



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 9, Issue 9, September 2020

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512

 9940 572 462

 6381 907 438

 ijirset@gmail.com

 www.ijirset.com

Seismic Analysis and Comparative Study Of Vertically Irregular R.C. Building Frames

Pradip Janardan Borate, S.S.Kadam

M.Tech. (Civil Structures), S.K.N. Sinhad College of Engineering Korti, Pandharpur, India

Asst. Professor, Department of Civil Engineering, S.K.N. Sinhad College of Engineering Korti, Pandharpur, India

ABSTRACT: Major structural collapses occur when a building is under the action of Dynamic Loads which includes both Earthquake and Wind loads. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. In the present work, “Effect Of Vertical Irregularity In Multi-Storied Buildings Under Dynamic Loads Using Linear Static Analysis”, considering four types of 20- Storied 3-D frames (i.e., a symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from tenth floor, placed at corner, at the center and at edge of the plan respectively) it is focused to study their response using Linear Static Analysis. From the studied results of the analysis of four frames, it is observed that in the regular frame, there is no Torsional effect in the frame because of symmetry. The response for vertically irregular buildings is different for the columns which are located in the plane perpendicular to the action of force. This is due to the Torsional rotation in the structure.

KEYWORDS: Vertical Irregularity, Multistoried Building, Seismic Loading

i. INTRODUCTION

1.1 General

At the time of earthquake, failure of structure starts at points of weakness. This shortcoming emerges arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are named as Irregular structures. Irregular structures contribute a big portion of urban infrastructure. At the time of earthquake, Vertical irregularities are one of the major reasons of failures of structures. For example structures with soft storey were the most notable structures which collapsed. Thus, the impact of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings dissimilar from the regular building. (Thowdoju et al. 2016)

The irregularity in the building structures might be because of irregular distributions in their mass, strength and stiffness along the height of building. At the point when such structures are built in high seismic zones, the investigation and configuration turns out to be increasingly confounded. There are two types of irregularities- (Thowdoju et al. 2016)

A structure is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting rudiments. Asymmetrical arrangements cause a large torsion force. IS 1893: 2002 (part) has clarified building configuration system for better performance of RC buildings during earthquakes. The building configuration has been depicted as regular or irregular in terms of the size and shape of the building, arrangement of structural the elements and mass. There are two different types of irregularities 1) Horizontal irregularities refers to asymmetrical plan shapes (L, T, U and F) or discontinuities in horizontal resisting elements such as re-entrant corners, large openings, cut outs and other changes like torsion, deformations and other stress concentrations, 2) Vertical irregularities referring to sudden change of strength, stiffness, geometry and mass of a structure in vertical direction. The main objective of the present work is to learn the response of the irregular structures under dynamic loads. In this project it is proposed to consider the building frames that are irregular in elevation and analyze the response and behavior of the structures under earthquake and wind loads. For this purpose, four RC building frames are selected and it is proposed to analyze all the frames that are considered and are modeled. STAAD analysis package is proposed for the analysis of all structures, to get the all nodal displacements. Frames considered in this study are 15,20,25 Storied 3-D frames with symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from tenth

floor, placed at corner, center and edge of the plan respectively as shown in Figure 1. It is proposed that the behavior of all the above frames are to be determined for all the load combinations. Lateral loads and Storey shears of all the three frames due to earthquake loads is proposed to determine using ESA (linear static analysis) method, even though the IS 1893(Part 1) : 2002 has suggested dynamic analysis (linear dynamic analysis).

1.2 Vertical Irregularities

Vertical Irregularities are mainly of five types-

i) a) **Stiffness Irregularity** — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storey’s above. (Thowdoju et al. 2016)

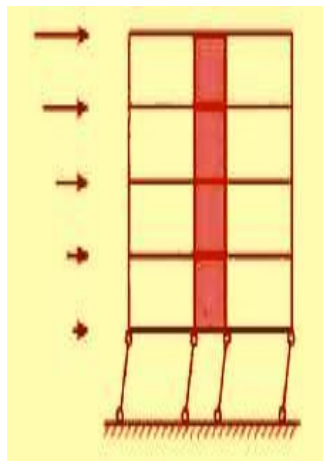


Figure 1.1 Stiffness Irregularities

b) **Stiffness Irregularity — Extreme Soft Storey**-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storey’s above. (Thowdoju et al. 2016)

ii) **Mass Irregularity**-Mass irregularity shall be painstaking to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey’s. In case of roofs irregularity need not be considered. (Thowdoju et al. 2016)

iii) **Vertical Geometric Irregularity**- A structure is painstaking to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey. (Thowdoju et al. 2016)

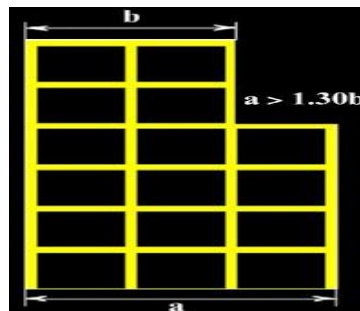


Figure 1.2 Vertical Geometric Irregularities in Building

iv) **In-Plane Discontinuity in Vertical Elements Resisting Lateral Force**-An in-plane offset of the lateral force resisting elements greater than the length of those elements. (Thowdoju et al. 2016)

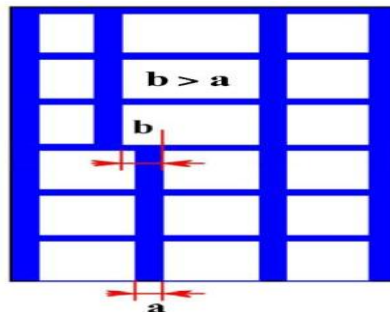


Figure 1.3 In-plane discontinuities in vertical lateral force-resisting element

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is below than 80 percent of that in the storey above. (Thowdoju et al. 2016)

As per IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of restricted height as in this process lateral forces are calculated as per code based fundamental time period of the structure. Linear dynamic analysis are an improvement over linear static analysis, as this analysis produces the impact of the higher modes of vibration and the actual distribution of forces in the elastic range in a improved way. (Ramayakrishna et al. 2017)

Buildings are designed mostly as per Design based earthquake, but the actual forces acting on the structure is far more than that of DBE. Thus, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary purpose in designing earthquake resistant structures is to assure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake. (Ramayakrishna et al. 2017)

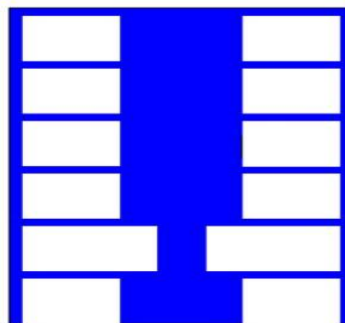


Figure 1.4 Discontinuity in capacity

1.3 Criteria for vertical irregularities in building codes

In the earlier versions of IS 1893 (BIS, 1962, 1966, 1970, 1975, 1984), vertical irregularity in building frames were not mentioned. However, in the recent version of IS 1893 (Part 1)-2016 (BIS, 2002), irregular configuration of buildings has been defined explicitly. Five types of vertical irregularity had been listed as shown in Figure 1. They are: stiffness irregularity (soft story), mass irregularity, vertical geometric irregularity (set-back), in-plane discontinuity in lateral-force-resisting vertical elements, and discontinuity in capacity (weak story). NEHRP code (BSSC, 2003) has classifications of vertical irregularities similar to those described in IS 1893 (Part 1)-2016 (BIS, 2002). As per this code, a structure is defined to be irregular if the ratio of one of the quantities (such as mass, stiffness or strength) between adjacent stories exceeds a minimum prescribed value. These values (such as 70-80% for soft story, 80% for weak story, and 150% for set-back structures) and the criteria that define the irregularities have been assigned by judgment. Further, various building codes suggested dynamic analysis (which can be elastic time history analysis or elastic response spectrum analysis) to come up with design lateral force distribution for irregular buildings rather than using equivalent lateral force (ELF) procedures.

1.4 PROBLEM STATEMENT

Present research involves the study of effect of vertical irregularity in multistoried building under seismic loading. For this study, a G+15, G+20, G+25 story building with 3.1 meters height for each story, regular in plan is considered. This building is considered to be situated in seismic zone III and designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures IS 1893(part-I):2016. The base of building is considered to



be fixed.. The building is modeled using relevant software. Model is studied for comparing base shear, Storey drift. We also study effect of mass irregularity and stiffness irregularity in various height structures.

Table1.1: Problem Data

Type of structure	Special Moment Resisting frame (SMRF)
Number of stories	G+15, G+20, G+25
Seismic zone	III
Floor height	3.1m
Type of soil	Medium
Size of Column	300*600, 300*450
Size of Beam	300*600
Depth of Slab	150mm
Live Load	3.5 KN/m ²
Material	M30 & Fe 500 reinforcement,
Unit weight	Concrete -25 KN/m ³
Damping in structure	5%
Importance factor	1.5

1.5 OBJECTIVES OF THE STUDY

The main objectives of the present work is to study the effect of vertical irregularity in Multi-Storied building

- 1) To calculate the design lateral forces on regular buildings using Equivalent static method.
- 2) To study two irregularities in structures namely mass and stiffness irregularities.
- 3) To study the structural response of the building models with respect to following aspects Base shear, Storey drift.
- 4) To determine the percentage variation of quantity of steel of various heights of Building.

1.6 NEED FOR RESEARCH

Irregular buildings constitute a big portion of the modern urban infrastructure. Structures are never perfectly regular and hence the designers routinely need to determine the likely degree of irregularity and the effect of this irregularity on a structure during an earthquake. Need for research is required to get economical & efficient lateral stiffness system for high seismic prone areas for optimization & design of high rise building with different structural. Framing systems subjected to seismic loads to improve the understanding of the seismic behavior of building structures with vertical irregularities.

II. LITERATURE REVIEW

Arelekar et al. (1997) had discussed importance of explicitly recognizing the presence of the open first storey in the analysis of the building. The open first storey is an important functional requirement of almost all the urban multi-storey buildings, and hence, cannot be eliminated. Alternative measures need to be adopted for this specific situation. The under-lying principle of any solution to this problem is in (a) increasing the stiffness's of the first storey such that the first storey is at least 50% as stiff as the second storey, that is., soft first storey's are to be avoided, and (b) providing adequate lateral strength in first storey. The possible schemes to achieve the above are (i) provision of stiffer columns in the first storey, and (ii) provision of a concrete service core in the structure.

Sadjadi et al. (2007) presented an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. The analytical models were validated against available experimental results and used in a study to evaluate the seismic behavior of these 5-story frames. It was concluded that both the ductile and the less ductile frames behaved very well under the earthquake considered, while the seismic performance of the GLD structure was not satisfactory. The retrofitted GLD frame had improved seismic performance.

Stefano and Barbara (2007) carried out review on the seismic behavior of irregular structure. The paper presents an overview of the progress in research regarding seismic response of plan and vertically irregular building structures.

Three areas of research are surveyed. The first is the study of the effects of plan-irregularity by means of single-storey and multi-storey building models. The second area encompasses passive control as a strategy to mitigate torsional effects, by means of base isolation and other types of devices. Lastly, the third area concerns vertically irregular structures and setback buildings. They discuss the review on the paper which includes effects of torsional coupling in one story, Multi-storey and vertically irregular structures setback multi-storey buildings asymmetric building structures.

Athanassiadou (2008) concluded that the effect of the ductility class on the cost of buildings is negligible, while performance of all irregular frames subjected to earthquake appears to be equally satisfactory, not inferior to that of the regular ones, even for twice the design earthquake forces. DCM frames were found to be stronger and less ductile than the corresponding DCH ones. The over strength of the irregular frames was found to be similar to that of the regular ones, while DCH frames were found to dispose higher over strength than DCM ones. Pushover analysis seemed to underestimate the response quantities in the upper floors of the irregular frames.

Karavasilis et al. (2008) had discussed the inelastic seismic response of plane steel moment-resisting frames with vertical mass irregularity. The analysis of the created response databank showed that the number of storeys, ratio of strength of beam and column and the location of the heavier mass influence the height-wise distribution and amplitude of inelastic deformation demands, while the response does not seem to be affected by the mass ratio.

Sarkar et al. (2010) discussed on 'Stepped building' frames, with vertical geometric irregularity, are now increasingly encountered in modern urban construction. This paper proposes a new method of quantifying irregularity in such building frames, accounting for dynamic characteristics (mass and stiffness). The proposed 'regularity index' provides a basis for assessing the degree of irregularities in a stepped building frame. This paper also proposes a modification of the code specified empirical formula for estimating fundamental period for regular frames, to estimate the fundamental time period of the stepped building frame. The proposed equation for fundamental time periods is expressed as a function of the regularity index. It has been validated for various types of stepped irregular frames.

Duana and Mary (2012) According to the numerical results, the structures designed by GB50011-2010 provides the inelastic behavior and response intended by the code and satisfies the inter-storey drift and maximum plastic rotation limits recommended by ASCE/SEI 41-06. The push-over analysis indicated the potential for a soft first story mechanism under significant lateral demands.

Kumar and Gupta (2012) Studied the results of the numerical analysis showed that any storey, especially the first storey, must not be softer/weaker than the storeys above or below. Irregularity in mass distribution also contributes to the increased response of the buildings. Their regularities, if required to be provided, need to be provided by appropriate and extensive analysis and design processes.

Ravikumar et al. (2012) Studied fragility based seismic vulnerability of structures with consideration of soft -storey (SS) and quality of construction (CQ) was demonstrated on three, five, and nine storey RC building frames designed prior to 1970s. Probabilistic seismic demand model (PSDM) for those gravity load designed structures was developed, using non-linear finite element analysis, considering the interactions between SS and CQ. The reaction surface strategy is utilized to build up a prescient condition for PSDM parameters as an element of SS and CQ. Result of the analysis shows the sensitivity of the model parameter to the interaction of SS and CQ.

Kabade and Shinde (2012) Studied a G+3 vertically irregular building was modeled as 3D space frame for the analysis with discontinuous column at top floor. To response parameters like base shear, storey displacement of the structure under seismic force under the linear dynamic & non linear static analysis is studied. The result remarks the conclusion that, a building structure with irregularity produced due to column discontinuity provides instability and increases storey displacement. They concluded that base shear of regular and irregular frame in both the orthogonal direction is more than the calculated base shear. It is very clear that the structural irregularity produced due to column discontinuity increases displacement but reduces the base shear under seismic loading for irregular buildings, The common observation is that the drift in both the orthogonal direction is suddenly increases at the discontinuous level. It is recommended that the irregularity in column is vulnerable condition for the building structure and it creates the soft storey effect. It also affects on overall performance of the building under the seismic loading.

Rajeev and Tesfamariam (2012) discussed on Poor seismic performance of non-code conforming RC buildings, mainly designed for gravity loads prior to 1970s highlights the need for reliable vulnerability assessment and retrofitting. The vulnerability is compounded since the RC buildings are subject to different irregularities such as weak storey, soft storey, plan irregularities, and poor construction quality; and interaction of different irregularities. Fragility based

seismic vulnerability of structures with consideration of soft storey (SS) and quality of construction (CQ) is demonstrated on three-, five-, and nine-storey RC frames designed prior to 1970s. Probabilistic seismic demand model (PSDM) for those gravity load designed structures is developed, using the nonlinear finite element analysis, considering the interactions between SS and CQ. The response surface method is used to develop a predictive equation for PSDM parameters as a function of SS and CQ. Result of the analysis shows the sensitivity of the model parameter to the interaction of SS and CQ. The accuracy of the predictive equations is checked for randomly selected SS values and three levels of CQ. Further, the fragility curves are developed for the three structures considering SS, CQ and of their interactions. Finally, confidence bounds on the fragilities are also presented as a measure of their accuracy for risk-informed decision-making.

Mahdia and Bahreinib (2013) discussed the nonlinear seismic behavior of intermediate moment-resisting reinforced concrete (RC) space frames with unsymmetrical plan in three, four and five stories are evaluated. The plan configurations of these space frames contain reentrant corners. Analyses of these buildings are made with and without considering the masonry infill (MI). For infills, three types of arrangements and two material types (strong and weak) have been considered. For lateral seismic loads, two types of lateral loads distributions have been assumed. The results revealed that the existence of infill increases the stiffness and decreases the drifts. However, by omitting infills from the ground floor (the soft story arrangement), the beams and the columns of the ground floor show inferior performance.

Marco (2013) discussed that the effectiveness of different strategies for the seismic retrofitting of a gravity-load-designed plan-wise irregular R/C building tested at the JRC Elsa Laboratory. An alternative retrofitting intervention based on both FRP wrapping and R/C jacketing applied to selected critical columns was proposed. The retrofitting strategy was focused on two main objectives: 1) relocating the centre of stiffness and strength in order to reduce the torsional component of the response of the structure; 2) increasing the local deformation capacity of columns and thus the global deformation capacity of the structure. Nonlinear dynamic time history analyses and simplified procedures based on nonlinear static pushover analyses were carried out and comparison with the retrofitting interventions carried out at the JRC ELSA Laboratory were performed. Bidirectional damage indexes were used to identify the most critical columns affecting the seismic performance of the structure. The simplified procedure provided results consistent with the experimental evidence and allowed to easily select a suitable retrofitting strategy. Numerical results showed the effectiveness of the strength-and stiffness relocation strategy based on R/C jacketing of selected columns, but the local ductility increase based on FRP wrapping of the other columns was necessary for significantly improving the global seismic performance of the structure in case of severe seismic excitation.

III. METHODOLOGY

The finite element analysis is a numerical technique. In this strategy every one of the complexities of the issues, such as fluctuating shape, limit conditions and loads are kept up as they are nevertheless the arrangements gotten are estimated. In light of its decent variety and adaptability as an investigation apparatus, it is accepting much consideration in building. The fast improvements in computer hardware technology and slashing of cost of computers have boosted this method, since the computer is the basic need for the application of this method. Various prominent brand of limited component examination bundles are currently accessible monetarily.

A portion of the famous bundles are STAAD-PRO, GT-STRUDEL, NASTRAN, NISA and ANSYS. Utilizing these bundles one can dissect a few complex structures. The limited component examination started as a strategy for stress investigation in the structure of airplanes. It began as an augmentation of framework strategy for auxiliary examination. Structural designers utilize this strategy widely for the examination of pillars, space outlines, plates, shells, collapsed plates, establishments; shake mechanics issues and leakage investigation of liquid through permeable media.

Both static and dynamic issues can be taken care of by limited component investigation.

3.1 Description of Method

In engineering problems there are some basic unknowns. If they are found, the behavior of the entire structure can be predicted. In a continuum, these unknowns are infinite. The limited component technique decreases such questions to a limited number by isolating the arrangement locale into little parts called components and by communicating the obscure field factors in terms of assumed approximating functions (Interpolating functions/Shape functions) within each element. The approximating functions are defined in terms of field variables of specified points called nodes or nodal points. In this manner in the limited component investigation the questions are the field factors of the nodal focuses. Subsequent to choosing components and nodal questions following stage in limited component examination is to gather component properties for every component. For instance, in strong mechanics, we need to discover the power removal i.e. stiffness qualities of every individual component. Mathematically this relationship is of the form.

3.1.1 Finite Element Analysis

$$[k]e \{\delta\} = \{F\} e$$

Where $[k]e$ is element stiffness matrix, $\{\delta\}$ is nodal displacement vector of the element and $\{F\}e$ is nodal force vector. The element of stiffness matrix k_{ij} represent the force in co-ordinate direction 'i' due to a unit displacement in coordinate direction 'j'. Four methods are available for formulating these element properties viz. direct approach, Element properties are used to assemble global properties/structure properties to get system equations $[k] \{\delta\} = \{F\}$. Then the boundary conditions are imposed. The solutions of these simultaneous equations give the nodal unknowns. Using these nodal values additional calculations are made to get the required values e.g. stresses, strains, moments, etc. in solid mechanics problems.

Thus the different steps involved in the finite element analysis are:

- (i) Select suitable field variables and the elements.
- (ii) Discretise the continua.
- (iii) Select interpolation functions.
- (iv) Find the element properties.
- (v) Assemble element properties to get global properties.
- (vi) Impose the boundary conditions.
- (vii) Solve the system equations to get the nodal unknowns.
- (viii) Make the additional calculations to get the required values

3.2 Methods of Seismic Analysis of Building

3.2.1 General

Earthquakes are nature's greatest hazards to life on this planet. The risks forced by seismic tremors are one of a kind in numerous regards, and thusly wanting to moderate quake dangers requires a special designing methodology. An important distinction of the earthquake problem is that the hazard to life is associated almost entirely with manmade structure expect for earthquake triggered landslides, the only earthquake effect that causes extensive loss of life are collapse of bridges, buildings, dams, and other works of man. This aspect of earthquake hazard can be countered only by designs and construction of earthquake resistant structure. The optimum engineering approach is to design the structure so as to avoid collapse in most possible earthquake, thus ensuring against loss of life but accepting the possibility of damage.

Various methods for determining seismic forces in structures fall into two distinct categories:

(I) Equivalent static force analysis (II) Dynamic Analysis

3.2.2 Equivalent static force analysis:

These are approximate methods which have been evolved because of the difficulties involved in carrying out realistic dynamic analysis. Codes of practice inevitable rely mainly on the simpler static force approach, and incorporate varying degree of refinement in an attempt to simulate the real behavior of structure. Basically they give total horizontal force (Base Shear) V , on a structure:

$$V = ma$$

Where,

m is mass of structure

V is applied to the structure by a simple rule describing its vertical distribution. In a building this generally consist of horizontal point loads at each concentration of mass, most typically at floor level. The seismic forces and moments in the structure are then determined by any suitable analysis and the results added to those for the normal gravity load cases. An important feature of equivalent static load requirement in most codes of practice is that calculated seismic forces are considerably less than those which would actually occur in the larger earthquakes likely in the area concerned.

$$V = F_1 + F_2 + F_3$$

3.2.3 Seismic Analysis using IS 1893 (Part1):2016

In this approach the earthquake force is applied on the structure using seismic coefficient method. In this method the design horizontal seismic coefficient A_h for the structure is given as

$$A_h = \frac{Z}{2} \cdot \frac{I_m}{R} \cdot \frac{S_a}{g}$$

Where,

A_h is seismic horizontal acceleration (Generally in the range of 0.05g to 0.2g) Z is zone factor as per different zones, IS 1893 :2016 has classified India in to four zones II to V. In zone II seismic intensity is low and very severe for zone v, $I =$



importance factor, depending upon the functional use of the structures, R= Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio I/R shall not be greater than 1.0 and Sa/g = Average response acceleration coefficient for rock or soil sites. This ratio depends upon the time period and site condition. For the calculation of the earthquake force soils are grouped into three groups as shows in table 3.2 below.

Table 3.1 Soil groups for calculations of seismic forces

Group	Soil Type
Group 1	Hard soil
Group 2	Medium soil
Group 3	Soft soil

Figure 2 of IS 1893-2016(I) shows the proposed 5 percent spectra for rocky and soils sites and Table 3 of IS 1893-2016(I) gives the multiplying factors for obtaining spectral values for various other damping.

For rocky, or hard soil sites

$$Sa/g = 2.5 \quad 0.0 \leq T \leq 0.1$$

$$1/T \quad 0.1 \leq T \leq 0.4$$

$$1.36/T \quad 0.4 \leq T \leq 4$$

For medium soil,

$$Sa/g = 2.5 \quad 0.0 \leq T \leq 0.1$$

$$1.36/T \quad 0.1 \leq T \leq 0.55$$

$$1.36/T \quad 0.55 \leq T \leq 4$$

For soft soil,

$$Sa/g = 2.5 \quad 0.0 \leq T \leq 0.1$$

$$1.67/T \quad 0.1 \leq T \leq 0.67$$

$$1.67/T \quad 0.67 \leq T \leq 4$$

Where T is approximate fundamental time period of vibration in seconds of all building. It is estimated by expression.

For RC frame building

$$Ta = 0.075h^{0.75} \tag{3.10}$$

For Steel frame buildings-

$$Ta = 0.085h^{0.75} \tag{3.11}$$

And the approximate fundamental natural period of vibration in seconds for other types of buildings including moment resisting building with infill can be estimated as-

For other buildings

$$Ta = \frac{0.09h}{\sqrt{d}} \tag{3.12}$$

Where, h = Height of building in meters. This excludes the basement storeys where basement walls are connected with ground floor deck or fitted with building columns, however, it includes the basement when they are not connected.

d = base dimension of the building at the plinth level in meters along considered direction of the lateral force.

The total design lateral force (design seismic base shear) along any principal direction shall be calculated by using following expression

$$V_B = A_h W \tag{3.13}$$

Where,

V_B = design seismic base shear

A_h = design horizontal seismic coefficient for structures as explained in section 3.10.1 of IS 1893-2016.

W= seismic weight of building as full dead load and appropriate amount of imposed load.

3.2.4 Distribution of Seismic Forces

Lateral load distribution with building height depends on the natural periods, mode shapes of the building, and shape of design spectrum. In low and medium rise buildings, fundamental period dominates the response and fundamental mode shape is close to a straight line (with regular distribution of mass and stiffness). For tall buildings, contribution of higher modes can be significant even though the first mode may still contribute the maximum response. The base shear shall be distributed along the height of building by using following expression.

$$Q_i = V_B \cdot \frac{W_i h_i^2}{\sum_{j=1}^n W_j h_j^2} \quad (3.14)$$

Where,

Q_i = Design lateral force at floor i ,

W_i = Seismic weight of floor i ,

h_i = Height of floor i measured from base, and

n = Number of storey in the building, the number of levels at which the masses are located.

Load Combination

In the limit state design of reinforced concrete structures, following load combinations shall be accounted as per I.S. 1893 (Part I)- 2016. Where the terms DL, IL, and EL stand for the response quantities due to dead load, imposed load designated earthquake load respectively.

1.5 (DL + IL)

1.2 (DL + IL ± EL)

1.5(DL ± EL)

0.9 DL ± 1.5 EL

(3.15)

3.2.5 Dynamic analysis

For large or complex structure static methods of seismic analysis are not accurate enough. Various methods of differing complexity have been developed for the dynamic seismic analysis of structures. They all have in common the solution of the equation of motion as well as the usual static relationship of equilibrium and stiffness. The three main techniques currently used for dynamics analysis are:

(I) Direct integration of the equation of motion by step by step procedure

(II) Normal Mode Analysis

(III) Response spectrum Technique

Direct integration provides the most powerful and informative analysis for any given earthquake motion. A time dependent forcing function (earthquake accelerogram) is applied and the corresponding response history of the structure during the earthquake force is computed. The moment and force diagram at each of series of prescribed interval throughout the applied motion can be found. Three dimensional nonlinear analysis have been devised which can take three orthogonal accelerogram components from a given earthquake, and apply them simultaneously to the structure. This is the most complete dynamic analysis technique and is unfortunately expensive to carry out.

Normal mode analysis depends on artificially separating the normal modes of vibration and combining the force and displacement associated with a chosen number of them by superposition. As with direct integration techniques, actual earthquake accelerograms can be applied to the structure and a stress-history determined, but because of the use of superposition the techniques is limited to linear material behavior. Although modal analysis can provide any desired order of accuracy for linear behavior by incorporation all the modal responses, some approximation is usually made by using only the few modes to save computation time. Problems are encountered in dealing with system where the mode coupling occurs.

3.3 Time History Analysis

In this method of dynamic analysis, instead of going through a process of determining a response spectrum for a given ground motion and then applying the results to given structure, it is possible by using computers to apply the earthquake motion directly to the base of a given structure. Instantaneous stresses throughout the structure are calculated at small interval of time for full duration of the earthquake or significant portion of it. The maximum stress in any member that occur the earthquake can then be found by scanning the output records and the design reviewed. The procedure usually includes the following steps: The earthquake record is selected which represent the expected earthquake. The record is digitized as a series of small time interval of about 1/4 to 1/25 of a second with given levels of acceleration occurring for each interval. The digitized record is applied to the model as acceleration at the base of

structure. The acceleration and relative displacement of the lumped masses are translated into member stresses. The maximum values can then be found by scanning of each output record. This process automatically included various modes of vibration and combines their effects as they occur, thus eliminating the uncertainties of combining the modes which are inherent to the spectrum analysis. Response spectrum technique is a simplified case of modal analysis. The modes of vibration are determined in period and shape in the usual way and the maximum response magnitude corresponding to each mode is found by reference to a response spectrum. An arbitrary rule is then used for superposition of the maximum response in various modes. The resultant moments and forces in the structure correspond to envelop of maximum values rather than as set of simultaneously existing values. The response spectrum method has the great virtues of speed and cheapness. This technique is strictly limited to a linear analysis because of the use of superposition. Simulations of nonlinear behaviour have been made using pairs of response spectra, one for deflection and one for acceleration.

Modal combination rules

I) Square- Root of sum of squares (SRSS)

This rule for modal combination developed in E. Rosenblueth's Ph.D. thesis (1951) is

$$r_o = \left(\sum_{n=1}^N r_{no}^2 \right) \quad (3.16)$$

The peak response in each mode is squared. The squared modal peaks are summed, and the square root of the sum provides an estimate of the peak total response. This modal combination rule provides excellent response estimates for structures with well-separated natural frequencies. This limitation has not been recognized in applying this rule to practical problems, and at times it has been misapplied to systems with closely spaced natural frequencies, such as piping systems in nuclear power plants and multistoried buildings with unsymmetrical plan.

II) The Complete Quadratic combination (CQC)

This rule for modal combination is applicable to a wider class of structures as it overcomes the limitations of the SRSS rule.

$$r_o = \left(\sum_{n=1}^N \sum_{i=1}^N i = 1 P_{in} r_{io} r_{no} \right) \quad (3.17)$$

Where

r_o = Peak value of $r(t)$

$r(t)$ = any response quantity

P_{in} = Cross correlation spectrum ordinate

The modal combination rules will become less accurate for short duration impulsive ground motions and are not recommended for ground motions that contain many cycles of essentially harmonic excitation. Thus, modal combination rules are intended for use when excitation is characterized by smooth response spectrum, based on response spectra for many earthquake excitations.

3.4 Current practice and comments

The foreword of the current Bureau of Indian standard code IS 1893-2016 (Part1) does mention inadequacy of the 'seismic coefficient' method and suggest that a detailed dynamic analysis is carried out in case of important structure in earthquake prone areas. The mentioned inadequacy in method has higher underlining significance in geotechnical engineering and structures subjected large earthquake forces. There is no any provision of base isolation design and combine effect of soil-base isolation. There is need to include guidelines on base isolation design and effect of SSI with base isolation subjected to ground motion.



3.6 Design Criteria

Following are the major steps in determining the seismic forces:

3.6.1 Determination of base shear:

For the determination of seismic forces, the country is classified in four seismic zones:

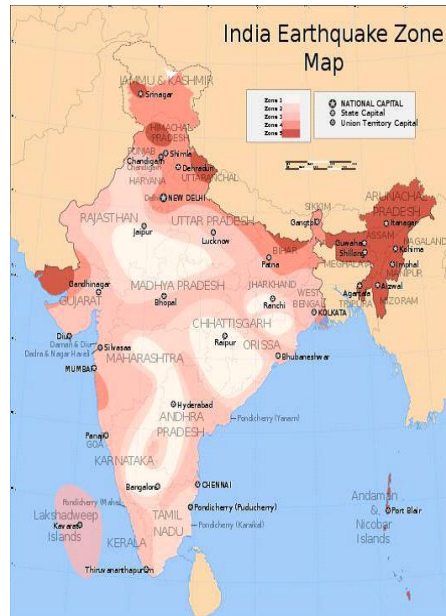


Fig no 3.2 India earthquake zone map

The total design lateral force or design base shear along any principal direction shall be determined by this expression

$$V_b = A_h * W \dots\dots\dots(B)$$

Where,

A_h = design horizontal seismic coefficient for a structure

W = seismic weight of building

The design horizontal seismic coefficient for a structure A_h is given by

Z is the zone factor given in Table 2 of IS 1893:2016 (part 1) for the maximum considered earthquake (MCE) and service life of a structure in a zone. The factor 2 is to reduce the MCE to the factor for design base earthquake (DBE)

I is the importance factor, depending upon the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical or economic importance. The minimum values of importance factor are given in table 6 of IS 1893:2016 R is the response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. The need for introducing R in base shear formula

S_a/g is the average response acceleration coefficient for rock and soil sites as given in IS 1893:2016 (part 1). The values are given for 5 % of damping of the structure.

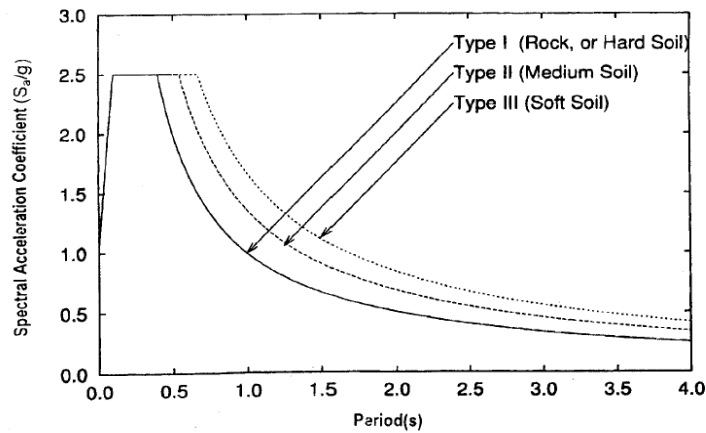


Fig no 3.3 IS code spectra from IS 1893 -2016

3.7 Material Properties

It shows the concrete and steel bar properties, which are used for modelling of the reinforced concrete buildings in STAAD PRO.

Table 3.2 : Concrete and steel bar properties as per IS 456 -2000

Concrete Properties		Steel Bar Properties	
Unit weight (γ_{cc})	25 (KN/m ³)	Unit weight (γ_{ss})	76.9729 (KN/m ³)
Modulus of elasticity (EE_{cc})	22360.68 (MPa)	Modulus of elasticity (EE_{ss})	2x10 ⁵ (MPa)
Poisson ratio (ν_{cc})	0.2	Poisson ratio (ν_{ss})	0.3
Thermal coefficient (α_{cc})	5.5x10 ⁻⁶	Thermal coefficient (α_{ss})	1.170x10 ⁻⁶
Shear modulus (GG_{cc})	9316.95 (MPa)	Shear modulus (GG_{ss})	76923.08 (MPa)
Damping ratio (C_{cc})	5 (%)	Yield strength (FF_{yy})	500(MPa)
Compressive strength (FF_{cc})	30 (MPa)	Tensile strength (FF_{uu})	485 (MPa)

IV.VALIDATION OF SOFTWARE

4.1 Problem Statement

Given data

Thickness of slab: 130mm

Beam size: 250mm X 350 mm

Column size at G.L.:250mm X 400 mm

Thickness of outer wall including plaster: 250 mm

Thickness of partition wall including plaster: 175 mm

Load due to roof finish: 2kN/m²

Load due to floor finish: 1kN/m²

Imposed load: 4kN/m²

Type of foundation: Isolated footing

Soil Condition: Hard Murum available at depth of 1.5m below G.L.

Zone-III



4.2 Manual Calculation

Solution

Seismic weight

$$\text{Total floor area } A_f = 20 \times 13.5 = 270 \text{ m}^2$$

At roof level no imposed load is lumped. The roof load consist of self-weight of slab+ 50% load due to weight of wall above story

Weight of wall at each floor level: W_1 W_2 W_3

$$= 2 \times (20+13.5) \times 0.25 \times 3 \times 20 + (2 \times 20+3 \times 13.5) \times 0.175 \times 3 \times 20$$

$$= 1005 + 845$$

$$= 1850 \text{ kN}$$

Roof load W_4

$$= (25 \times 0.13 + 2) \times 270 + 1850/2$$

$$= 2343 \text{ kN}$$

Wall Load = 1850 kN

$$\text{Load at plinth } W_0 = 1850/2 + (25 \times 0.23 \times 0.45 \times 20) \times 4/2 + 1688 = 2716 \text{ kN}$$

Total seismic weight = 15673 kN

Natural period along Z direction

$$\frac{0.09h}{\sqrt{d}}$$

$$T_a = \frac{0.09h}{\sqrt{d}} = 0.09 \times 16/\sqrt{13.5} = 0.39 \text{ sec}$$

Natural period along X direction

$$\frac{0.09h}{\sqrt{d}}$$

$$T_a = \frac{0.09h}{\sqrt{d}} = 0.09 \times 16/\sqrt{20} = 0.32 \text{ sec}$$

Design horizontal acceleration coefficient X direction

$$A_h = \frac{Z}{2} \cdot \frac{I_m}{R} \cdot \frac{S_a}{g} = 0.16/2 \times 1/5 \times 2.5 = 0.04$$

Design horizontal acceleration coefficient Z direction

$$A_h = \frac{Z}{2} \cdot \frac{I_m}{R} \cdot \frac{S_a}{g} = 0.16/2 \times 1/5 \times 2.5 = 0.04$$

Design base shear along X direction

$$V_B = A_h * \sum W = 0.04 \times 15673 = 626.92 \text{ KN}$$

Design base shear along Z direction

$$V_B = A_h * \sum W = 0.04 \times 15673 = 626.92 \text{ KN}$$

V. CASE STUDY

5.1 Modeling

The analysis of frames with various vertical irregularities is to be performed. For this purpose, three frames are selected. Frame-1 is a irregular frame that consists of fifteen storey's with a unsymmetrical plan configuration of square shape provided with bays as shown in Figure 1 and is considered whose centre of mass coincides with the centre of rigidity. Two other frames (6 x 6 bays up to tenth floor and 3 x 3 bays from tenth floor to twentieth floor and Twenty fifth floor in another model) with unsymmetrical vertical configuration starting from tenth floor, placed at corner, respectively are also considered. All these are 15, 20, 25-storied building frames with floor heights of 3.1 m and bay size of 3m x 3m. height of ground floor is 3.1 m and the total height of the all building frames is 46.5m of first ,62m of second model,77.5of third model As per IS code 1893 -2002, the natural time period is 2.025 sec. Number of members, nodes and supports of four building frames are given in the Table 1. Material properties assumed for the analysis using STAAD are given in the Table 2. Physical properties of members selected for the analysis are given in the Table 3 Table 4. Earthquake loads considered for the computation of seismic weights are as per the IS 1893(Part 1): 2002 and are given in the Table 5.



Table 5.1: Member, Nodes and Supports for All Frames

Building frames	Regularity	Number of members	Number of nodes	Number of supports(fixed)
Frame-1	Irregular in vertical	1959	784	64
Frame-2	Irregular in vertical	2180	864	64
Frame-3	Irregular in vertical	2359	984	64

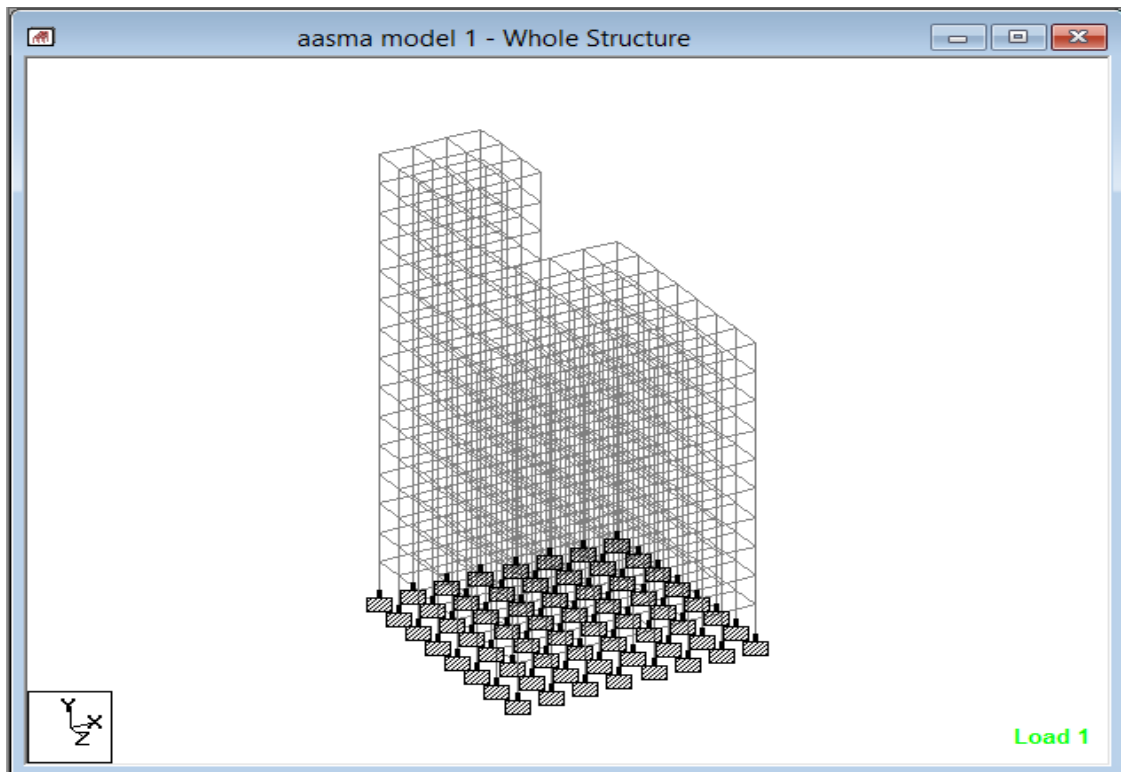


Figure 5.1 Model 1

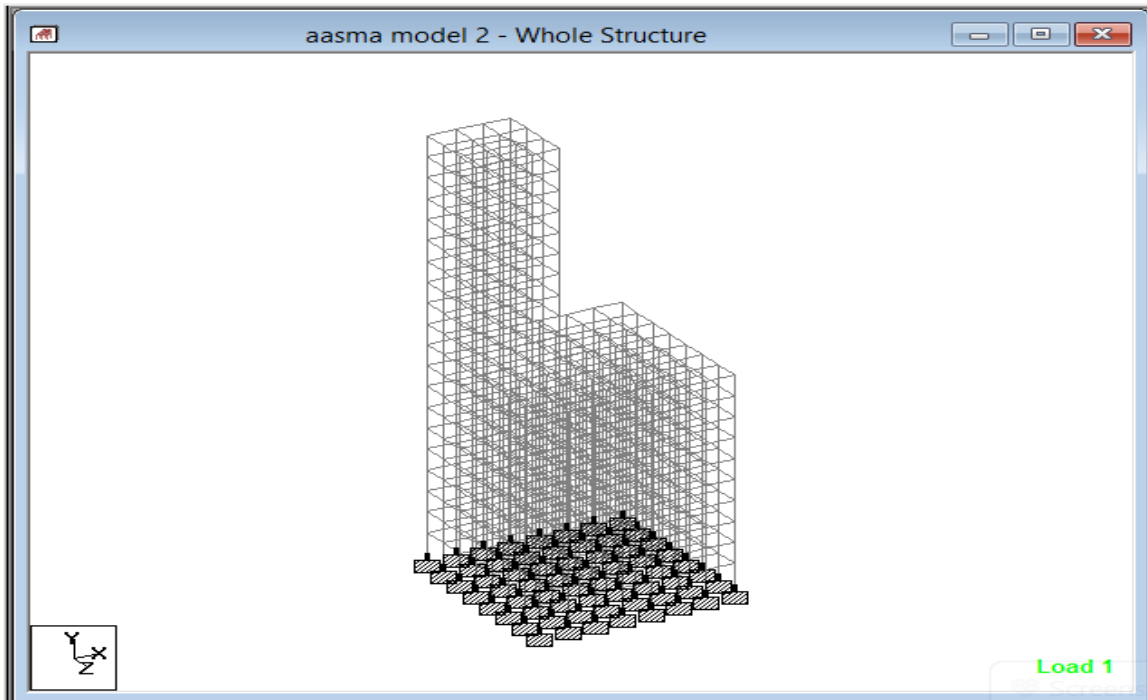


Figure 5.2 Model 2

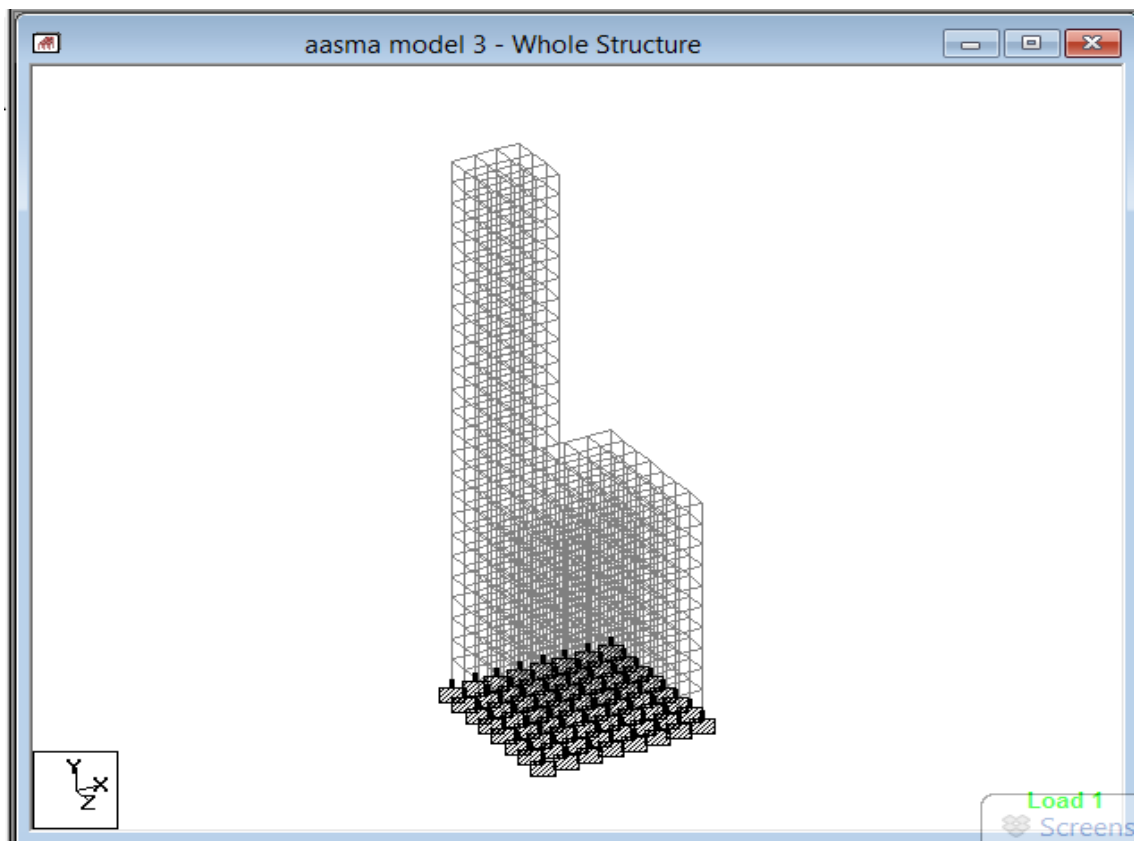


Figure 5.3 Model 3



Table 5.2: Material Properties Considered for the Analysis

Modulus of elasticity (E) KN/m ²	Poisson ratio	Unit Weight KN/m ³	Coefficient of thermal expansion @ / 0K	Damping ratio
2.17185E+007	170 E-3	23.561	1E-005	0.05

Table 5.3: Physical properties of the columns and beams

Member	Size
Columns for all floors	300mm x 600mm, 300mm x 450mm,
Beams for all floors	300mm x 600mm

Table 5.4: Dead load and Live loads considered for the analysis

Type of load	Load value
Dead load	
On floor slabs	
Self weight	3.75 KN/m ²
partition wall (assumed)	2.00 KN/m ²
floor finish (assumed)	1.00 KN/m ²
Total dead load on floors	6.75 KN/m ²
On roof slab	
Self weight	3.75 KN/m ²
weathering course (assumed)	2.00 KN/m ²
Total dead load on roof	5.75 KN/m ²
Live load	
On floor slabs	
Live load on floors	2.50 KN/m ²
On roof slab	
Live load on floors	1.50 KN/m ²



Table 5.5: Loads considered for the calculation of seismic weights

Loads on the floors
Full dead load acting on the floor plus 25 percent of liveload (since, as per clause 7.3.1 Table 8 of IS 1893(Part 1):2002, for imposed uniformly distributed floor loads of 3KN/m ² or below, the percentage of imposed load is 25 percent)= $6.75 + ((25/100) \times 2.5) = 7.375 \text{ KN/m}^2$
Loads on the roof slab
Full dead load acting on the roof (since, as per clause 7.3.2, for calculating the design seismic forces of the structure, the imposed load on roof need not be considered.) hence take the load as 5.75 KN/m ²

For the analysis purpose, these structures are assumed to be located in zone- III (zone factor-0.16) on site with medium soil and Sa/g value taken from the of IS-1893: 2002 that is, Response spectra for rock and soil sites for 5% damping. These structures are taken as important building and hence Importance factor is taken as 1.5 and the frames are proposed to Special moment resisting frame and hence the Reduction factor is taken as 5 .

VI. RESULT AND DISCUSSION

6.1 GENERAL

In this study nodal displacements and drifts of the frames that are determined are studied and observed for a comparison. Also vertical irregularity, Time history and response spectrum analysis, earthquake load considered. Frame wise observations are deliberated in detail with floor displacement figures.

6.2 RESULTS FOR MODELS:

Idealization of above problem statement is modeled in finite element analysis tool STAAD PRO .Following models are prepared for comparative analysis.

Table 6.1: Member, Nodes and Supports for All Frames

MODEL NO.1	G+15 STORY FRAME
MODEL NO.2	G+20 STORY FRAME
MODEL NO.3	G+25STORY FRAME

MODE SHAPES:-

MODEL 1:-

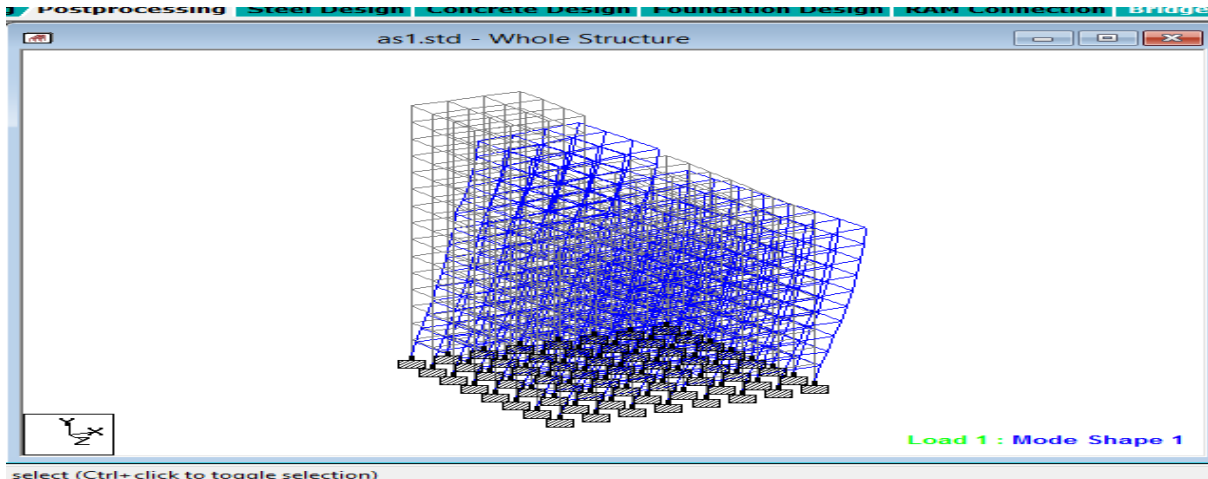


Fig no 6.1 Mode shape 1

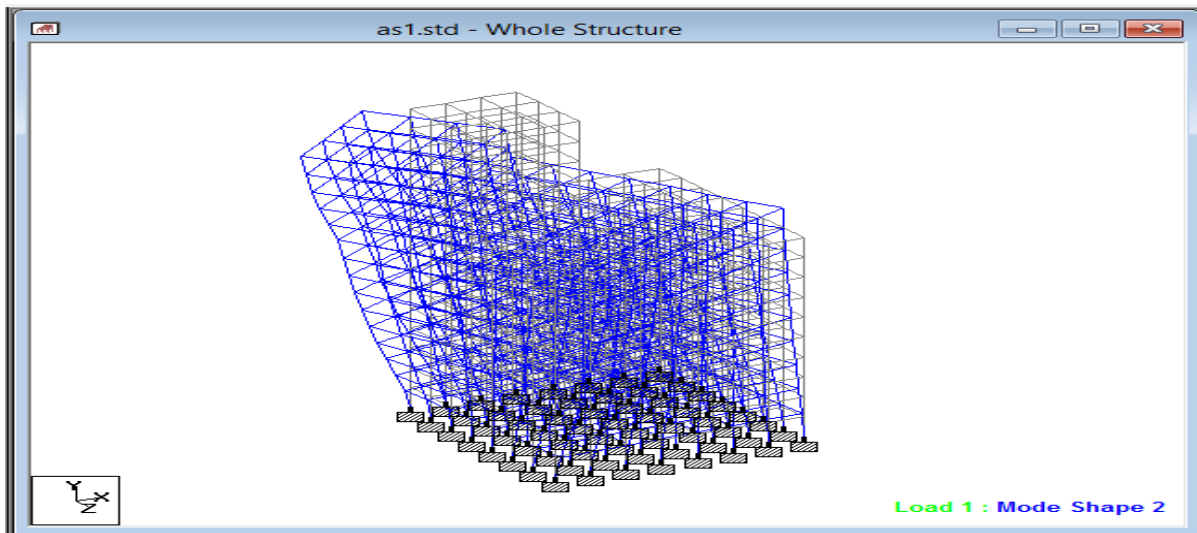


Fig no 6.2 Mode shape 2

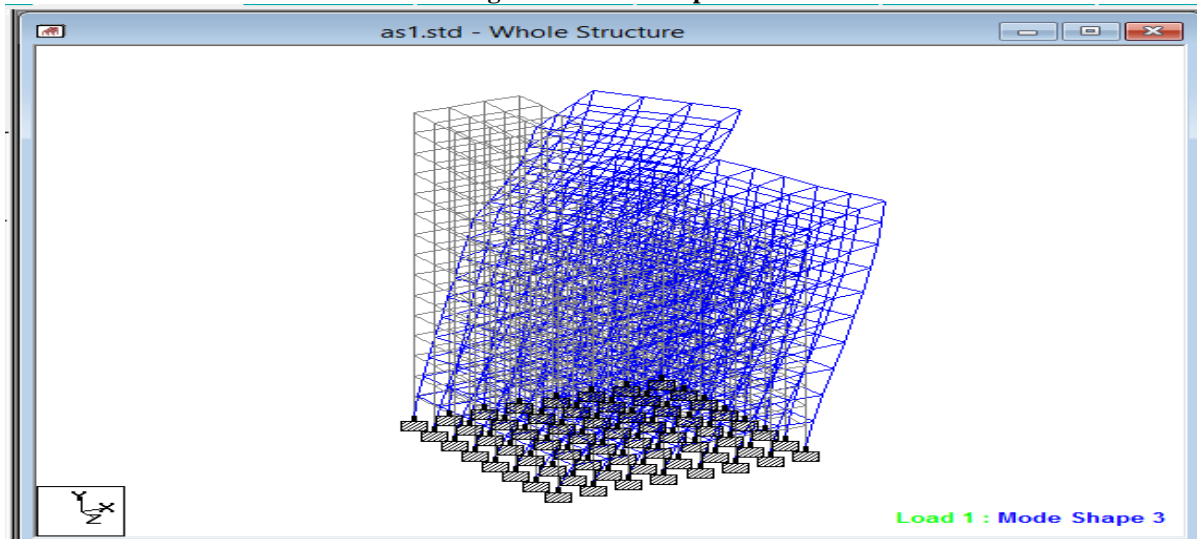


Fig no 6.3 Mode shape 3

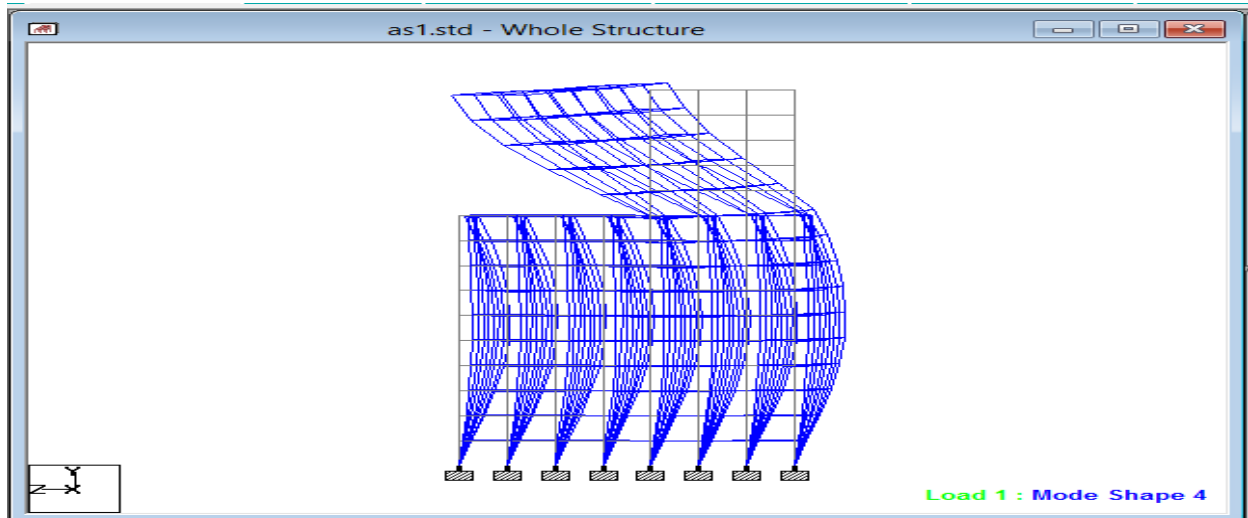


Fig no 6.4 Mode shape 4

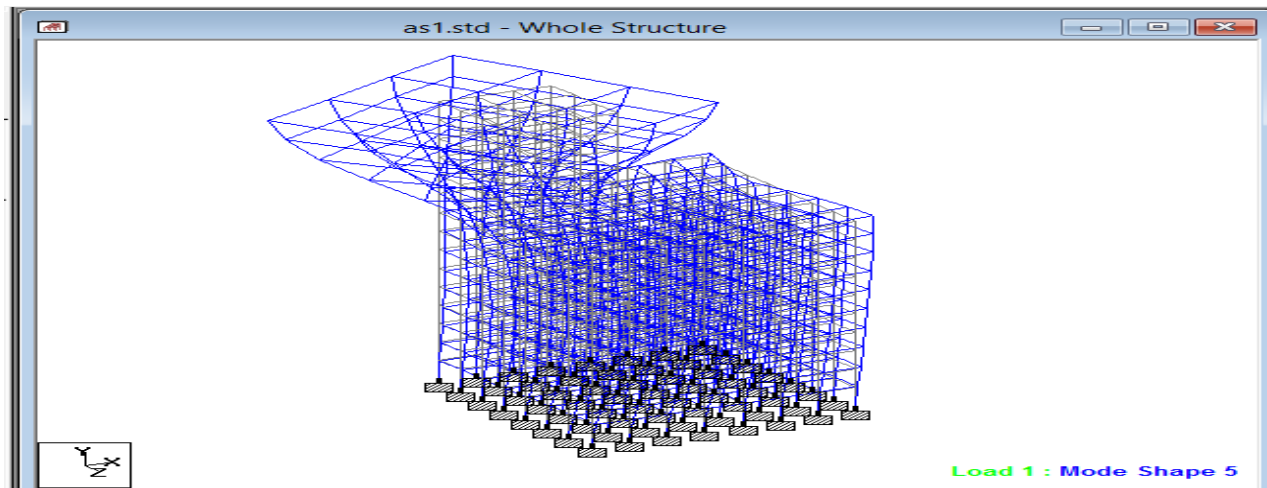


Fig no 6.5 Mode shape 5

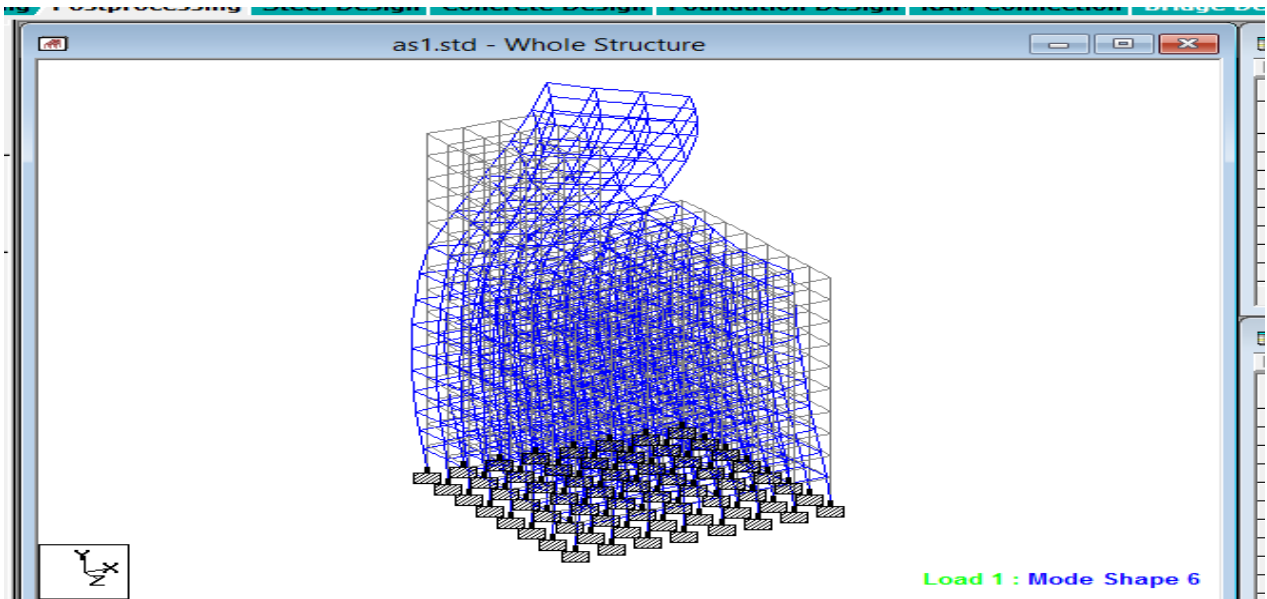


Fig no 6.6 Mode shape 6

VII. CONCLUSION

1. The storey shear force is Minimum for the first storey and it increases to maximum in the top storey.
2. It is concluded that storey drift of G+25 is more than G+15, G+20 Storey frame.
3. It is concluded that base shear of G+25 is more than G+15, G+20 Storey frame.
4. The stiffness irregular structure experiences lesser base shear than similar regular structures.
5. It is concluded that stiffness irregular building frames experience larger base shear than similar regular building frames.
6. It is concluded that mass regular building frames experience larger base shear than similar irregular building frames.
7. Quantity of steel increases as storey height increases.
8. Vertical sporadic structures can be planned precisely and monetarily for seismic tremor obstruction building utilizing STAAD.pro v8i.

According to NTH results, the storey shear force was found to be maximum for the last storey and it increased to maximum in the bottom storey in all cases. It was discovered that mass sporadic structure casings experience bigger base shear than comparative customary structure outlines. The solidness sporadic structure experienced lesser base shear and has bigger bury story floats. If there should be an occurrence of mass sporadic structure, Time History Analysis yielded marginally higher relocations for upper stories than that in ordinary structure, though as we descend, lower stories appeared higher relocations when contrasted with that in normal structures.

REFERENCES

- 1) PiyushMandloi “Seismic Analysis of Vertical Irregular Building with Time History Analysis” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 4 Ver
- 2) Om Prakash Mahato “ Study on Effect of Geometry on RC Multistory Building Under Seismic Load” International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019
- 3) Lovneesh Sharma “Dynamic Seismic Evaluation of Irregular Multi-Storey Buildings Using Bracing in Zone V as Per Is: 1893-2016” International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-7, May, 2019
- 4) ShaikMuneerHussain “Study on Torsional Effects of Irregular Buildings Under Seismic Loads” International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 55-60
- 5) VinayVerma “SEISMIC ANALYSIS AND COMPARISON OF VERTICAL IRREGULAR BUILDING CASES USING RESPONSE SPECTRUM METHOD” International Journal of Application or Innovation in Engineering & Management (IJAIEM) Web Site: www.ijaiem.org Email: editor@jaiem.org Volume 7, Issue 8, August 2018
- 6) Mr. PathanIrfan Khan “seismic analysis of multistoried rcc building due to mass irregularity” 2016 IJEDR | Volume 4, Issue 3 | ISSN: 2321-9939
- 7) Nonika. N “SEISMIC ANALYSIS OF VERTICAL IRREGULAR MULTISTORIED BUILDING” IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308
- 8) Akhileshrathi “Design And Analysis of Regular And Vertical Irregular Building By Using E-TABS” International Journal of Management, Technology And Engineering Volume 8, Issue X, OCTOBER/2018 ISSN NO : 2249-7455
- 9) DileshwarRana “Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 02 Issue: 04 | July-2015
- 10) Devesh P. Soni “QUALITATIVE REVIEW OF SEISMIC RESPONSE OF VERTICALLY IRREGULAR BUILDING FRAMES ” ISET Journal of Earthquake Technology, Technical Note, Vol. 43, No. 4, December 2006, pp. 121-132



INNO SPACE
SJIF Scientific Journal Impact Factor

**Impact Factor:
7.512**

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details