SEISMIC ANALYSIS OF BUILDING WITH MASS IRREGULARITY

Submitted in fulfilment of the requirement for the

award of degree of

Master of Technology

In

STRUCTURAL ENGINEERING

By

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(2K16/STE/07)

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CANDIDATE'S DECLARATION

I do hereby certify that the work presented is the report entitled "**SEISMIC ANALYSIS OF BUILDING WITH MASS IRREGULARITY**" within the partial fulfilment of the requirement for the award of the degree of "Master of Technology" in Structural Engineering submitted within the branch of Civil Engineering, Delhi Technological university, is an real file of my very own paintings executed beneath the supervision of Assistant Prof.Hrishikesh Dubey, branch of Civil Engineering. I've not submitted the matter embodied inside the report for the award of any other diploma or degree to any other group.

(CHOPPA SRAVAN KUMAR)

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CERTIFICATE

This is certified that the work contained in this minor project entitled "**SEISMIC ANALYSIS OF BUILDING WITH MASS IRREGULARITY**" by CHOPPA SRAVAN KUMAR(2K16/STE/07) is the requirement for the fulfilment of the degree of STRUCTURAL ENGINEERINGE at Delhi Technological University. This work was completed under my direct supervision and guidance. The student has completed his work with utmost sincerity and diligence.

Place: Delhi

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ABSTRACT

This thesis is concerned with the consequences of various vertical irregularities on the seismic response of the structure. Objective of the project is to carry out Response spectrum analysis (RSA) and Push Over Analysis of vertically irregular RC building frames. Comparison of the results of irregular structures with regular structure is done.

During this mass irregularity and vertical irregularity were considered. The story shear force was observed to be maximum for the first story and it diminishes in the top storeys. In this mass irregular structures were found larger base shear than similar regular structures. if the tall building structure (low natural frequency) that is the structure with 4-8 storeys are more vulnerable to earthquake. So, in the present study G+7 storied building is considered. In this study push-over analysis is performed in the SAP2000 software. Various pushover curves are obtained. Performance point is obtained using capacity spectrum method.

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LIST OF ABBREVIATIONS

18	NBCC	National Building Code of Canada	**10**
19	NZS	New Zealand seismic design standard	**10**
20	RCC	Reinforced cement concrete	**14**
21	EC8	Euro code 8	**14**
22	DCH	High ductility class	**15**
23	SMF	Steel moment frame	**15**

CHAPTER 1
INTRODUCTION

1.1INTRODUCTION

During an earthquake, failure of structure begins at points of weakness. This weakness emerges because of irregularity in mass, stiffness and geometry of structure. The structures having this discontinuity are named as Irregular structures. irregular structures contribute a huge part of urban infrastructure. Vertical irregularities are one of the significant reasons of failures of structures during earth quakes. For example, structures with soft story were the most notable structures which collapsed. In this way, the impact of vertically irregularities in the seismic performance of structures turns out to be extremely essential. Height-wise changes in stiffness and mass render the dynamic characteristics of these structures not quite the same as the regular building.

IS 1893 definition of Vertically Irregular structures:

The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design become more complicated.

There are two types of irregularities-

1. Plan Irregularities
2. Vertical Irregularities.

Vertical Irregularities are mainly of five types-

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 storeys above.

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 storeys above.

Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

Vertical Geometric Irregularity-A structure is considered 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.

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.

b) Discontinuity in Capacity —

Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

According to IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated according to code based fundamental time period of the structure. linear dynamic analysis are improvement over linear static analysis, as this analysis creates the impact of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. Structures are designed according to Design based quake, however the actual forces acting up on the structures is much more than that of DBE. so, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary target in designing seismic resistant structures is to ensure that the building has enough ductility to withstand the quake forces, which it will be subjected to during an earth quake.

1.2 SCOPE OF STUDY: -

1. Comparison between regular and vertical irregular frame on the basis of mass irregularity.
2. Equivalent static load method, response spectrum analysis method and push over analysis method were used in design.
3. Comparison of results from static and dynamic methods.
4.Obtaining various graphs of pushover analysis using SAP2000 software.

1.3 METHODOLOGY: -

The steps undertaken in the present study to accomplish the above-mentioned objectives are as follows:

- Review of existing literatures by different researchers
- Selection of types of structures
- Select an irregular and regular building frame model with heights (G+7stories) assuming equal bay width of 4m along X and Y direction bays
- Performing dynamic analysis i.e response spectrum analysis and push over analysis on selected building models using STAAD.Pro V8i and SAP2000.
- Detailed discussion on the results with the help of graphs and tables considering all the included parameters.

1.3.1 SEISMIC ANALYSIS METHODS: -

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of structures because of seismic excitation's in a simpler way. for the most part, the structures were composed only for gravity loads and seismic analysis is a recent development. It is a part of structural analysis and a part of structural design where earthquake is predominant. The following are different types of quake analysis methods. Some of them used in the project are:

- Equivalent Static Analysis
- Response Spectrum Analysis
- Push Over Analysis

1.3.2 EQUIVALENT STATIC ANALYSIS METHOD: -

The equivalent static analysis procedure is essentially an elastic design technique. The equivalent static method is the simplest method of analysis. Here, force depend upon the fundamental period of structures defined by IS Code 1893:2002 with some changes. First, design base shear of complete building is calculated, and then distributed along the height of the building, based on formulae provided in code. Also, it is suitable to apply only on buildings with regular distribution of mass and stiffness. Following are the major steps in determining the seismic forces: -

1.3.3 DETERMINATION OF BASE SHEAR:-

The total design lateral force or design base shear along any principal direction is determined by the expression: -

$$\mathbf{V = A_h W}$$

Where,

A_h = design horizontal seismic coefficient for a structure

W = seismic weight of building

The design horizontal seismic coefficient for a structure A is given by:-

$$\mathbf{A_h = (Z*I*Sa)/ (2*R*g)}$$

Where:

Z is the zone factor in Table 2 of IS 1893:2002 (part 1).

I is the importance factor

R is the response reduction factor; Sa/g is the average response acceleration coefficient for rock and

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; 0.00 \le T \le 0.10 \\ 2.50; 0.10 \le T \le 0.40 \\ 1.00/T; 0.40 \le T \le 4.00 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50; & 0.10 \le T \le 0.55 \\ 1.36/T; & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50; & 0.10 \le T \le 0.67 \\ 1.67/T; & 0.67 \le T \le 4.00 \end{cases}$$

T is the fundamental natural period for buildings calculated as per clause 7.6 of IS 1893:2002 (part1).

Ta = $0.075h^{0.75}$ for moment resisting frame without brick infill walls

Ta = $0.085h^{0.75}$ for resisting steel frame building without brick infill walls

Ta = $0.09h/\sqrt{d}$ for all other buildings including moment resisting RC frames

h is the height of the building in m and d is the base dimension of building at plinth level in m.

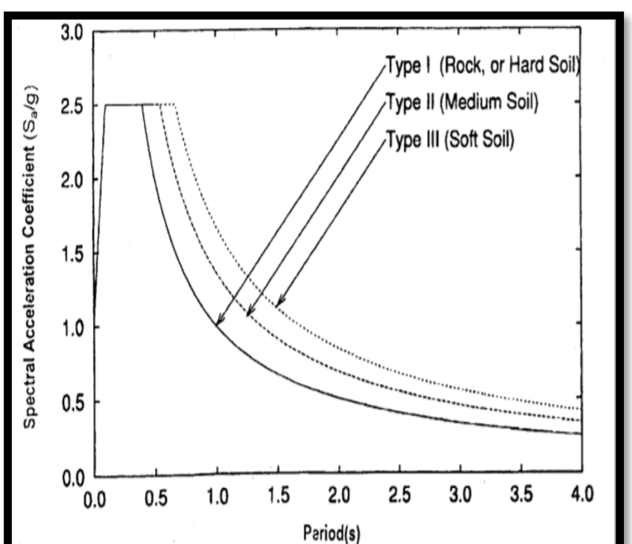

Fig:1.1 Shows the graph between spectral acceleration and period soil sites as given in figure 2 of IS 1893:2002 (part 1). The values are given for 5% damping of the structure.

1.3.4 LATERAL DISTRIBUTION OF BASE SHEAR: -

The total design base shear must be distributed along the height of the building. The base shear at any story level relies upon the mass and deformed shape of the building. Seismic forces have a tendency to deflect the building in various shapes, the natural mode shape which in turn depends on the degree of freedom of the building. A lumped mass model is idealized at each floor, which in turn converts over a multi storied building with infinite degree of freedom to a single degree of freedom in lateral displacement, resulting in degrees of freedom being equal to the number of floors.

The magnitude of lateral force at floor (node) depends upon: -

- Mass of that floor
- Distribution of stiffness over the height of the structure
- Nodal displacement in given mode

Distribution of base shear along the height is done according to this equation: -

$$Q_i = V_B \times \frac{W_i\, h_i^2}{\sum_{j=1}^{n} W_j\, h_j^2}$$

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

1.3.5 LOAD CALCULATIONS: -

Loads and Load combinations are given as per Indian standards. (IS 875:1984, IS 1893:2002 and IS 800:2007*)*

Seismic Loading: -

Seismic load is given as per IS 1893- 2002. Following assumptions are used for the calculation.

Zone factor – 0.24

Soil type – 2 (medium stiff Soil)

Importance Factor – 1

Response reduction – 5

Time period in X-direction – 0.408 seconds

Time period in Z-direction – 0.408 seconds

Dead loads: -

For floors; unit weight of reinforces cement concrete= 25 KN/M^3

Assume depth of slab= 150mm

Imposed loads: -

For residential buildings i.e. hostels

Hostels, hotels, boarding houses, lodging houses, dormitories, residential clubs:

Living rooms, bed rooms and dormitories = 2.0 KN/M^3 (IS: 875, Part 2- 1987)

Load combinations: -

1) 1.5 (DL+ IL)
2) 1.2 (DL+ IL $\pm$ EL)
3) 0.9 DL$\pm$ 1.5 EL
4) 1.2 (DL+ IL $\pm$ WL)
5) 0.9 DL$\pm$ 1.5 WL

CHAPTER 2

LITERATURE REVIEW

Kara Vasilis et al., (2008) considered the inelastic seismic response of plane steel moment-resisting frames with vertical mass irregularity. The analysis of the created response databank demonstrated that the number of storey's, the quantitative relation of strength of beam and column and the location of the heavier mass impact the height-wise distribution and amplitude of inelastic deformation demands, while the response does not appear, by all accounts, to be influenced by the mass quantitative relationship.

Valmundsson et al., (1997) assessed the earthquake response of 5-, 10-, and 20 story framed structures with non-uniform mass, stiffness, and strength distributions. The response calculated from TH analysis was compared and that and expected by the ELF system embodied in UBC. Based on this comparison, the point was to judge the present requirements underneath that a structure can be considered regular and the ELF provisions applicable. Building codes give criteria to classify the vertically irregular structures and elastic response solely. Dominant part of the studies has focused on investigating two types of irregularities: those in set-back and soft and/or weak initial storey structures. Conflicting conclusions are found for the set-back structures; the greater part of the studies, however, agrees on the rise in drift demand for the tower portion of the set-back structures.

Poonam et al., (2012): - Results of the numerical analysis demonstrated that any story, particularly the first story, should not be softer/weaker than the stories to finish everything or underneath. Irregularities in mass distribution also contribute to the increased response of the structures. The irregularities, if necessary to be given, got to be provided by applicable and intensive analysis and design processes.

Sadashiva et al., (2008): -Vertical and horizontal regularity provisions within the current New Zealand seismic design standard, NZS 1170.5 (SNZ 2004) are based on overseas codes. This paper proposed a novel method of quantifying irregularity limits for structures analyzed using the simpler analysis procedures regulated by design codes. The new methodology was illustrated using vertical mass irregularity for three and nine storey frames. Mass ratios of 1.5, 2.5, 3.5 and 5 times the floor mass of a regular structure were applied at bottom, mid-height and topmost levels of a redesigned structure to determine the median will increases in interstorey drift responses. It absolutely was shown that the impact of irregularity depends on the structural model used, the irregularity locations and therefore the analysis methodology used for the design. The proposed methodology permits acceptable irregularity limits to be determined from an acceptable increase in a specified response. The method is simple to use and sufficiently versatile enough to be developed in many ways and applied in design procedures.

Tremblay et al., (2014): -in this journal seismic forces and deformations obtained from the equivalent static force procedure and dynamic analysis procedure for the planned 2005 NBCC were compared for multistoried building structures situated in a Vancouver and Montréal. the structures were four, eight, twelve, and sixteen storey in height and therefore the seismic forces were resisted by continuous braced steel frames.

Valmundsson et al., ASCE: - study was conducted in and supported by, the Department of Civil Engineering at North Carolina State University. During this study, the earthquake response of 5-, 10-, and 20 story framed structures with non-uniform mass, stiffness, and strength distributions has been assessed. The structures were modeled as two-dimensional shear structures. The response ascertained from TH analysis was compared therewith expected by the ELF method encapsulated in UBC. Supported with this comparison, the point was to gauge the present necessities under which a structure can be viewed as general, and furthermore the ELF arrangements relevant.

Seon Lee et al., (2004): - Many RC building structures of numerous utilizations developed in Korea have the anomalies of torsion and additionally delicate story at base stories. The target of this examination is to explore through shaking table tests the seismic reaction of skyscraper RC bearing-divider structures with three kinds of abnormality at the base stories. For this reason, three 1:12 scale 17-storey strengthened solid model structures were developed by the comparability law, in which the upper 15 stories have a direction divider framework while the lower two stories have the casing framework with various formats in design: The first has one minute opposing casing framework (Model 1), the second has an infilled shear divider in the focal casing (Model 2), and the third has an infilled shear divider in just a single of the outside edges (Model 3). At that point, these models were subjected to a similar arrangement of reproduced seismic tremor excitations.

The presence of shear divider diminishes strikingly shear misshapening at the lower outline, yet has very nearly an immaterial impact on the lessening of the upsetting disfigurement, base shear, and OTM

Sarkar et al., (2010): - Stepped fames outlines constitute a classification of vertical irregularity, whose seismic behavior has not received satisfactory consideration in existing exploration and code formulation. In this paper, a detailed examination has been completed to address this inadequacy.

1. A measure of vertical irregularity, suitable for stepped structures, called 'regularity index', is proposed, speaking to the modifications in mass and stiffness along the height of the building. This is straightforward in idea and is seemed to perform better than existing measures.

2. An empirical formula (adjustment of the current code condition for general RC framed building) is proposed to figure the fundamental time period of stepped working, as a function of regularity index. This has been approved by free vibration analysis, performed on 78 stepped frames

3.A case study of an existing stepped building situated at New Delhi exhibits that the proposed redress to the code determined exact equation brings about a precise gauge of the crucial period, notwithstanding for three-dimensional building models. Pathan Irfan Khan,

Dhamge et al., (2016): -In this explained about mass irregularity is an important factor to be considered along with the other relevant joint displacement, base shear and storey drift will help which structure is efficient. Based on analysis and study of chapters drawn some conclusion which are presented below.

1. In this models are compared with each other and behavior is studied, but not much change is seen, except magnitude is seen in different zones.

2. According to RSA results storey shear force was found to be maximum for first storey and it decreased to a minimum in top storey in all cases.

3. Permissible limit of storey drift 14mm as per IS1893 (part1)-2002. By analysis of G+10 storey structure it is found that maximum storey drift of RCC structure is 14.726 mm and 16.617mm in X and Z direction respectively. Storey Drift is mainly critical in 3, 4, 5 floor.

Poncet et al., (2005): - The effect of mass irregularity on building seismic response is assessed for eight-story concentrically supported steel layout with different difficulty designs achieving sudden diminishments in design measurements and seismic weight along the height of the structure. Three regions of mass discontinuity are viewed as (25, 50, and 75% of the building height), together with two extents of seismic weight (200 and 300%).A reference regular structure was also considered for comparison. The plan of each structure was performed by the proposed 2005 National Building Code of Canada NBCC courses of action using two examination systems: The equivalent static force procedure and the reaction range examination methodology. Although severe, mass irregularity conditions considered in this examination were found to have restricted negative impact on the seismic execution of the structures arranged with static analysis method. The execution of irregular structures demonstrating lower performance could be upgraded by using dynamic analysis strategy in design. Regardless, not to the level achieved by reference normal structure.

Darshan et al., (2016) - In this after the analytical study of 12 storey building models the accompanying conclusions are made,

BASE SHEAR:

The mass of the building in model 3 lead to increment in base shear contrasted with different models. This demonstrates that increase in mass in model 3(1st, 2nd, 3rd and fourth) expands the base shear contrasted with different models.

MODE PERIOD:

The mode period of model-5 with mass irregularity in top 4 stories is observed to be greatest when contrasted with different models. From examination it is discovered that model-3 with mass inconsistency in base stories has less mode period when contrasted with different models

STORY DRIFT:

The story float in both the examination (RS and TH), it has been found that model-3 indicates more storey drift in both X-X and Y-Y direction compared to different models. Though model-1 and model-2 indicates less story drift contrasted with different models. So dissemination of mass ought to be equivalent in every one of the stories which will brings about the less story drift.

TORSION

Twisting moment (torsion) of the structure will rely upon the dispersion of mass in each model. Display 3 is influenced by more torsion as the mass abnormality is at the last four stories (1st, 2nd, 3rd and fourth stories) contrasted with every other model.

Guruprasad et al., (2017) - This paper is concerned about the impacts of different vertical irregularities on the seismic response of a structure. Irregularity in plan shape which is due to the difference between the situation of the Centre of stiffness and the mass center of a structure caused by architectural requirements is typically unavoidable. The goal of the venture is to do in unique examination of vertically irregular RC building frames. Comparison of the results of analysis and design of irregular structures with general structure was done.

Devesh et al., (2006) - This study outlines best in class data in the seismic response of vertically irregular building frames. Criteria describing vertical irregularity as per the present construction standards have been inspected. A survey of concentrates on the seismic conduct of vertically irregular structures along with their findings has been shown. It is watched that building codes offer criteria to describe the vertically irregular structures and propose dynamic analysis to arrive to design lateral forces it can be presumed that innumerable investigations and construction standards have kept an eye on the issue of effects of vertical irregularities. Construction regulations offer criteria to describe the vertically irregular structures and propose elastic time history analysis or elastic response spectrum analysis to get the design lateral force distribution. A majority of studies have evaluated the elastic response only.

Ansari et al., (2016)- This study introduces the system for seismic evaluation of vertically mass irregular reinforced concrete structures in view of an idea of the capacity spectrum method. In this study, 3d analytical model of twelve storied structures have been generated for vertically mass irregular structures. Models are analyzed using structural analysis tool 'ETABS. The analytical model of the structures incorporates impact of the mass at various story of the structure i.e. at fourth floor, eighth floor and twelfth floors separately. Furthermore, the outcomes are thought about for models having irregular mass at various floors with regular frames. Additionally, the results of Linear Static (Equivalent static method) and Linear dynamic Analysis (Response spectrum Analysis).

Ramasco et al., (2008) - The paper demonstrates the results of an research study concerning the seismic response and design of RC frames with strength discontinuities in height. The irregularities are obtained assigning over strengths either to the beams or to the columns of a "regular frame" (accepted as reference). The "regular frame" is designed according by the Euro code 8 (EC8) High Ductility Class (DCH) rules. The over strengths of expected irregular frames are assigned modifying the reinforced both of the beams or of the columns at various floors.

For all frames the criteria of vertical strength irregularity of numerous international seismic codes are applied. To this reason, the storey strengths are figured by two distinct strategies: the first just considers the flexural resistance of columns, while the second one likewise considers the beam flexural resistance. Nonlinear static and dynamic analysis are performed: mechanical non-linearity is concentrated at the element ends.

Sehgal et al., (2012) - This paper discusses the research works done in the past with respect to different types of structural irregularities i.e. Plan and vertical irregularities. Criteria and limits of restriction specified for these irregularities as defined by different codes of practice (IS 1893:2002, EC8:2004 etc.) have been discussed briefly. It was watched that the limits of both Plan and vertical irregularities suggested by these codes were similar. The presence of structural irregularity changes the seismic response and the modification in the seismic response depends on types of structural irregularities. On comparing research works with respect to plan and vertical irregularity, it was found that strength irregularities had the maximum impact and mass irregularity had the minimum impact on seismic response.

Concerning vertical irregularities, it was discovered that strength irregularity had the most extreme impact and mass irregularity had the base impact with respect to seismic response. As for examination method MPA (Modal pushover analysis) technique even after much change was seen to be less precise when contrasted with dynamic examination Regarding the vertical irregularities it was found that strength irregularity had the most extreme effect and mass irregularity had the base effect on seismic response. With respect to investigation technique MPA (Modal pushover analysis) method even after much change was observed to be less precise when contrasted with dynamic investigation.

Kien Le-et al., (2008)- This paper centers around examining the seismic practices of vertically irregular steel moment frame (SMF) structures by correlation with the regular counterpart. All structures of this examination were depended upon to arrange in Los Angeles and subjected to 20 quake ground movements with a seismic risk level of 2% likelihood of exceedance in 50 years. These 20-story structures were relied upon to comply with the prerequisites for steel SMFs as exhibited by IBC 2000 arrangements, and the bar section associations of the structures were appeared to consider the panel zone deformation. So also, a flexible association of the structures was shown to consider the examination program with an extreme target to obtain more correction happens.

Three types of the irregularities (mass, stiffness and strength irregularity) chose as vertical irregularities in the IBC 2000 game plan were compelled to the main building. Nonlinear static and dynamic examinations were performed, and the certainty levels of which the execution question will be fulfilled were registered as well.

Dileshwar et al., (2015) - The seismic parameters which are considered for this study are shear force, bending moment, storey drift and storey displacement and sectional displacement. The essential most prominent characteristics are taken in each one of the cases. The Z directional shear force and bending moment are considered. The storey drift and maximum storey nodal displacement of both the horizontal direction X and Z are noted down. The point of the examination is to find out the variety of these parameters among five frame configurations. At first these results are looked at for same story heights, by then after conclusion will be made considering about all storey heights. The basic qualities are being taken that are greatest among the all load cases. The seismic execution and behavior of any building frames effectively be anticipated in view of concentrate these parameters.

Raja et al., (2017)- As demonstrated by this paper vertically irregular structures have performed ineffectively amid earthquakes. The execution-based examination like push over investigation is very fundamental to comprehend the behavior of the structures. As building turns out to be increasingly vertically irregular (mass irregular), the storey shear keeps growing as appeared differently in relation to mass regular building. if irregularities are to be introduced in a building, they should be designed properly according to the conditions of IS 1893: 2002 (section 1) and IS-456: 2000 [8], and joints should be made ductile according To IS 13920:1993. The complex molded structures are better known, yet they convey a danger of managing harms amid of earth quakes. Henceforth, such structures should be planned appropriately taking with their dynamic behavior.

Singhal et al., (2016)- It is assumed that each floor of asymmetrical building (asymmetrical in more than one direction) is subjected to higher horizontal displacement in examination of each floor of building having asymmetry in just a one direction.

It is furthermore watched that, the storey drift values in the building is high in base floors than top floors as shear is overwhelming then the bending. If there should arise an occurrence of higher uneven building, drift values are generally higher then drift values in less asymmetrical building. If there should arise an occurrence of decline in stiffness or mass in a building, a sudden jump can be found in drift values. It is moreover reasoned that higher asymmetrical building is subjected to more torsion then less asymmetrical building.

Baek et al., (2015) - In this examination, the nonlinear seismic time history analysis for the 5-storey RC building designed by the KBC was done to assess the storey drift response depending upon the vertical stiffness and strength irregularity. The parametric analysis was led considering differing stiffness and strength ratios of the first storey to the second storey from 0.1 to 1.0. The outcomes demonstrated that the storey drift had a tendency to be expanded and concentrated on the first storey as the strength and stiffness ratios of the storey diminished contrasting and the normal model. That tendency was inverse relative to the Regularity Index, characterized as the result of quality and stiffness ratios of the soft weak storey. Likewise, when the Regularity Index was under 0.65, the drift of the soft weak storey was surpassed the 1.5% limit prescribed by KBC.

There results lead us to the conclusion that the recommended Regularity Index could be used for assessing the seismic performance and behavior of the irregular building with soft weak storey quantitatively. Further studies for more variables and diverse cases are expected to apply it to seismic design and evaluation.

Ravindra et al., (2017) - Three types of irregularities particularly mass irregularities, stiffness irregularity and vertical geometry irregularity were considered. all three types of irregular RC building frames had plan symmetry. Response spectrum analysis (RSA) was directed for each kind of irregularity and the storey shear force was observed to be most extreme for the main storey and it diminished to the top storey in each cases.

According to outcomes of RSA, it was found that mass irregular building frames experience extensive base shear than regular building frames. According to results of

RSM, the stiffness irregular building experienced lesser base shear and has larger inter storey drifts.

Robert Tremblay et al., (2014)- The seismic forces and deformations got from the equivalent static force strategy and the dynamic analysis method proposed for the 2005 NBCC were looked at for multistoried building structures arranged in Vancouver and Montreal. The structures were 4,8,12, and 16 stories in tallness, and the seismic forces were restricted by continuous braced steel frames. The structures had a difficulty bringing about mass irregularity of 200% or 300% arranged at 25%, 50% or 75% of their height. With the special case of the 12 and 16 story stage Vancouver that had half or a more prominent measure of their mass arranged in the lower 25% of their height, the quake lateral force v at the base of the structures and the force and deformations along the building structure as got with the ESFP surpassed the relating values decided from dynamic analysis is used as a part of the static method.

Ambrisi et al., (2008) - In this paper the frequency of mass eccentricity has been contemplated with reference to a confined six story 3D building structure planned by EC8.A detailed model 1 has been set with the program ZEUS and time-history analysis have been performed to obtain values of response parameters such a top displacement and interstorey drifts.

Cimellaro et al., (2014)- Nonlinear static technique are less tedious than NRHA; Therefore, nowadays they are extensively practically every type of building. However, because the majority, real structures are irregular, pushover methods need to be improved to take into account the torsion impacts of structures and directivity of seismic ground movement before being implemented in design codes. In this paper, a modification of the N2 strategy to defeat the tensional issue in plan and elevation of asymmetric structures subjected to bidirectional ground development is proposed.

IS 1893(Part-1)-2002," Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1: General Provision and Buildings", Bureau of Indian Standards, New Delhi- The code gives information regarding the linear approach used for seismic resistant design of the structure. it also provides information regarding the response spectrum on the basis of soil type and zone of interest.

ATC-40-(1996)" Seismic Analysis and Retrofit of concrete Buildings", vol. I, Applied Technology Council, Rewood City, CA, USA. ATC 40 provides information regarding the CAPACITY SPECTRUM method of pushover analysis and finding the target displacement of a structure using it. This code also provide method of finding the target displacement of a structure using it.This code also provide method of finding equivalent viscous damping of response spectrum and converting the MDOF pushover curve into SDOF spectral acceleration and spectral displacement graph.

ATC 40 also gives insight detail of limits and performance objectives of the structure and also recommended predefined limits for safe working of structure for a seismic hazard of known severity.

Pu YANG et al., (2000)-This is the study of improvement of pushover analysis. The static pushover analysis is becoming popular as a simplified computer method for seismic performance evaluation of structures. This method implies the response of the structure is only controlled by the first mode, and mode keeps constant during time history. Several example illustrates that the structural maximum responses under-estimated the influence of higher modes compared to results obtained from dynamic analysis.

Qian et al., (2008)-Application of Pushover analysis of earthquake response prediction of complex large-span steel structures.in this two complex large span steel structures are analyzed namely A380 hanger and the National stadium. this indicate that plastic hinges appear at few members and the whole structure is within elastic under severe earthquake. For certain types of complex large-span steel structure, when the total modal mass participation factor is larger than about 0.65, results of pushover analysis will be close to those of dynamic analysis. In this case, pushover analysis appears to be accurate for predicting response of complex large-span steel structures under severe earthquakes.

Rahman et al., (2012)-Nonlinear static Pushover Analysis of an Eight Storey RC Frame-Shear wall building in Saudi Arabia. The western region of Saudi Arabia lies in a moderate seismic zone and seismic events of magnitude 5.7 were recorded in 2009 in areas near the holy city of Madinah. A historical event involving ground cracking and fissuring with volcanic city took place in the year 1256.The recent seismic events have lead to concerns on safety and vulnerability of RC buildings, which were designed only for gravity loads in the past devoid of any ductile detailing of joints.

This paper presents a 3D nonlinear static analysis for seismic performance evaluation of an existing eight-storey reinforced concrete frame shear wall building in Madinah. The building has a dome, reinforced concrete frame, elevator shafts and ribbed and flat slab systems at different floor levels. The seismic displacement response of the RC frame - shear wall building is obtained using 3D pushover analysis. The 3D static pushover was carried using SAP2000 incorporating the inelastic material behavior for concrete and steel.

CHAPTER 3

Analysis and Modelling

3.1 STRUCTURAL MODELLING OF REGULAR STRUCTURE: -

Table 3.1: Shows specifications of regular structure

SIZE OF COLUMN	300*300mm
SIZE OF BEAM	300*400mm
LIVE LOAD	3KN/M^2
SLAB THICKNESS	150mm
HEIGHT OF THE STRUCTURE	G+7
NO OF BAYS ALONG X DIRECTION	7
NO OF BAYS ALONG Z DIRECTION	7
DENSITY OF CONCRETE	25KN/M^2
DENSITY OF BRICK	20KN/M^2
THICKNESS OF EXTERNAL WALL	230mm
THICKNESS OF INTERNAL WALL	115mm
ZONE	IV
SOIL TYPE	MEDIUM SOIL
IMPORTANCE FACTOR	1
STRUCTURE TYPE	SPECIAL MOMENT RESISTING FRAME
RESPONSE REDUCTION FACTOR	5
FUNDAMENTAL NATURAL PERIOD OF VIBRATION(T)	0.408
DAMPING RATIO	0.05
AVERAGE RESPONSE ACCELERATION COEFFICIENT	S_a/g =2.5

3.2

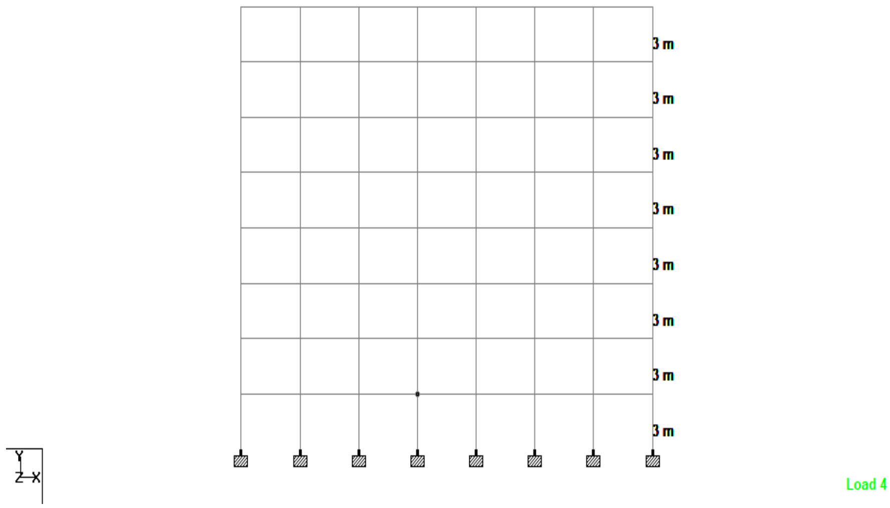

Fig.3.1: Model of regular structure

3.2 MODELLING OF IRREGULAR STRUCTURE

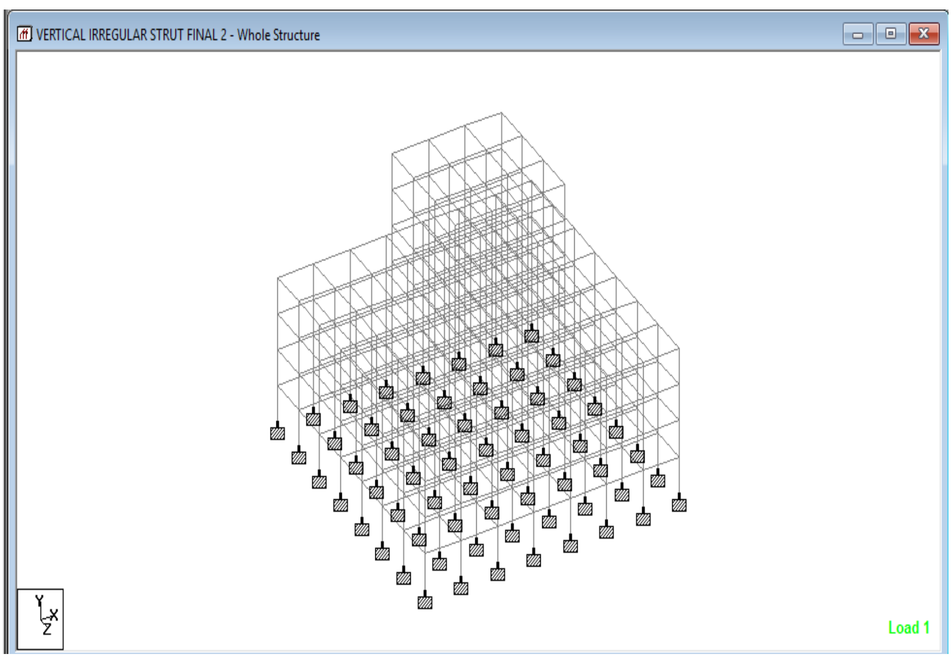

Fig. 3.2: Model of irregular building

3.3 Static analysis of regular structure

Table 3.2 Parameters and calculations of regular structure

S.NO	PARAMETERS	CALCULATION
1	Effective weight at each floor will be	4+2+0.25*3=6.75(KN/M^2)
2	Effective weight at roof	4(KN/M^2)
3	Total length of beams at each floor	112*4=448M
4	Total weight of beams at each floor	0.3*0.3*448*25=1008KN
5	Total length of columns at each floor	64*2.7=172.8M
6	Total weight of columns at each floor	0.3*0.3*172.8*25=388.8KN
7	Total weight of columns at roof	388.8/2=194.4KN
8	Plan area	28*28=784M^2
9	Equivalent load at roof level	4*784+1008+194.4=4338.4KN
10	Equivalent load at other floors	6.75*784+1008+388.8=6688.8KN

3.4 Static analysis of irregular structure:

Table 3.3: The seismic parameters and calculations of irregular structure

S.NO	PARAMETERS	CALCULATION
1	Effective weight at each floor will be	4+2+0.25*3=6.75(KN/M^2)
2	Effective weight at roof	4(KN/M^2)
3	Total length of beams at each storey from ground to 4th storey	112*4=448M

4	Total weight of beams at each storey from ground to 4th storey	0.3*0.3*448*25=1008KN
5	Total length of beams at each storey from 5th to 8th storey	24*4=96M
6	Total weight of beams at each storey from 5th to 8th storey	0.3*0.3*96*25=216KN
7	Total length of columns at each storey from ground to 4th storey	64*2.7=172.8M
6	Total weight of columns at each storey from ground to 4th storey	0.3*0.3*172.8*25=388.8KN
7	Total length of columns at each storey from 5th to 8th storey	16*2.7=43.2M
8	Total weight of columns at each storey from 5th to 7th storey	0.3*0.3*2.7*16*25=97.2KN
9	Total weight of columns at 8th storey	97.2/2=48.6KN
10	Plan area of each storey from ground to 4th storey	28*28=784M^2
11	Plan area of each storey from 5th to 8th storey	12*12=144M^2
12	Equivalent load at roof level	4*144+216+48.6=840.6KN
9	Equivalent load of each storey from ground to 4th storey	6.75*784+1008+388.8=6688.8KN
10	Equivalent load of each storey from 5th to 7th storey	6.75*144+216+97.2=1285.2KN

11	Design horizontal seismic coefficient	A_Z=Z/2*S_a/g*I/R=0.24/2*2.5*1/5=0.060
12	Base shear	$V_{B=}A_h$ W=0.060*31451.4=1887.084KN
13	Seismic weight	4*6688.8+3*1285.2+840.6=31451.4KN

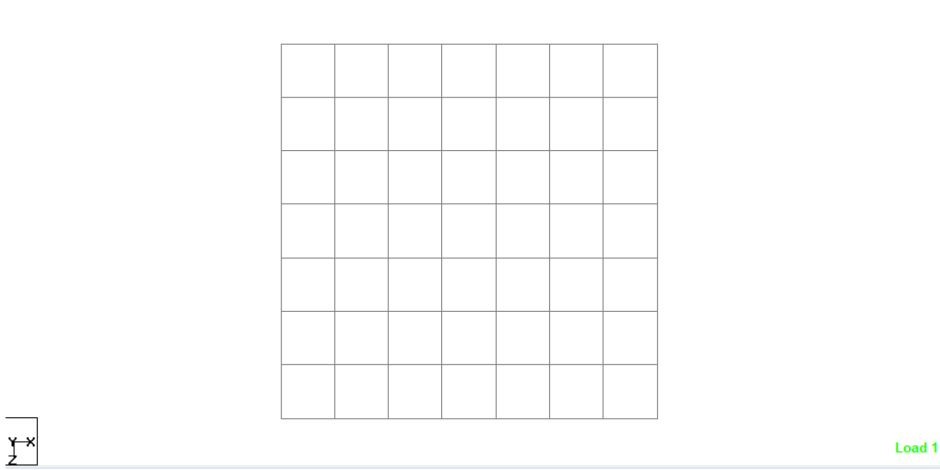

Fig.3.3: Plan of the 4th floor

Table3.4: Parameters and loads of 5th storey

PARAMETERS	LOADS
The dead load per unit area of floor which consists of floor slab, finishes etc.	4KN/M^2
Weight of partitions on floor is	2KN/M^2
Live load	3KN/M^2
Effective weight of each floor would be	4+2+3*0.25=6.75KN/M^2
Number of beam	112
Total length of beams each of 4m is	448
Total Weight of beams	(0.3*0.3*448*25) =1008KN
Weight of 64 columns at each floor	(0.3*0.3*2.4*25*64) =345.6KN
Plan area of building	(28M*28M) =784M^2

Total equivalent load at each floor	(6.75*784+1008+345.6) =6645.6KN
Therefore, seismic weight at 4th floor	=6645.6KN
Therefore, seismic weight at 4th floor	=6645.6KN

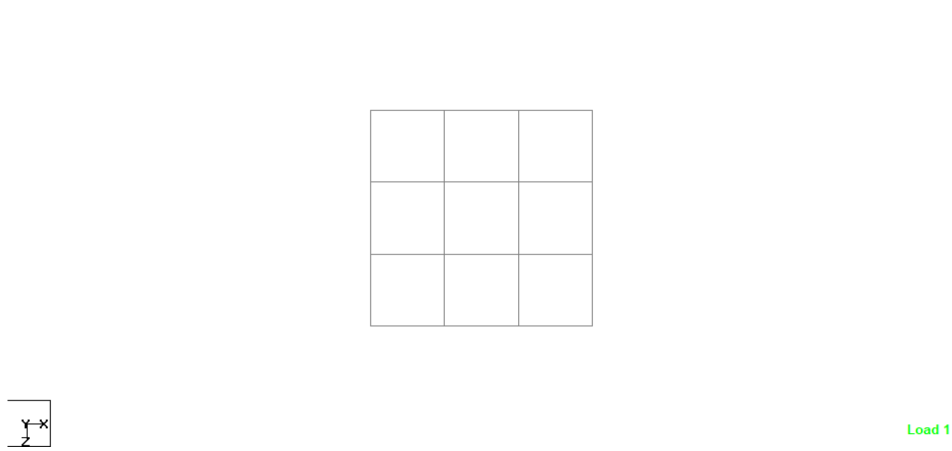

Fig.3.4: The plan of the 5th storey of the building

Table 3.5: The parameters of 5th storey

PARAMETERS	LOADS
The dead load per unit area of floor which consists of floor slab, finishes etc.	= 4KN/M^2
Weight of partitions on floor is	=2KN/M^2
Live load	=3KN/M^2
Effective weight on the floor will be	(4+2+0.25*3) =6.75KN/M^2
Number of beams	=24
Total length of beams each of 4m is	=96M
Total Weight of beams	(0.3*0.3*96*25) =216KN
Weight of 16 columns of 5th storey	(0.3*0.3*2.4*25*16) =86.4KN
Plan area of 5th storey	(12M*12M) =144M^2

Total equivalent load of 5^{th} storey	(6.75*144+216+86.4) =1274.4KN
Therefore, seismic weight at 5^{th} storey	=1274.4KN

Seismic weight of 4^{th} storey is 6645.6KN which is greater than 200% of 5^{th} storey. Hence the mass irregularity exists.

3.6 Mode Shapes of regular structure: -Mode shape oscillation associated with a natural period of a building is the deformed shape of the building when shaken at the natural period. Hence a building has as many mode shapes as the number of natural periods. For a building, there are infinite number of natural period**.** Fundamental and two higher translational modes of oscillation along X-direction of a multi-storey building. First modes shape has one zero crossing of the un-deformed position, second two and third three zero crossing.

There are three basic modes of oscillation. Namely pure translational along X-direction, pure translational along Y-direction and pure rotation about Z-axis. Regular buildings have these pure mode shapes. regular buildings too, care should be taken to locate and size the structural elements such as torsional and mixed modes of oscillation do not participate much in the overall oscillatory motion of building.one way of avoiding torsional modes to be the earlier modes of oscillation in buildings is increasing the torsional stiffness of building. This is achieved by adding in-plane stiffness in the vertical plane in select bays along the perimeter of the building.

3.6.1 Factors influencing Mode Shapes: - Overall geometry of building governs the mode shape, in addition to that geometric and material properties of structural members, and connections between the structural members and the ground at the base of the building also influences mode shape. Buildings exhibit flexural mode shape, shear mode shape, or a combination of these depending on the above-mentioned factors.

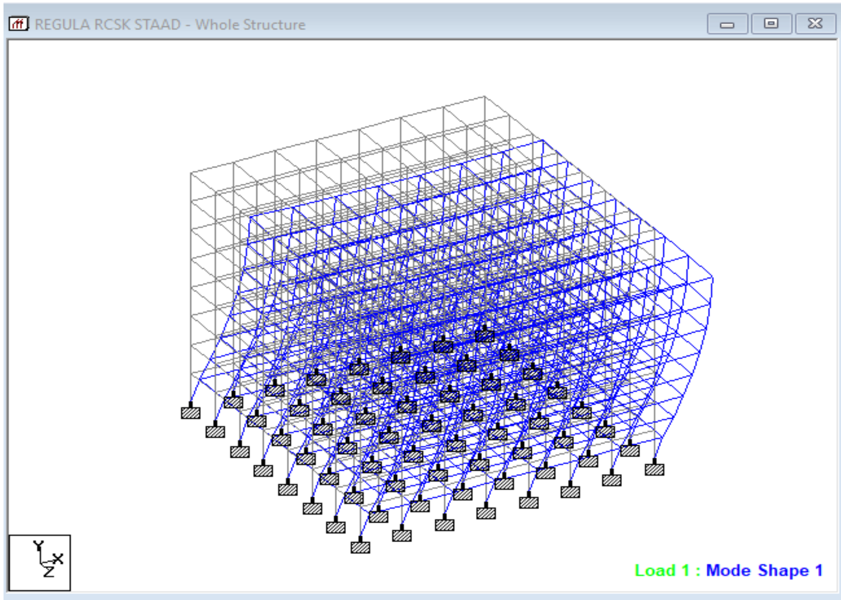

Fig.3.5: The 3D view of mode shape 1with time period 2.308sec

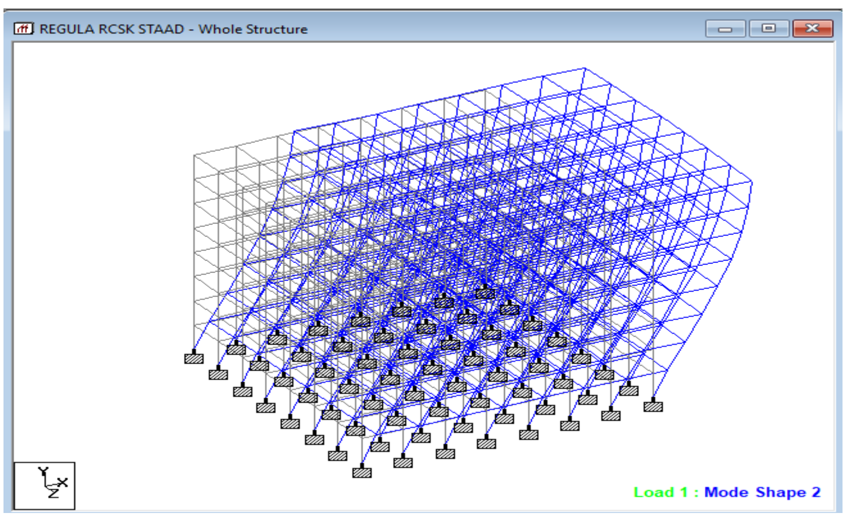

Fig.3.6: The 3D view of mode shape 2 with time period 2.308sec

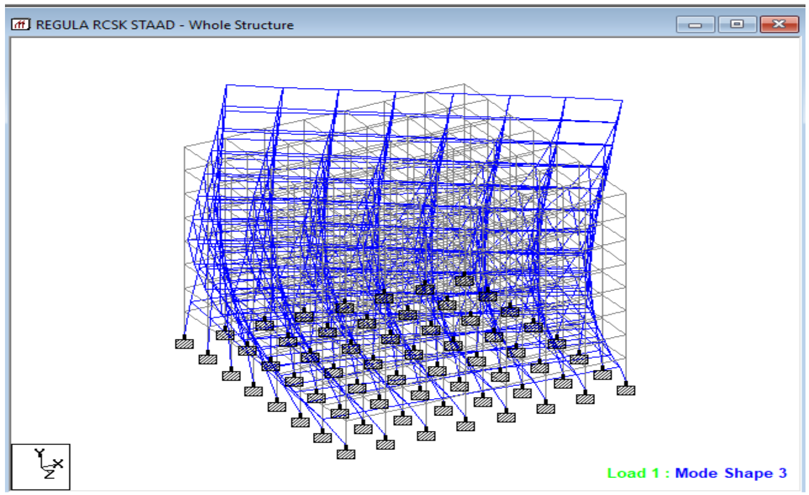

Fig.3.7: The 3D view of mode shape 3 with time period 2.150sec

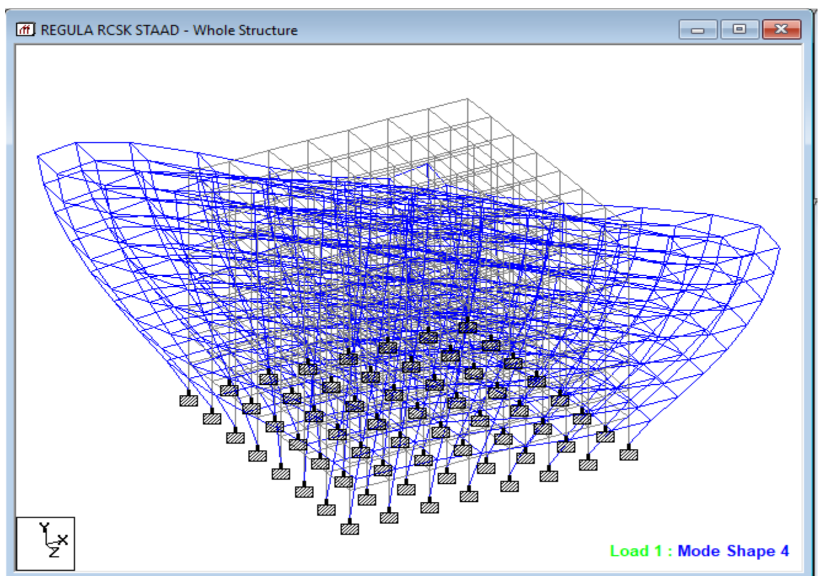

Fig.3.8:The 3D view of mode shape 4 with time period 1.071sec

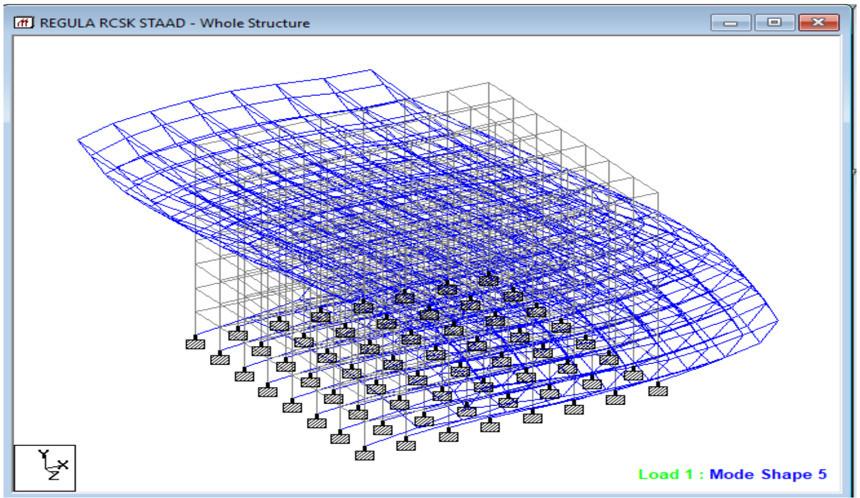

Fig.3.9: The 3D view of mode shape 5 with time period 0.771 sec

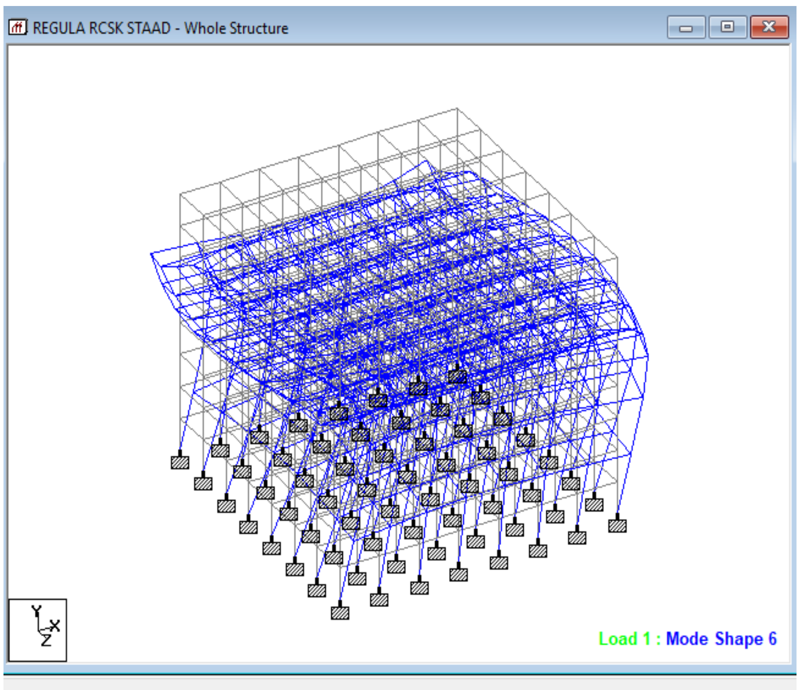

Fig.3.10: The 3D view of mode shape 6 with time period 0.771 sec

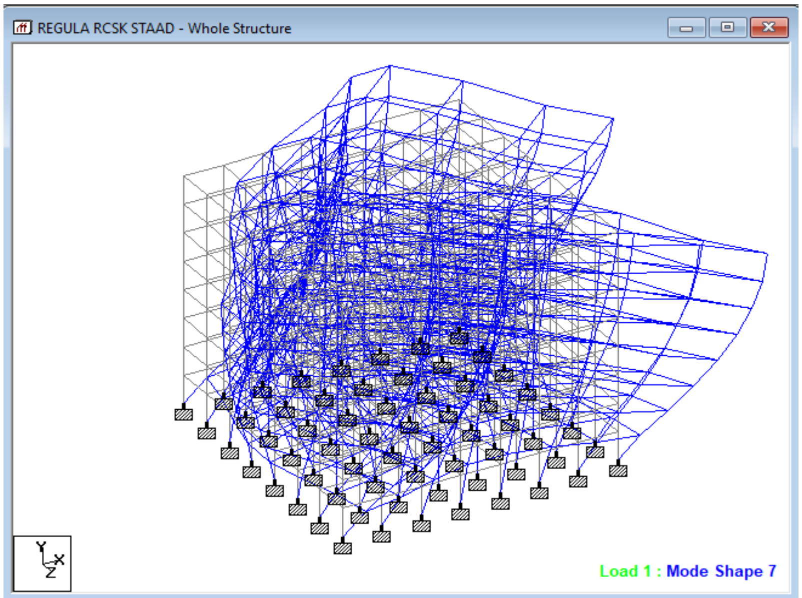

Fig.3.11: Shows the mode shape 7 with the time period of 0.740 sec

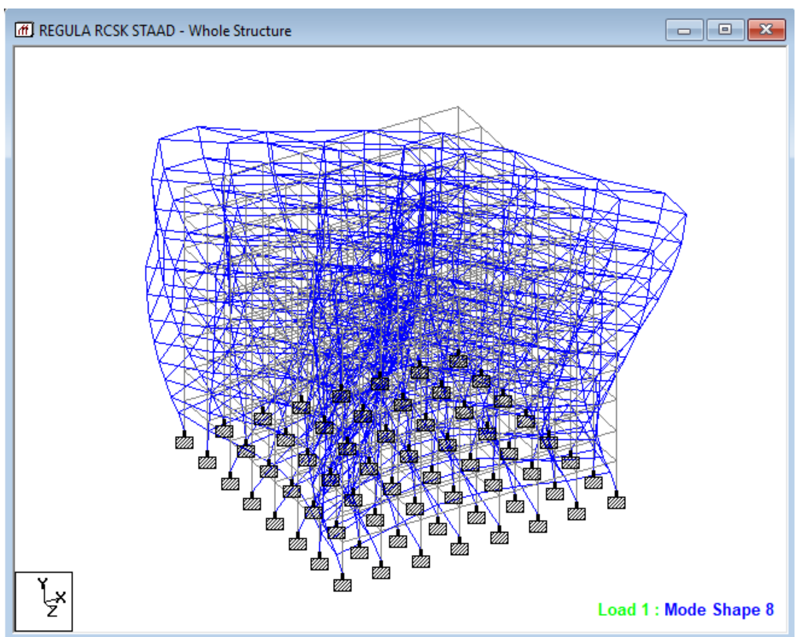

Fig.3.12: Shows the mode shape 8 with time period of 0.740 sec

The net modal effect of 4and 8 are zeo because of their mode shape.for the 4^{th} mode left side effect should be equal to right side effect.so the net effect is equal to zero.for the 8^{th} mode mode shape is distributed in all the direction so the net effect is equal to zero.

3.7 Mode shapes of irregular structures: -

Generally irregular buildings i.e buildings that have irregular geometry, non-uniform distribution of mass and stiffness in plan along the height have mode shapes that are a mixture of translational along X-direction, pure tractional along Y-direction and pure rotation about z-axis. Of pure mode shapes. Each of these mode shapes is independent, indicating it cannot be obtained by combining any or all of the other mode shapes. The overall response of abuilding is the sum of the responses of all its modes. The contributions of different modes of oscillation vary. Usually contribution of some modes dominates.

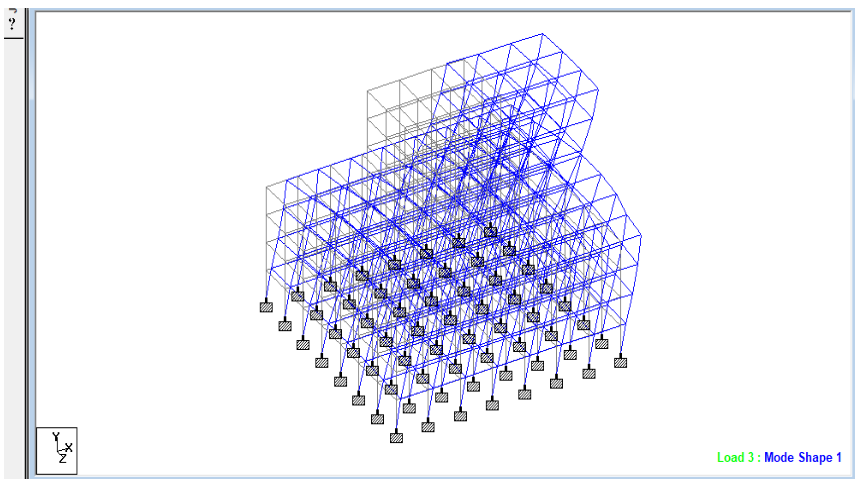

Fig.3.13: Mode shape 1 of irregular structure with time period of 2.177 sec

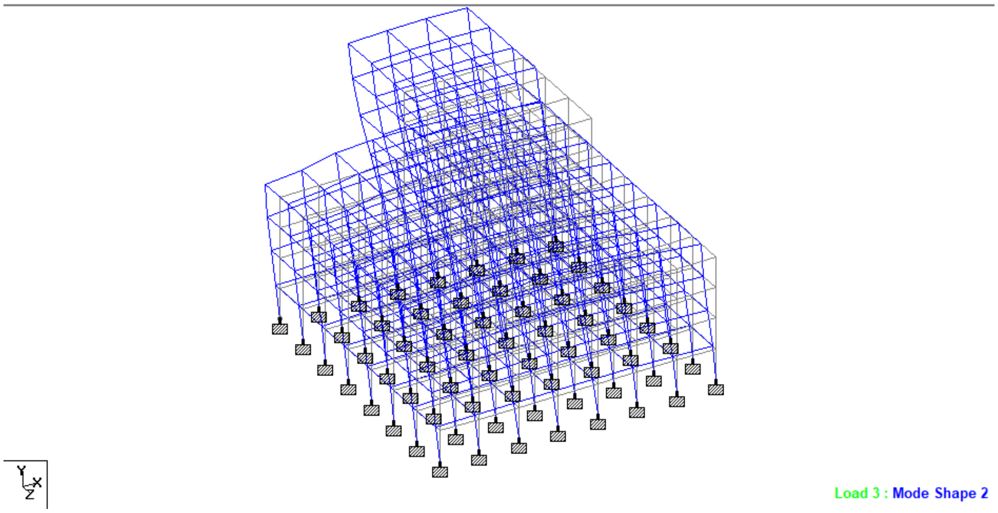

Fig.3.14: Mode shape 2 of irregular structure with time period 1.95 sec

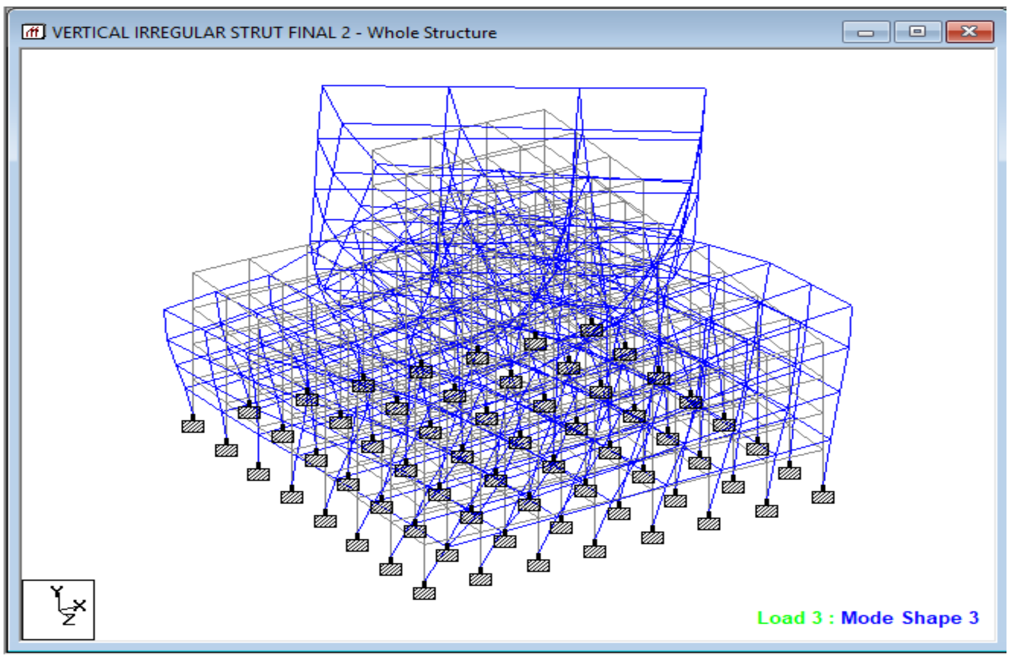

Fig.3.15: Mode shape 3 of irregular structure with time period 1.614 sec

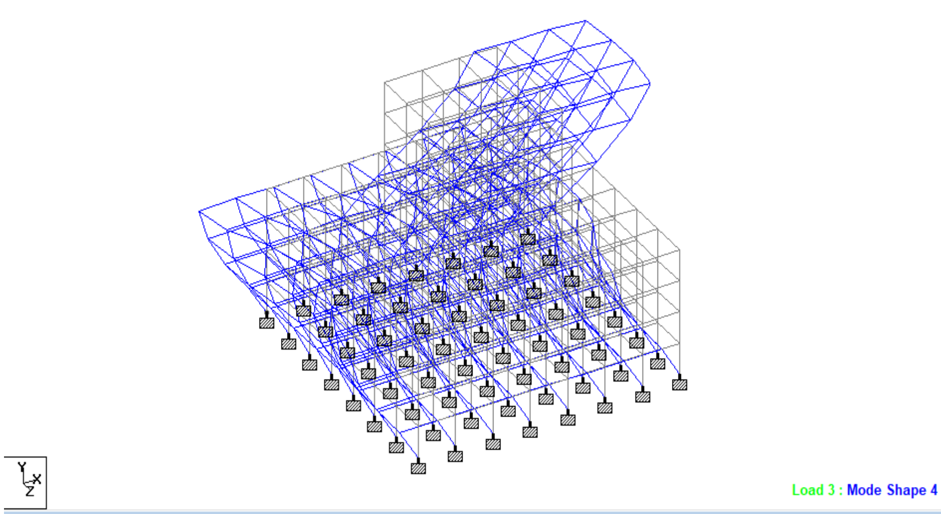

Fig.3.16: Mode shape 4 of irregular structure with time period 1.20 sec

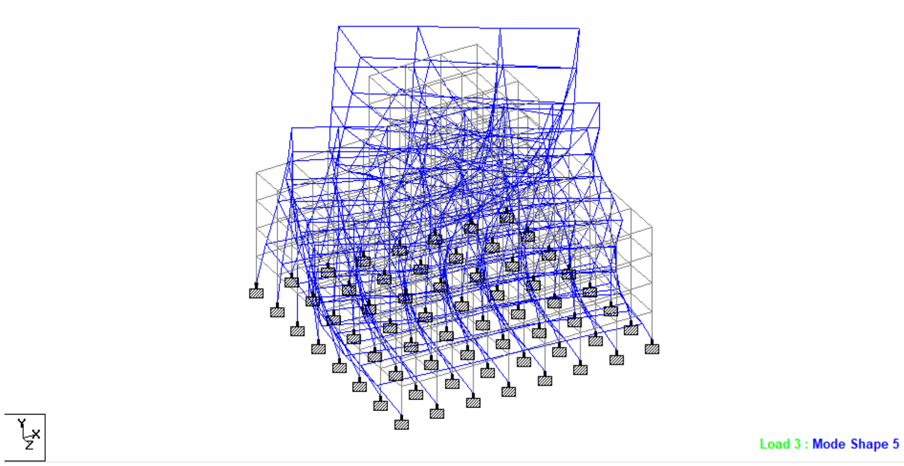

Fig.3.17: Mode shape 5 of irregular structure with time period 1.19 sec

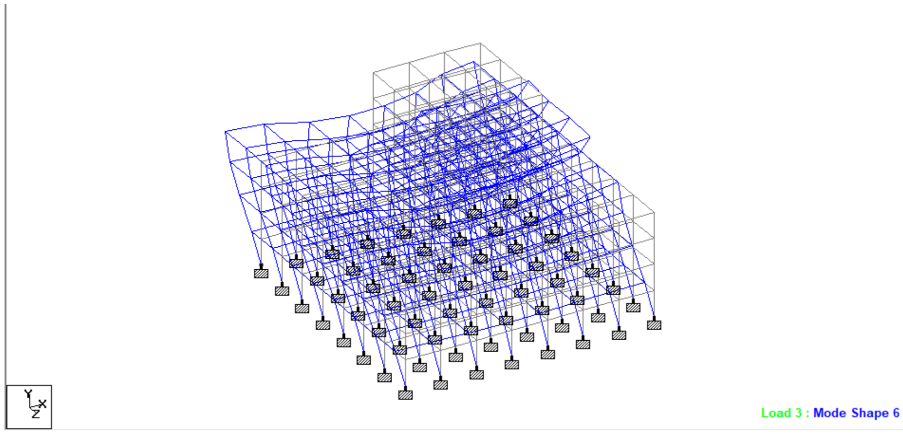

Fig.3.18: Mode shape 6 of irregular structure with time period of 1.089 sec

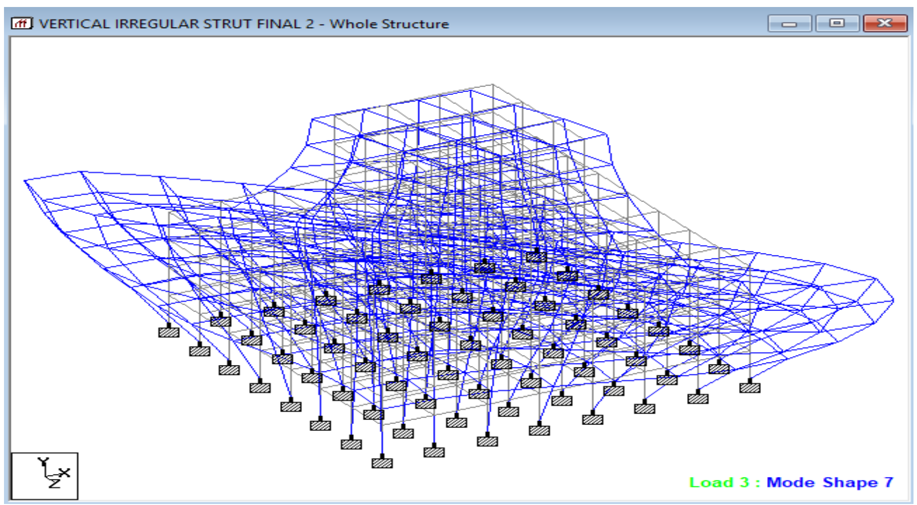

Fig.3.19: Mode shape 7 with time period of 0.972 sec

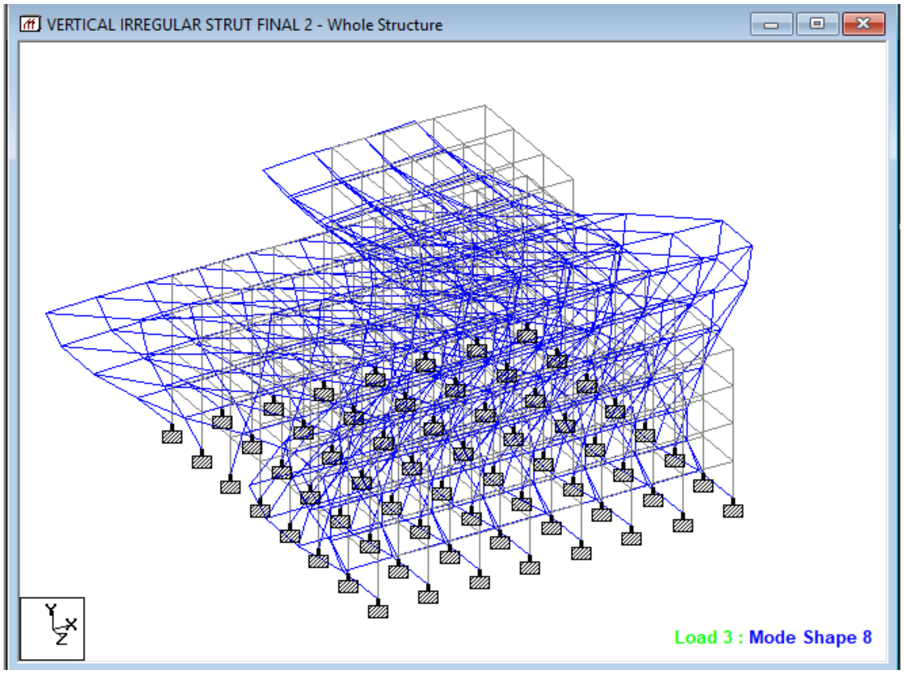

Fig.3.20: Mode shape 8 with time period of 0.792 sec

From the above observation mode shape 3 and 5 are torsional modes. And from the above observation the net effect of modes 3 and 7 are zero.

3.8 Mass participation results for regular buildings

3.6 Table: Mass participation results for regular building

mode	mass participation x	mass participation along z
1	0	83.63
2	83.63	0
3	0	0
4	0	0
5	4.76	4.76
6	4.76	4.76
7	0.01	0.01
8	0.01	0.01

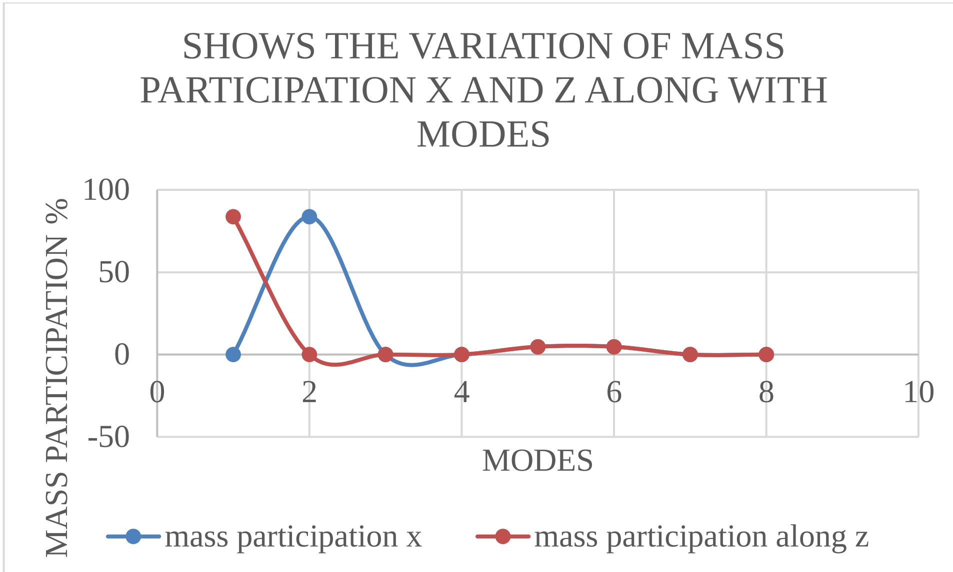

Fig. 3.21: The variation of mass participation with number of modes for regular model.

Mass participation along x- direction for the fundamental mode is zero. and it start increase and maximum for the 2nd mode and later start decreases for the remaining modes. mass participation along z-direction for the fundamental mode is maximum and it start decreases for the remaining modes.

Table 3.7: Mass participation factors for irregular buildings

MODE	MASS PARTICIPATION ALONG X-DIRECTION	MASS PARTICIPATION ALONG Z- DIRECTION
1	61.69	0
2	0	62.2
3	0	0
4	26.03	0
5	0	0
6	0	25.42
7	0	0
8	0.01	0

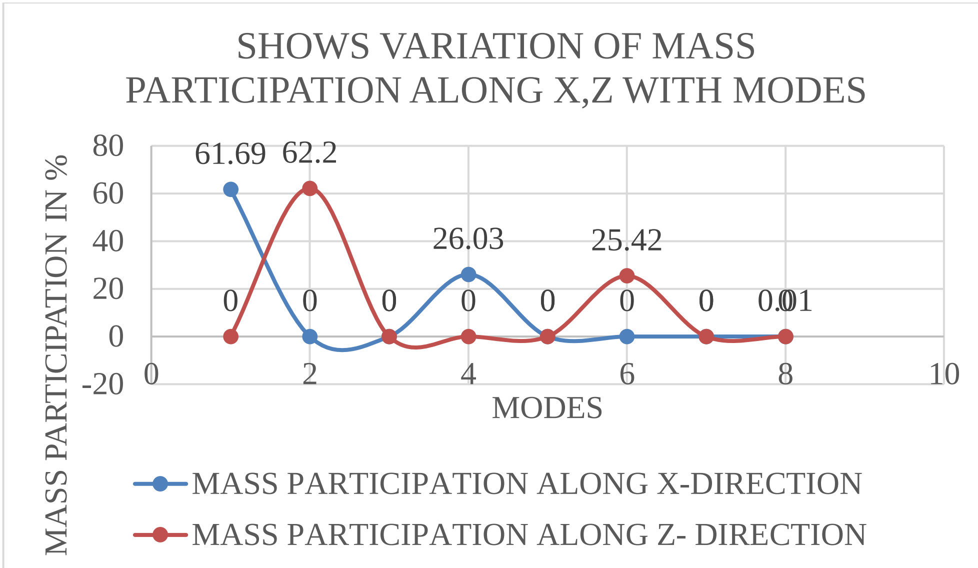

Fig.3.22**:** Mass participation for irregular building

From the above graph we can say that mass participation along x-direction is more for initial number of modes. Later it decreases for higher number of modes. Mass participation along z direction for fundamental mode is zero. later it starts increases for the first mode and decreases for the remaining modes.

If we compare the both mass participation graphs, for the first graph i.e. for regular building mass participation along x-direction is minimum compared to 2nd graph i.e. for irregular building for fundamental mode. if we compare the mass participation graphs, along z-direction mass participation for the regular building has more value than the mass participation of irregular building for fundamental modes of vibration.

3.9 Response spectrum analysis for regular structure:

Response spectra are curves plotted between maximum response of SDOF subjected to specified earthquake ground motion and its time period(or frequency). Response spectra can be interpreted as locus of maximum response of a SDOF system for given damping ratio. Response spectra thus helps in obtaining the peak structural response under the linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-resistant design of structures.

This approach allows the numerous methods of response of a building to be taken into account. This is required in numerous building codes for all except from extremely basic or exceptionally complex structures. The structural response can be characterized as a combination of numerous modes. Computer analysis can be utilized to determine these modes for a structure. For every mode, a response is obtained from the design spectrum, relating to the modal frequency and the modal mass, and afterward they are combined to estimate the total response of the structure. In this the magnitude of forces in all direction is calculated and then effects on the building are observed. Following are the sorts of combination methods:

- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes
- absolute - peak values are added together

The result of an RSM analysis from the response spectrum of a ground motion is normally not quite the same as that which would be calculated directly from a linear dynamic analysis using that ground motion directly, information of phase is lost during the process of generating the response spectrum.

In case of structures with large irregularity, too tall or of significance to a community in a disaster response, the response spectrum approach is no longer suitable, and more complex analysis is frequently required, for example, non-linear static or dynamic analysis.

Usually response of a SDOF system is determined for time domain or frequency domain analysis. and for a given time period of system maximum response is picked. This

Process is continued for all range of possible time periods of SDOF system. And final plot of maximum response on Y-axis and Time period on X-axis is required response spectrum graph.

Table 3.8: The different parameters for the response spectrum analysis

PARAMETERS	VALUES
ZONE	IV
SOIL TYPE	MEDIUM SOIL
IMPORTANCE FACTOR	1
STRUCTURE TYPE	SPECIAL MOMENT RESISTING FRAME
RESPONSE REDUCTION FACTOR	5
FUNDAMENTAL NATURAL PERIOD OF VIBRATION(T)	0.408
DAMPING RATIO	0.05
AVERAGE RESPONSE ACCELERATION COEFFICIENT	S_a/g =2.5

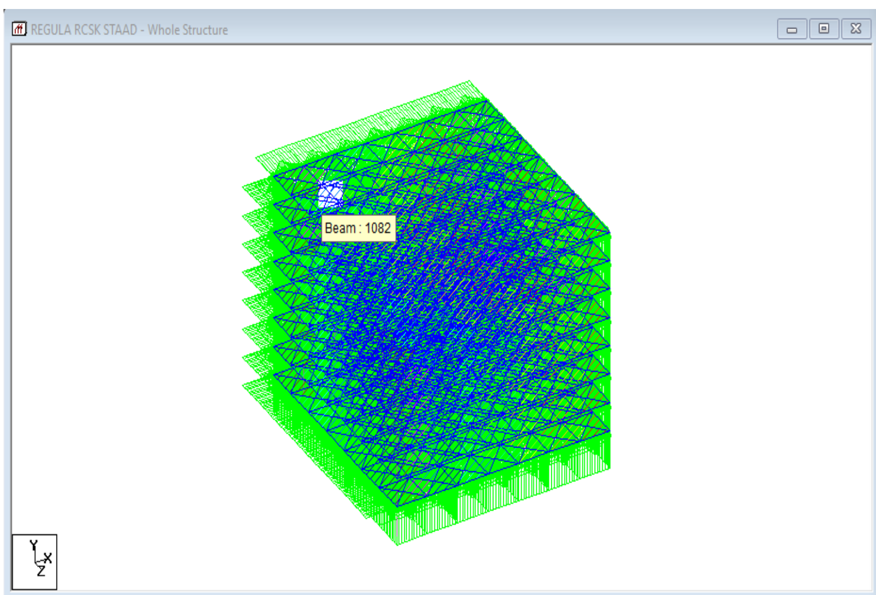

Fig.3.23: Regular Model of response spectrum load

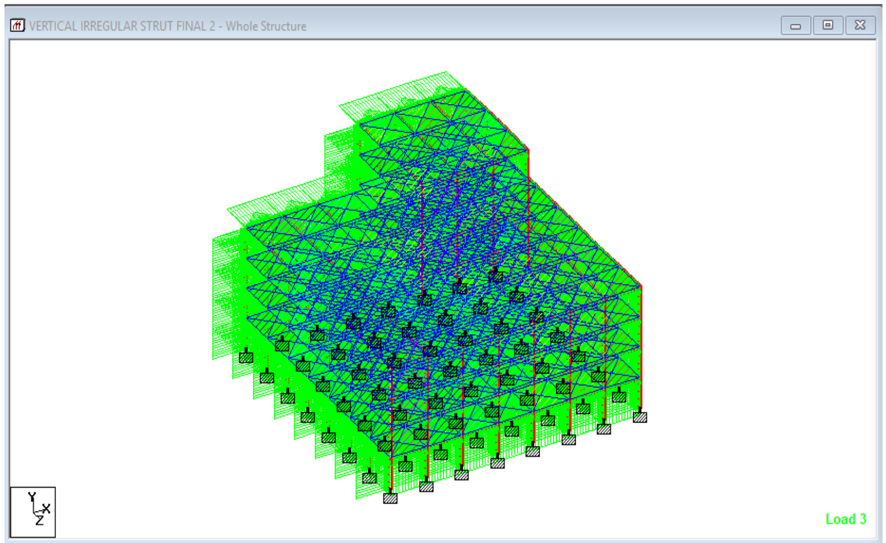

Fig.3.24: Irregular Model of response spectrum load

3.10 Push over analysis of structure using sap2000

Push-over analysis: It is a non-linear static analysis method where structure is subjected to constant gravity loading and a monotonic displacement-controlled lateral load pattern which continuously increases to estimate the strength capacity of the structure beyond its elastic limit up to its ultimate strength condition is reached.

Pushover analysis can help demonstrate how progressive failure in buildings really occurs and identify the mode of final failure. the method also predicts potential weak areas of the structure, by keeping track of the sequence of damages of each and every member of the structure(by use of what are called 'hinges they hold').Pushover analysis can be useful under two situations: when an existing structure has deficiencies in seismic resisting capacity, due to either omission of seismic design when built, or the structure becoming seismically inadequate due to later upgradation of seismic codes, is to be retrofitted to meet the (present) seismic demand, PA can show where the retrofitting is required and how much.

For a building in its design phase, PA results help scrutinize and fine tune the seismic design based on seismic analysis. Pushover analysis is widely used on predicting response of building structures subjected to severe earthquakes.

For a new building, Pushover Analysis is meant to be second stage analysis (The first stage being a conventional Seismic analysis-SA). This is because the details of reinforcement provided are required to calculate exact hinge properties (to be covered later). But one has to design the structure based on SA in order to obtain the reinforcement details. This means that Pushover analysis is meant to be a second stage analysis (the first stage being the conventional seismic analysis).

Thus, the emerging methodology to an accurate seismic design is:

1.First a conventional linear seismic analysis based on which a primary structural design is done:

2.Insertion of hinges determined based on design/detail and then

3.A pushover analysis is done, followed by

4.Modification of the design and detailing, wherever necessary, based on the latter analysis.

5. The above steps may have to be repeated, if required

3.10.1 STEPS FOR PERFORMANCE OF NON-LINEAR STATIC ANALYSIS USING SAP-2000

STEP 1 Linear analysis:

- Design the model by giving all the required parameters. Perform linear analysis using expected strength and modified safety factors.
- Go to define command change the number of modes. And after this in the define command go to function option and
- Go to response spectrum option give the required values according to is1893-2002 code.

STEP2 Define New Load Case of Gravity Loads:

- Go to Define >Load Case>Add New Load Case consisting of Gravity loads (i.e dead load and % of live load). Add EQX and EQZ load cases.

- This load case consists of force-controlled loads and load application type should be full load.
- In loads applied edit box include all dead loads and % of live loads.
- Select Load Case Type>Static, Analysis Type>Nonlinear and Geometric Non-linearity Parameters as P-Delta.

STEP-3 Assignment of Hinges to Frame Elements

- Select all beams in the model. Go to Assign>Frame>Hinges. The hinge form will appear.
- Add hinges to the selected beams the hinge type form will appear in the box.
- The hinges should be assigned at both the ends which means at relative distance of 0 and 1. the hinge type is M3 for beams.
- In similar manner assign hinges to all columns by repating steps as previously done for beams the only difference is that column should be assigned P-M2-M3 hinges instead of M3 hinges in beams.
- And this run the models for the required load cases.

STEP-4 Define PUSHOVER load case

- Go to Define>Load case>Add New Load Case>Push consisting of load in proportion to the fundamental mode. This load case is deformation-controlled load case.
- Select Load Case Type>Static, Analysis Type>Nonlinear and Geometric Non-linearity Parameters as P-Delta.
- This load case should be started from a previous load case Gravity since gravity load will always be acting on the structure.
- Select Load Applied proportional to Mode in the considered direction of the analysis. The scale factor for this load case should be kept equal to 1.
- In pushover load case for other parameters, to modify the displacement up to which the force deformation curve needs to be monitored click Modify and the load application control for non-linear static analysis form will appear.
- In non-linear load application control parameters Load application should be Displacement control with monitored displacement. Generally, the monitored

displacement is kept equal to 2% of the height of the building. This displacement should be monitored in the considered direction of analysis (i.e either U1 or U2 degree of freedom).the joint at which the force deformation curve is monitored is generally taken as the Centre of mass of the building.

- In pushover load case for other parameters, to modify the steps at which results needs to be saved click Modify the results saved for non-linear static load case form will appear. In this form Multiple steps should be selected in order to save the results at the intermediate steps. In this form for each stage minimum and maximum saved steps should be kept 1000 to 5000 in order to avoid solution converge.
- In pushover load case for other parameters, the non-linear parameters should be by Default. If convergence problem occurs than Number of Null steps and number of constant stiffness iteration should be increased.

STEP-4 RUN ANALYSIS

- While running the analysis the analysis is important to run the modal and gravity analysis with pushover load case takes stiffness from gravity load case and mode shape from modal load case
- After completing the analysis, the analysis complete form will appear.
- The pushover analysis is a non-linear static analysis so depending upon system configuration it takes time to complete analysis.

Chapter 4
Results and discussion

Table 4.1: Peak storey shear of regular structure

LEVEL IN m	PEAK STOREY SHEAR IN X DIRECTION IN KN	PEAK STOREY SHEAR IN Z-DIRECTION IN KN
24	9661.7	9661.78
21	17704.16	17704.16
18	23215.13	23215.13
15	26743.46	26743.46
12	29778.83	29778.83
9	33263.21	33263.21
6	36536.76	36536.76
3	38216.6	38216.6
0	38216.6	38216.6

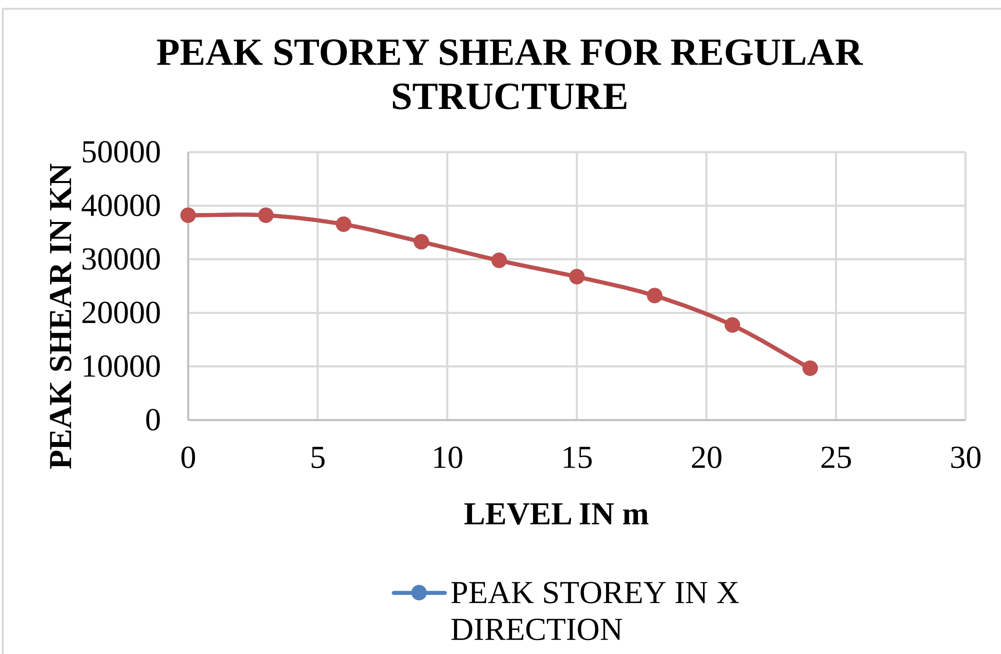

Fig. 4.25: Peak storey shear for regular structure in X and Z direction

Peak storey shear is maximum in the lower storey and it starts decreasing with increase in the storey. since the earthquake effect will have more for the ground storey. its effect reduces till the top floor so in the graph peak storey shear is maximum at ground floor and it decreased gradually to the top of the floor.

Table 4.2: Peak storey shear in X and Z direction

LEVEL IN m	PEAK STOREY SHEAR IN X-DIRECTION	PEAK STOREY SHEAR IN Z-DIRECTION
24	101.75	97.83
21	202.52	182.94
18	274.88	244.04
15	314.58	277.86
12	400.25	364.39
9	566.12	511.39
6	709.40	634.87
3	776.51	692.26
0	776.51	692.26

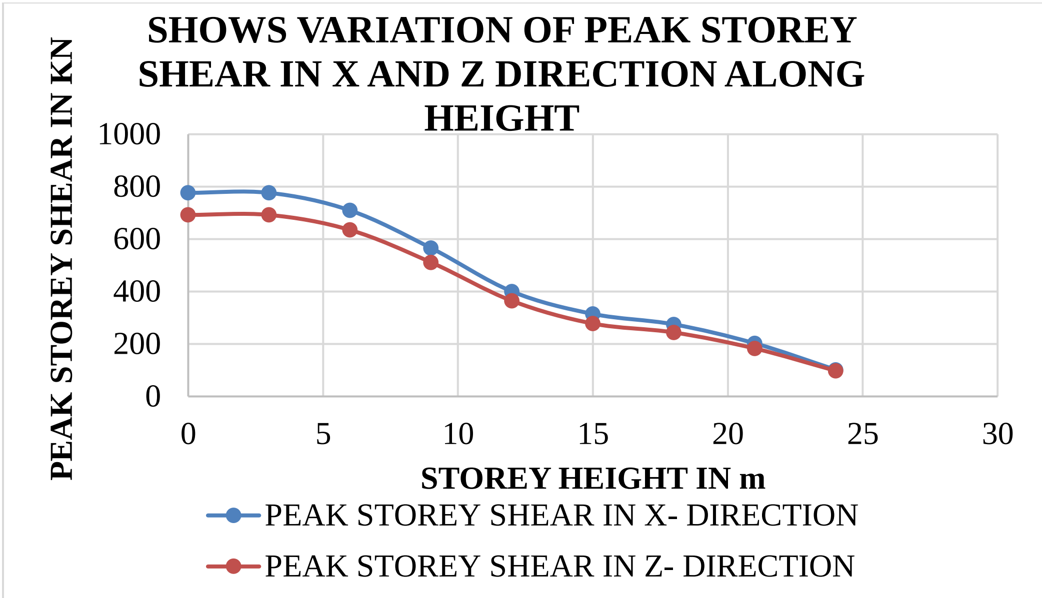

Fig.4.26: Variation of peak storey shear in X and Z direction along height

FOR REGULAR STRUCTURE:

Table 4.3: The variation of drift with height of storey

HEIGHT OF STOREY IN m	DRIFT IN mm
0	0
3	0.97198
6	1.21428
9	1.21424
12	1.16436
15	1.06955
18	0.91965
21	0.70041
24	0.40968

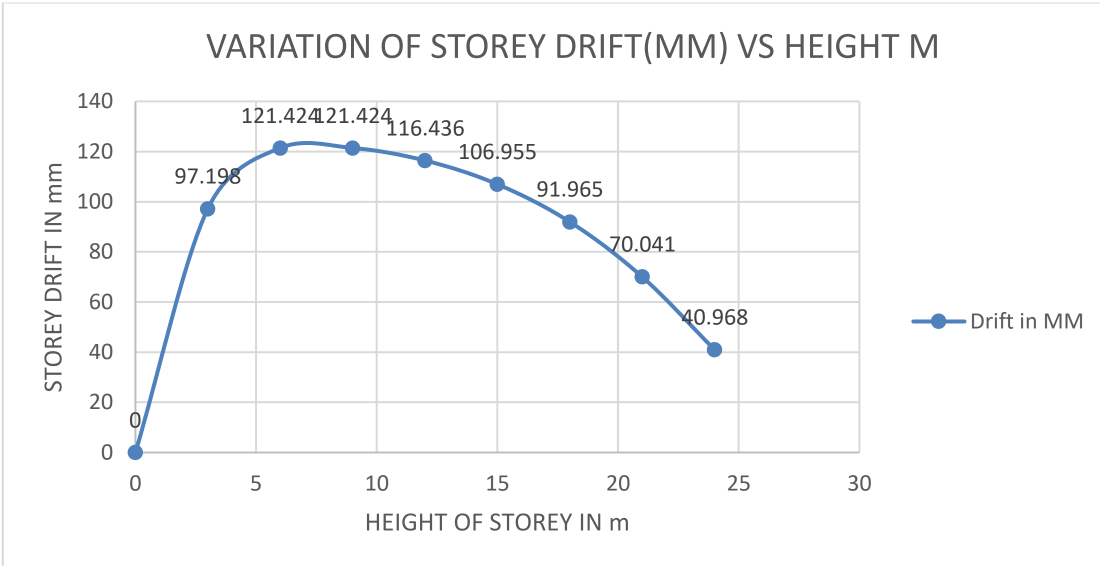

Fig. 4.27:Variation of Storey drift(mm) vs height of storey in (m) .Initially the storey drift was initially increased and then decreased.

Table 4.4: The variation of lateral load with height of storey

HEIGHT OF STOREY IN m	LATERAL LOAD IN KN
0	0
3	66.564
6	266.254
9	599.072
12	1065.02
15	1664.09
18	2396.29
21	3261.62
24	4156.75

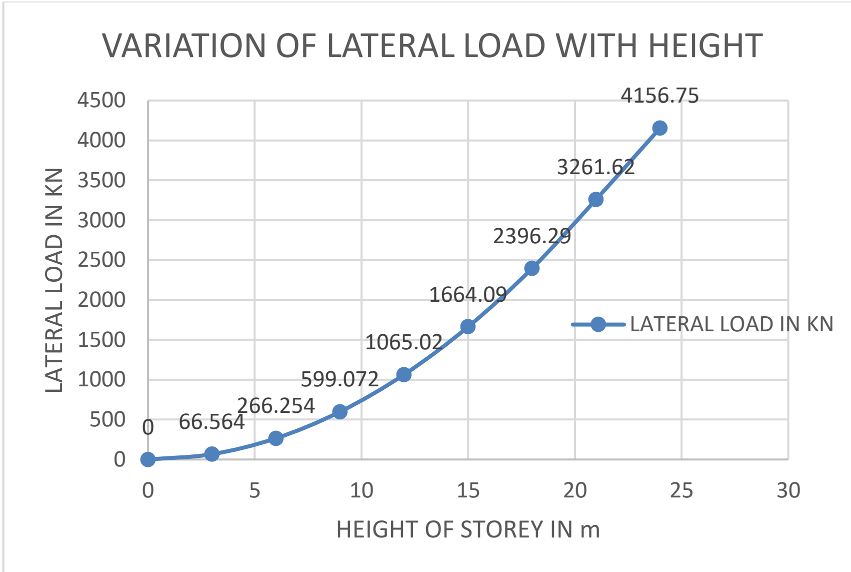

Fig.4.28:Variation of lateral load with height of building

With the increase in height lateral load also increases. Because the stiffness decreases with increase in the height of the building. For this we need to add shear wall to resist this lateral load.

For irregular structure

Table4.5 Storey drift vs Storey height

STOREY DRIFT IN mm	HEIGHT OF STOREY IN m
0	0
11.777	3
14.577	6
13.812	9
11.799	12
43.094	15
31.523	18
24.259	21
14.366	24

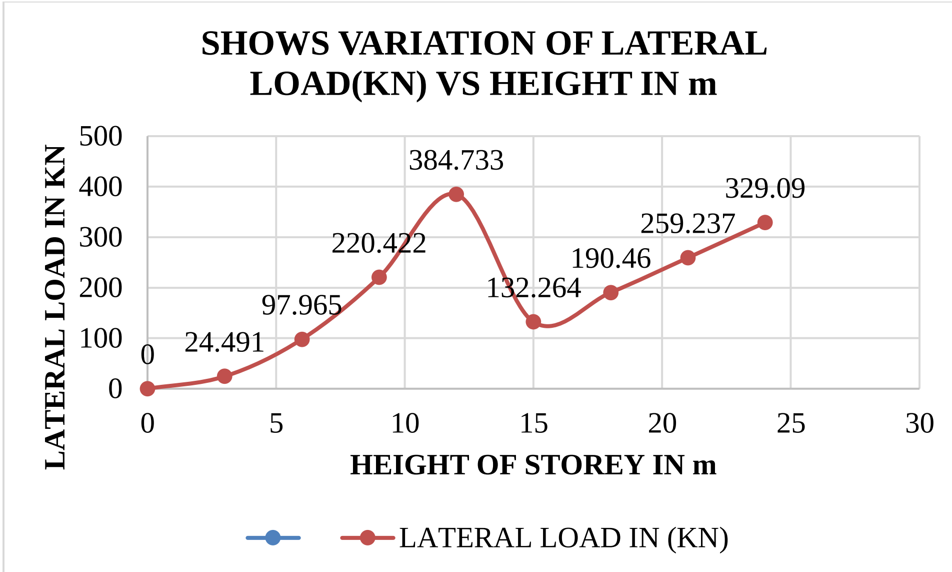

Fig.4.29: Variation of lateral load (KN) vs. height in M

In the above graph there was a large change in lateral load is observed between 4th and 5th storey in order to reduce this we have to use stiffeners.

Table 4.6: variation of lateral load with height of storey

LATERAL LOAD IN (KN)	HEIGHT OF STOREY IN m
0	0
24.491	3
97.965	6
220.422	9
384.733	12
132.264	15
190.46	18
259.237	21
329.09	24

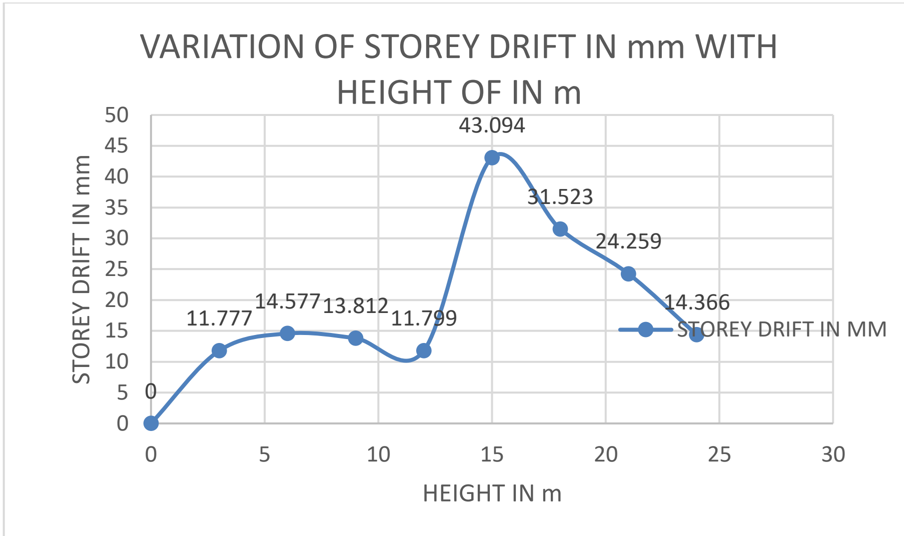

Fig.4.30: The variation of storey drift with the height of structure

In the above graph there is drastic variation in the storey drift.in order to reduce this we have to use shear walls or stiffener's or we have to redesign the column.

If we compare storey drift for regular and irregular structure in regular structure there is an gradual change where as in case of irregular structure there is an drastic change in the drift at irregularity which is given between 4th and 5th storey of the structure.so in order to reduce this we need to use stiffners or shear walls to reduce this drastic change in drift.in case of regular structure lateral load increases with height in case of irregular structure it drastically decreases and then increase.in order to avoid this we need to use stiffeners .

CHAPATER 5

CONCLUSION

In this thesis I have considered mass irregularity and vertical geometry irregularity. Both the regular and irregular frames have plan symmetry. response spectrum analysis was conducted on vertically irregular structure and regular structure and the results were compared. i.e.

- The mass irregular structures were ascertained to experience larger base shear than similar regular structures.
- for the regular structure the lateral load for 4th and 5th storey were 270.1248KN, 399.048KN and for irregular structure the lateral load for 4th and 5th storey were 509.51KN, 150. 966KN.this shows for regular structures lateral increases and for irregular structure at irregularity lateral loads decreases.
- Seismic weight of regular structure is 51160KN and for irregular structure is 31451.4KN.
- For irregular structure Seismic weight for 4th storey is 6645.6KN and for 5th storey is 1274.4KN the difference between these two stories is more than 200% of seismic weight which shows mass irregularity exists.
- From fig 4.25 and fig 4.26 it is concluded that peak storey shear is maximum for the lower storeys and it starts decreases for the higher storeys for both regular as well as irregular structures.
- In table no 15 shows the comparison of maximum displacements of regular and irregular structures.
- In this various mode shapes of regular and irregular structures were shown.
- In this regular and irregular model are developed and analyzed using SAP2000.
- Various pushover curves are obtained by the analysis of regular and irregular models using SAP2000.

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