Issue: 11, November 2014,pp. 197-204, e-ISSN: 2319-1163, p-ISSN: 2321-7308.
16. Nishith B Panchal and Vinubhai R Patel, "Diagrid structural system: strategies to reduce lateral forces on high-rise buildings", *International Journal of Research in Engineering and Technology (IJRET)*, Volume: 03, Issue: 04, April 2014, pp. 374-378.
17. Nitin Choudhry and Mahendra Wadia, "Pushover analysis of RC framed building with shear wall", *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),* Volume: 11, Issue: 02, March-April 2014, pp.09-13, e-ISSN: 2278-1684, p- ISSN: 2320-334X.
18. Giovanni Maria Montuori, Elena Mele, Giuseppe Brandonisio and Antonello De Luca, "Geometrical patterns for diagrid buildings: exploring alternative design strategies from the structural point of view", *Engineering Structure* 71, 2014, pp. 112-127.
19. Sepideh Korsavi, and Mohammad Reza Maqhareh, "The evolutionary process of diagrid structure towards architectural", *Architectural Engineering Technology (J Archit Eng Tech),* Volume: 03, Issue: 02, 2014, pp.1-11.
20. Khushbu Jania and Paresh V Patel, "Analysis and design of diagrid structural system for high rise steel building", Chemical, Civil and Mechanical Engineering Tracks of 3rd *Nirma University International Conference on Engineering (NUICONE),* 2013, pp. 92-100.
21. Ehsan Salimi Firoozbad, Rama Mohan Rao K, and Bahador Bagheri, "Effect of shear wall configuration on seismic performance of building", *Proc. of International Conference on Advances in Civil Engineering,* 2012.
22. Young-Ju Kima, Myeong-Han Kimb, In-Yong Jung, Young K. Ju and Sang-Dae Kima "Experimental investigation of the cyclic behavior of nodes in diagrid structures", *Engineering Structures*, 2011, pp. 2134-2144.