

Effect of Vertical Irregularity in Multistoried Building under Seismic Loading

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ABSTRACT: Behavior of a multi-storey building during strong earthquake motion depends on structural configuration. Irregular configuration either in plan or in elevation is recognized as one of the major causes of failure during earthquakes. Thus irregular structures, especially the ones located in seismic zones are a matter of concern. Structures generally possess combination of irregularities and consideration of a single irregularity may not result in accurate prediction of seismic response. 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, Seismic Loading, Dynamic Loads, Linear Static Analysis

1. INTRODUCTION

1.1 General

The choice of type, degree and location of irregularities in the design of structures is important as it helps in improving the utility as well as aesthetics of structures. Hence, the present study addresses the seismic response of reinforced concrete structures possessing various combinations of irregularities. A nine-storied regular frame is modified by incorporating irregularities in various forms in both plan and elevation to form 34 configurations with single irregularity and 20 cases with combinations of irregularities. Along with the regular configuration, 54 irregular configurations are analyzed and compared. All the frames are subjected to seismic loads and the response of the structures is computed numerically. It is observed that irregularity considerably affects the seismic response. 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. 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- 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.

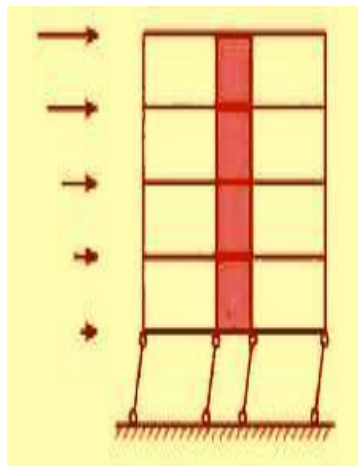


Figure 1.1 Stiffness Irregularities

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.

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.

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.

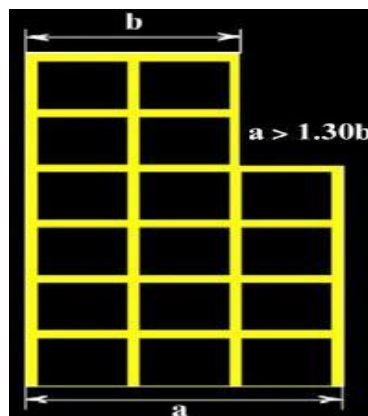


Figure 1.2 Vertical Geometric Irregularities in Building

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)

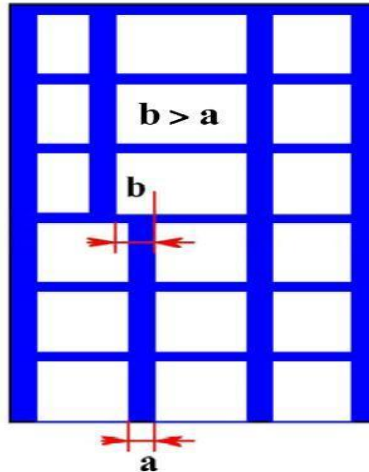


Figure 1.3 In-plane discontinuities in vertical lateral force-resisting element

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 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 is 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. 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

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.



Table 1.1 : 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.

1.7 RESEARCH METHODOLOGY

The primary focus of this study is on the Review of existing literatures by different researchers related to the effect of vertical irregularity

In second phase G+15.G+20 and G+25-story special moment resisting frame modeled with vertical irregularity.

In third phase, performing seismic analysis of G+15.G+20 and G+25-story special moment resisting frame and validation with literature review result.

1.8 DATA COLLECTION

The Primary data will be collected through analysis of multistoried building data using software and secondary data will be collected from previous literature papers and books.

1.9 DATA ANALYSIS

The result come through the analysis of multistoried building i.e primary data will compared with secondary data which is collected from previous literature results for validation of the model and results validation. A parametric study is carried out after validation results to studying correlation.

1.10 SCOPE OF STUDY

Following are the scope of the study:

1. G+15, G+20 and G+25 RC buildings are to be considered.
2. Only stiffness and mass irregularity are to be study.
3. Linear analysis is to be done on the structures.

4. Columns are modeled as fixed to the base.

II. LITERATURE REVIEW

Ramesh Konakalla et al. The roof displacement for the corners of a regular frame is same.

It is observed that, there is no torsional effect in the frame because of symmetry that is the center of mass coincides with the center of rigidity and the lateral displacements of the four corners are same in the direction of earthquake force. The same is observed in the case of wind loads. "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.

Pathan Irfan Khan et al. This project works seismic analysis of RCC buildings with mass irregularity at different floor level are carried out. The Model Considered was of G+10 having swimming pool on 3rd, 6th and 9th Floor. Maximum Base Shear along X and Z directions is also calculated. Lateral Displacements and Storey Drift is also evaluated for X and Z directions. Axial Forces, Torsion and Bending Moment are calculated for six different columns. The structures having this discontinuity are termed as Irregular structures. These structures contain a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the 'regular' building. Analyzing the structure for various Indian seismic zones and checking for multiple criteria at each level has become an essential.

Nonika. N et al. Irregular buildings are analyzed using linear equivalent static analysis and Response spectrum analysis considering different seismic zones according to code provisions, the results obtained highlights the importance of mass, stiffness and geometry of the structure. Following broad conclusions can be made in this respect: This study quantifies the effect of vertical irregularities in mass and stiffness on seismic demands. To quantify the effect of different degrees of irregularities all the structures are analyzed. In addition, the analysis carried out also enables to understand the behavior that takes place in irregular buildings in comparison to that in regular buildings. For this the behavior parameters considered are 1) Maximum displacement 2) Base shear, 3) Time period.

Nawaraj Kapil et al. we have displacements which tends to exceed limit. So it is needed to improve the stiffness in structure by placing bracings or infill. Displacement is noticeable from ground storey. Ground storey it is very negligible; this response is due to presence of foundation at each of these levels. Drift is maximum at ground level as the stiffness in structure changes from the below stories. Below ground storey it is very negligible; this response is due to displacement values. Over turning moment is maximum at basement 2 decreases gradually as the story shear decreases when SSI is not considered. The seismic behavior of the structure when hit by an Earthquake. Only few of the researchers have researched regarding the effects of vertical irregularities in a Structural Building considering Soil Structure Interaction.

Devsh P. Soni et al. carried out an experimental response study on two small scale models of reinforced concrete frame-wall structures subjected to strong base motions by using shake table. One of the test structures, designated as FFW, had two nine-story, three-bay frames and a nine-story, prismatic wall. The other structure, designated as FSW, was identical to FFW except that the wall extended only to the first floor level. Thus the test structures FFW and FSW represent the buildings having "regular" and "irregular" distributions of stiffness and strength in vertical plane respectively. They compared the measured response with that computed by the inelastic dynamic response time-history analysis, inelastic static analysis, elastic modal spectral analysis, and elastic static analysis. Several inelastic response time history analyses were conducted for each test structure. a large number of research studies and building codes have addressed the issue of effects of vertical irregularities. Building codes provide criteria to classify the vertically irregular structures and suggest elastic time history analysis or elastic response spectrum analysis to obtain the design lateral force distribution. A majority of studies have evaluated the elastic response only. Most of the studies have focused on investigating two types of irregularities: those in set-back and soft and/or weak first story structures. Conflicting conclusions have been found for the set-back structures; most of the studies, however, agree on the increase in drift demand for the tower portion of the set-back structures. For the soft and weak first story structures, increase in seismic

demand has been observed as compared to the regular structures. For buildings with discontinuous distributions in mass, stiffness, and strength (independently or in combination), the effect of strength irregularity has been found to be larger than the effect of stiffness irregularity, and the effect of combined-stiffness-and strength irregularity has been found to be the largest.

Ashwin Hardiya et al. The research includes analysis of four different building models which are vertically irregular. The method selected is vertical irregular problem analysis with respect to time history analysis. Four building models are considered with time history reference data to perform and conduct research work. Software used to perform analysis is ETABS. All analysis is compared for outcomes such as deflection, base reaction and stress.

The data collection is then arranged mainly in the tabular format for deflection, base shear and stress. The complete building analysis and data outcomes are arranged together. Time history based analysis is tested for vertical irregular buildings and cases. Result and discussion is described with the help of graphs and the graphs were critically analyzed and studied to conclude the outcome and summary of analysis from each graph. It is recommended as conclusion that irregular buildings are safer than regular building under seismic conditions and should be preferred over regular buildings. The column size is designed lighter with the height of building therefore it is concluded that designing lighter column saves cost of building and helps to achieve optimized design of building.

Akhilesh rathi et al. Period of setback buildings is found to be always less than that of similar regular building. Fundamental period of setback buildings are found to be varying with irregularity even if the height remain constant. The change in period due to the setback irregularity is not consistent with any of these parameters used in literature or design codes to define irregularity the analysis always depends on the forces and importance on the cost of analyzing the structure. Creating the 3D building model for both linear and non-linear dynamic method of analyses. Understanding the seismic behavior of Setback buildings and Co-relating the seismic behavior of the Setback building with that of a building without Setback finally comparing the regular building behavior of building with a setback at top most 5 stories to that of the building with a setback at each floor level. Study the influence of vertical irregularity in the building when compare to regular building. Findings: The present study is limited to reinforced concrete framed structure designed for setback and regular building of loads (DL, LL & EL). The behavior of 20-Storeyed buildings with and without setbacks was studied. The buildings were analyzed using Time History Analysis and Response Spectrum Method.

Piyush Mandloi et al. This paper analyzed four different building models which are vertically irregular and each model is analyzed for without mass irregularity, with mass irregularity increasing from bottom to top, and with mass irregularity decreasing bottom to top. Combinations of four models and three mass irregularities are then also analyzed against four different time histories which are Chichi (1999), Petrolia (1992), Friuli (1976), Northridge (1994) and Sylmar respectively. All analysis is compared for outcomes such as story deflection, story drift, overturning moment and base reaction. Conclusion for each model and mass irregularity combination is presented in different time histories at the end of the paper. Analyzed vertical irregular building with Response spectrum analysis and Time history Analysis. Irregularities considered are mass irregularity, stiffness irregularity and vertical geometry irregularity. The storey shear force was found maximum for the first storey and it decreases to minimum in the top storey in all cases. The outcomes vary from time history to time history. The designers worked for seismic zones must consider time history data while designing vertical and mass irregular buildings. Building with irregularities may be designed with software applications effectively. It saves time and cost for designer.

T.L. Karavasilis et al. seismic design approach for steel structures that concentrates damage in easy-to-replace steel energy dissipation devices and protects the main structural members from yielding with capacity design rules. This approach is further enhanced by using rate-dependent dampers in parallel to steel devices to achieve drift reduction and protection of drift-sensitive non-structural elements. A model for steel energy dissipation devices is proposed and calibrated against experimental results. The model can accurately predict the experimentally obtained hysteresis and is implemented in the Open Sees software for use in seismic response analysis. A prototype steel building equipped with steel devices and viscous dampers is designed according to explicitly defined minimal-damage performance objectives. Seismic analyses results indicate that the building is able to achieve immediate occupancy under the design seismic action and rapid return to occupancy under the maximum considered seismic action.

Vinay Verma et al. Analyses vertical irregular buildings seismic structural analysis and calculate response of building to earthquakes. The deflection and induced stresses causing failure of buildings can be calculated analytically or with the help of designing software. This analysis plays important role in designing building for seismic effective zones and areas all-around the world. Response Spectrum Analysis method is used which is based on ideal predefined data which

are not real time data's collected from real earthquake in the area. Proposed the impact and effect of mass irregularity considering case of an eight-storey concentrically braced steel frame structure with different setback configurations. Methods used in present paper are equivalent static load method and the response spectrum analysis method. The research paper considered several vertical irregular buildings for analysis. The studies suggested that for combined-stiffness-and-strength irregularity large seismic demands are found.

III. RESEARCH 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 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.

$$V=F1+F2+F3$$

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 S_a/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

$$Sa/g = 2.5 \begin{cases} 1+15T & 0.0 \leq T < 0.1 \\ 1/T & 0.1 \leq T \leq 0.4 \\ 1/T & 0.4 \leq T \leq 4 \end{cases}$$

For medium soil,



$$\begin{aligned} &1+15T && 0.0 \leq T \leq 0.1 \\ a/g = 2.5 && 0.1 \leq T \leq 0.55 \\ .36/T && 0.55 \leq T \leq 4 \end{aligned}$$

For soft soil,

$$\begin{aligned} &1+15T && 0.0 \leq T \leq 0.1 \\ Sa/g = 2.5 && 0.1 \leq T \leq 0.67 \\ 1.67/T && 0.67 \leq T \leq 4 \end{aligned}$$

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

For RC frame buildings-

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

For Steel frame buildings-

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

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

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

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.

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



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

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

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

Natural period along X direction

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

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

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

TABLE 4.1: COMPARISON OF RESULTS

Story level	W_i	H_i	$W_i * h_i^2$	$Q_i = \frac{V_B \cdot \frac{W_i h_i^2}{\sum_{j=1}^n W_j h_j^2}}$	Q_i STAAD-Pro	% Error
4	2343	16	599808	212.5	221.06	3.87
3	3538	13	597922	211.9	220.40	3.85
2	3538	10	353800	125.4	130.42	3.84
1	3538	7	173362	61.4	63.9	3.91
Plinth	2716	4	43456	15.7	16.3	3.68

V. RESULT AND DISCUSSION

5.1 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.

5.2 RESULTS FOR MODELS :

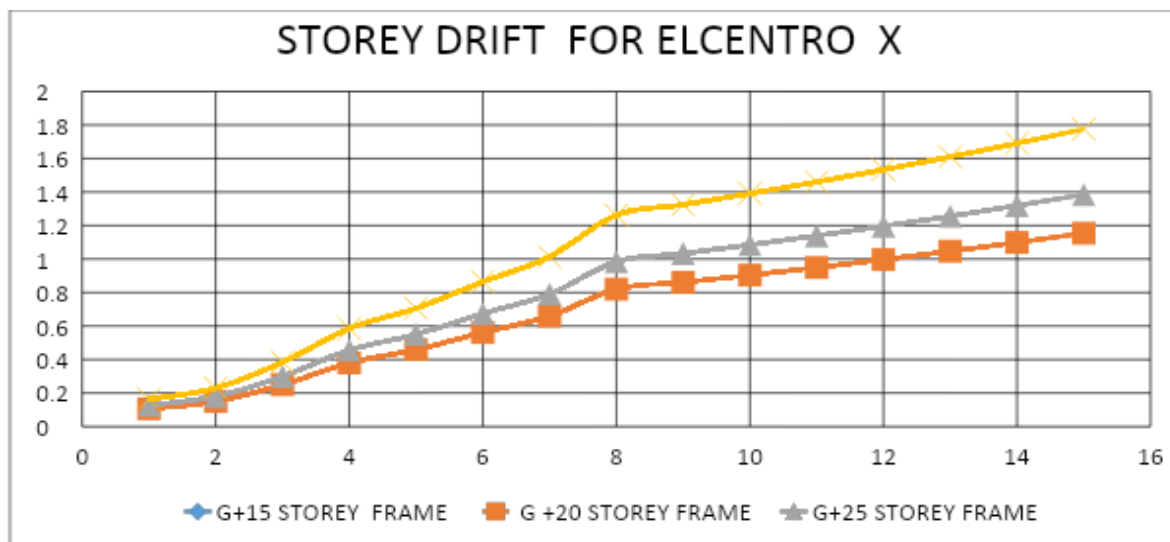
Idealization of above problem statement is modeled in finite element analysis tool STAAD PRO .Following models are prepared for comparative analysis.



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

STOREY NO.	G+15 STOREY FRAME	G +20 STOREY FRAME	G+25 STOREY FRAME
1	0.10647	0.127764	0.1638
2	0.14976	0.179712	0.2304
3	0.249795	0.299754	0.3843
4	0.38025	0.4563	0.585
5	0.459225	0.55107	0.7065
6	0.5616	0.67392	0.864
7	0.659295	0.791154	1.0143
8	0.82017	0.984204	1.2618
9	0.8611785	1.0334142	1.32489
10	0.904237425	1.08508491	1.3911345
11	0.949449296	1.139339156	1.460691225
12	0.996921761	1.196306113	1.533725786
13	1.046767849	1.256121419	1.610412076
14	1.099106242	1.31892749	1.690932679
15	1.154061554	1.384873864	1.775479313

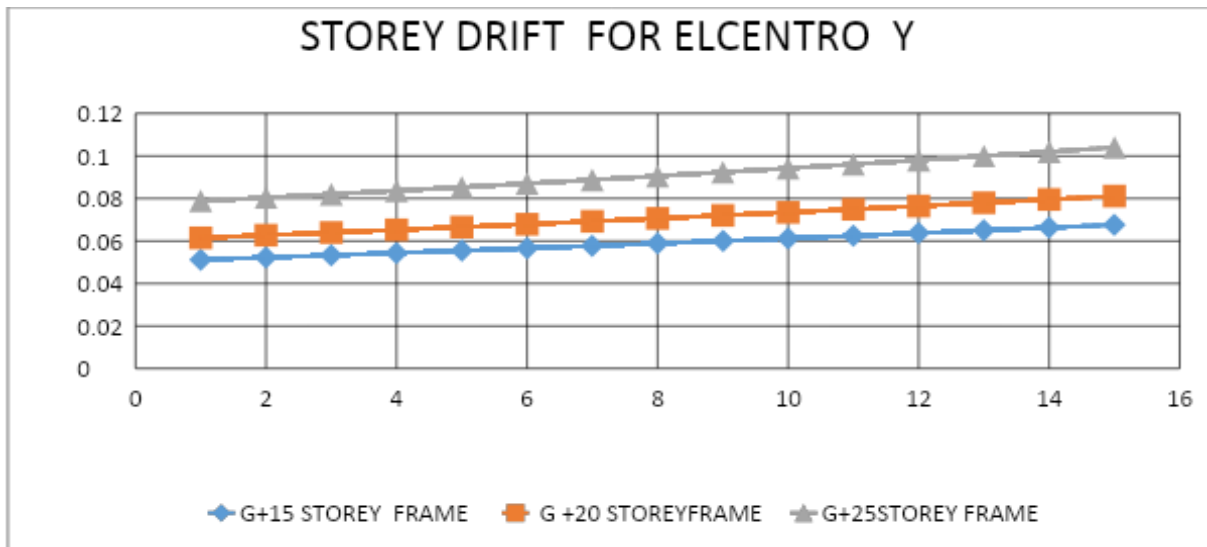


Graph 6.10 Storey level versus Storey drift



Table 6.3 Storey Drift for Elcentro in Y Direction

STOREY NO.	G+15 STOREY FRAME	G +20 STOREYFRAME	G+25STOREY FRAME
1	0.051246	0.0614952	0.07884
2	0.05227092	0.062725104	0.0804168
3	0.053316338	0.063979606	0.082025136
4	0.054382665	0.065259198	0.083665639
5	0.055470318	0.066564382	0.085338951
6	0.056579725	0.06789567	0.087045731
7	0.057711319	0.069253583	0.088786645
8	0.058865546	0.070638655	0.090562378
9	0.060042857	0.072051428	0.092373626
10	0.061243714	0.073492457	0.094221098
11	0.062468588	0.074962306	0.09610552
12	0.06371796	0.076461552	0.09802763
13	0.064992319	0.077990783	0.099988183
14	0.066292165	0.079550598	0.101987947
15	0.067618009	0.08114161	0.104027706

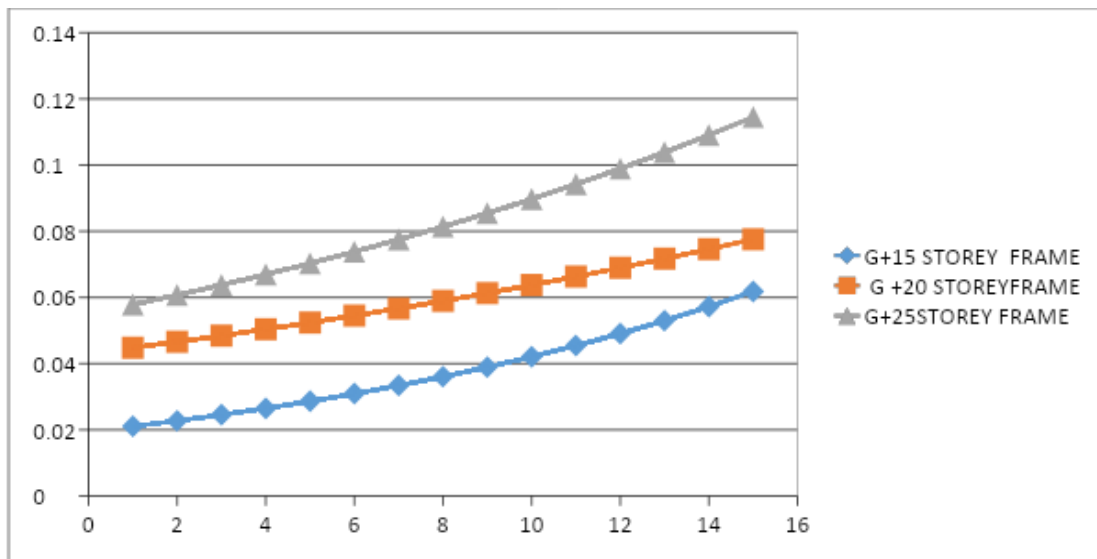


Graph 6.11 Storey level versus Storey drift



Table 6.4 Storey Drift For Bhuj In X Direction

STOREY NO.	G+15 STOREY FRAME	G +20 STOREY FRAME	G+25 STOREY FRAME
1	0.021049	0.0448	0.057843
2	0.02273292	0.046592	0.06073515
3	0.024551554	0.04845568	0.063771908
4	0.026515678	0.050393907	0.066960503
5	0.028636932	0.052409663	0.070308528
6	0.030927887	0.05450605	0.073823954
7	0.033402118	0.056686292	0.077515152
8	0.036074287	0.058953744	0.08139091
9	0.03896023	0.061311893	0.085460455
10	0.042077048	0.063764369	0.089733478
11	0.045443212	0.066314944	0.094220152
12	0.049078669	0.068967542	0.098931159
13	0.053004963	0.071726243	0.103877717
14	0.05724536	0.074595293	0.109071603
15	0.061824989	0.077579105	0.114525184

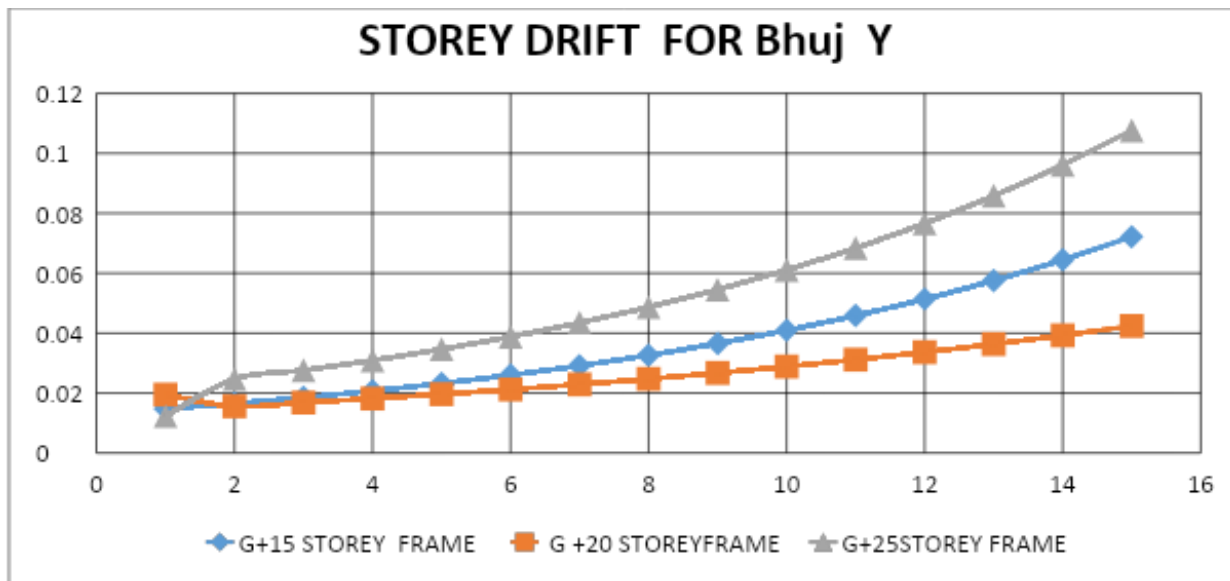


Graph 6.12 Storey level versus Storey drift



Table 6.5 Storey Drift for Bhuj InY Direction

STOREY NO.	G+15 STOREY FRAME	G +20 STOREY FRAME	G+25 STOREY FRAME
1	0.01477	0.01949	0.01234
2	0.0165424	0.015592	0.02468
3	0.018527488	0.01683936	0.0276416
4	0.020750787	0.018186509	0.030958592
5	0.023240881	0.01964143	0.034673623
6	0.026029787	0.021212744	0.038834458
7	0.029153361	0.022909763	0.043494593
8	0.032651764	0.024742544	0.048713944
9	0.036569976	0.026721948	0.054559617
10	0.040958373	0.028859704	0.061106771
11	0.045873378	0.03116848	0.068439584
12	0.051378183	0.033661959	0.076652334
13	0.057543565	0.036354915	0.085850614
14	0.064448793	0.039263308	0.096152687
15	0.072182648	0.042404373	0.10769101



Graph 6.13 Storey level versus Storey drift

VI. CONCLUSION

The storey shear force is Minimum for the first storey and it increases to maximum in the top storey. It is concluded that storey drift of G+25 is more than G+15, G+20 Storey frame. It is concluded that base shear of G+25 is more than G+15, G+20 Storey frame. The stiffness irregular structure experiences lesser base shear than similar regular structures. It is concluded that stiffness irregular building frames experience larger base shear than similar regular building frames. It is concluded that mass regular building frames experience larger base shear than similar irregular building frames. Quantity of steel increases as storey height increases. 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.

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