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Analysis of Dynamic and Wind Response of Tall Building with Vertical Irregularity

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Abstract: Major structural collapses occur when a building is under the action of Dynamic Loads which includes both Earthquake and Wind loads. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. In the present work, "Effect Of Vertical Irregularity In Multi-Storied Buildings Under Dynamic Loads Using Linear Static Analysis", considering four types of 20- Storied 3-D frames (i.e., a symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from tenth floor, placed at corner, at the center and at edge of the plan respectively) it is focused to study their response using Linear Static Analysis.
Keywords: Dynamic loads, building, Vertical irregularity, Horizontal irregularity, strength, stiffness.

I. INTRODUCTION

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. 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 becomes more complicated. There are two 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.

A. Plan Irregularities

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.

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 considered 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 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.

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.

v) 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

Buildings are designed as per Design based earthquake, but the actual forces acting on the structure is far 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 objective in designing earthquake resistant structures is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake.

B. Criteria for Vertical Irregularities in Building Codes

In the earlier versions of IS 1893 (BIS, 1962, 1966, 1970, 1975, 1984), there was no mention of vertical irregularity in building frames. However, in the recent version of IS 1893 (Part 1)-2016 (BIS, 2016), irregular configuration of buildings has been defined explicitly. Five types of vertical irregularity have 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, 2016). 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 suggest dynamic analysis (which can be elastic time history analysis or elastic response spectrum analysis) to come up with design lateral force distribution for irregular structures rather than using equivalent lateral force (ELF) procedures.

C. Objectives

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 and irregular buildings using Equivalent static method.
2) To validate the result, Calculate design lateral force of regular building using equivalent static frame method and compare the result with using STADD-Pro.
3) To study two irregularities in structures namely mass and stiffness irregularities.
4) To study the structural response of the building models with respect to following aspects Fundamental time period of the building, Base shear, Storey displacement.
5) To determine the percentage variation of quantity of steel of various heights of Building.
6) To study the effect of wind on multistoried building with mass and stiffness irregularity.

II. NEED FOR RESEARCH

Irregular buildings constitute a large portion of the modern urban infrastructure. Structures are never perfectly regular and hence the designers routinely need to evaluate 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.

III. DESCRIPTION OF METHOD

In engineering problems there are some basic unknowns. If they are found, the behaviour of the entire structure can be predicted In a continuum, these unknowns are infinite. The finite element procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements and by expressing the unknown field variables 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. Thus in the finite element analysis the unknowns are the field variables of the nodal points. After selecting elements and nodal unknowns next step in finite element analysis is to assemble element properties for each element. For example, in solid mechanics, we have to find the force-displacement i.e. stiffness characteristics of each individual element. Mathematically this relationship is of the form.

A. Finite Element Analysis

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

Where $[k]e$ is element stiffness matrix, $\{\delta\}$ eis nodal displacement vector of the element and $\{F\}$ $e$is nodal force vector. The element of stiffness matrix kij represent the force in coordinate 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 solution of these simultaneous equations give the nodal unknowns.

Thus the various steps involved in the finite element analysis are:
1) Select suitable field variables and the elements.
2) Discretize the continua.
3) Select interpolation functions.
4) Find the element properties.
5) Assemble element properties to get global properties.
6) Impose the boundary conditions.
7) Solve the system equations to get the nodal unknowns.
8) Make the additional calculations to get the required values

B. Methods of Seismic Analysis of Building

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

C. Staad Pro

STAAD or (STAAD.Pro) is a structural analysis and design software application originally developed by Research Engineers International in 1997. In late 2005, Research Engineers International was bought by Bentley Systems.[1] HYPERLINK "https://en.wikipedia.org/wiki/STAAD"[2]

STAAD.Pro is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber & aluminum design codes. It can make use of various forms of analysis from the traditional static analysis to more recent analysis methods like p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis methods from time history analysis to response spectrum analysis. The response spectrum analysis feature is supported for both user defined spectra as well as a number of international code specified spectra.

IV. PROBLEM STATEMENT

Present research involves the study 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 building is considered to be fixed at the base. The building is modeled using relevant software. Model is studied for comparing base shear, storey shear and max. Storey displacement, shear in column. Also different model are study with reduction of column sizes up to top floor and floating column at various floor height. We also study effect of mass irregularity and stiffness in various height structures.

V. DESIGN STEEL STRUCTURE

A. Purlin Design

Purlins are those members in truss system which carrying the roof sheets and transferring load to rafters. It is normally placed perpendicular to the rafters and sag rods may be added.
The purlins are not necessary to be analyzed as complicated as the other structural members. The satisfaction of purlins is approached by the empirical rules suggested in cl 4.12.4.3 as:

- The slope of roof should less than 30^o from horizontal
- The loading on the purlin should substantially uniformly distributed. Not
- The limitations of section modulus Z about its axis parallel to the plane of the cladding, member dimensions D perpendicular to the plane of caldding, B parallel to the plane of cladding.

A plane truss is arranged all purlins on its nodes. With the following data
- Spacing between trusses = 3 m
- Weight of roof sheet, insulation and purlins (on slope) = 0.35 kN/m^2
- Self-weight of truss (on slope) = 0.20 kN/m^2
- Imposed load (on plan) = 0.75 kN/m^2
- Section Modulus of Purlins, $Z_p = W_P L/1800$

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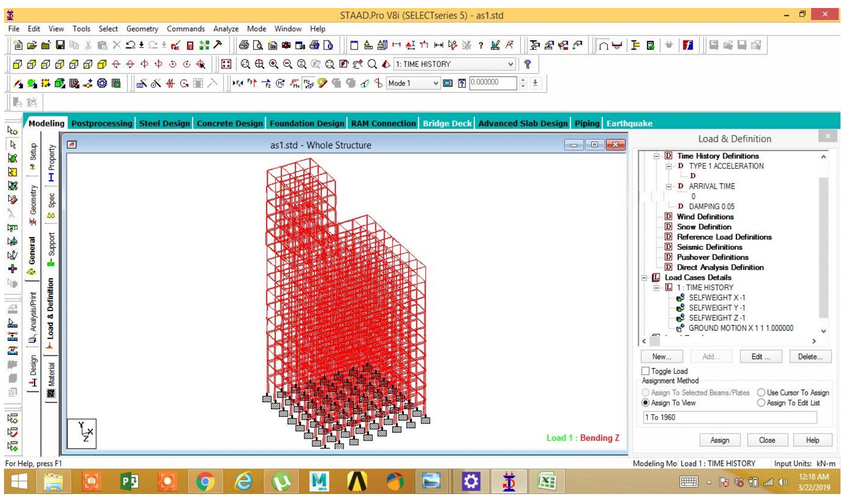
VI. RESULT AND DISCUSSION

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 discussed in detail with floor displacement figures. Results and figures are presented in this paper.

A. Results For Models Rcc

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

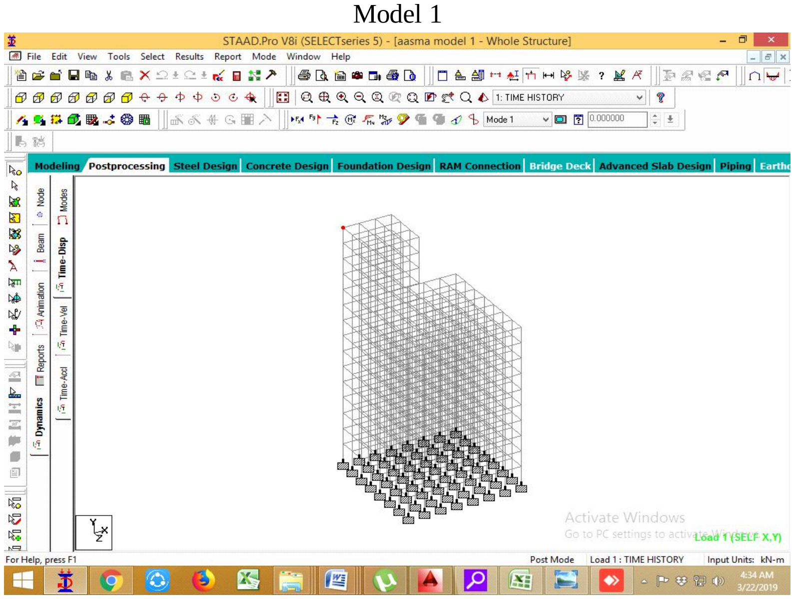
Model 1



B. Time History Analysis

Regular and various types of irregular buildings were analyzed using THA and the response of each irregular structure was compared with that of regular structure for IS code Ground motion. The IS code ground motion used for the analysis had PGA of 0.2g and duration of 40 seconds.

Model 1



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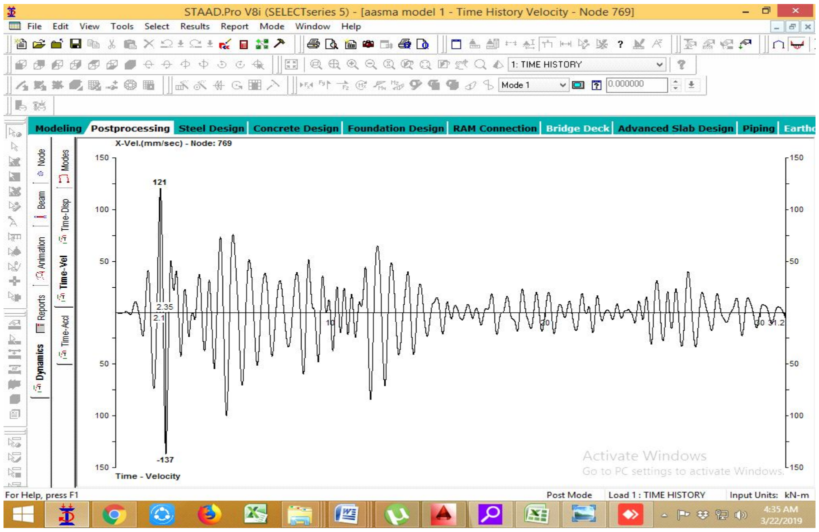

Model 1 time history analysis.

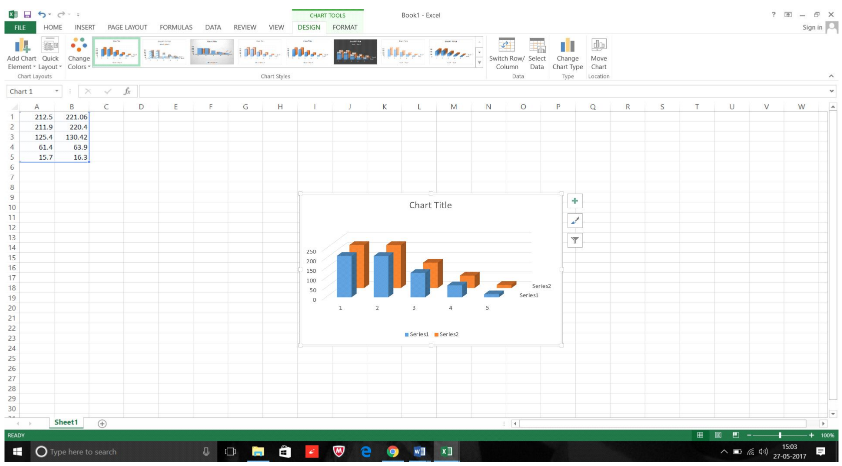

Chart. Graphical comparison of values of base shear

C. Graphs And Bar Charts

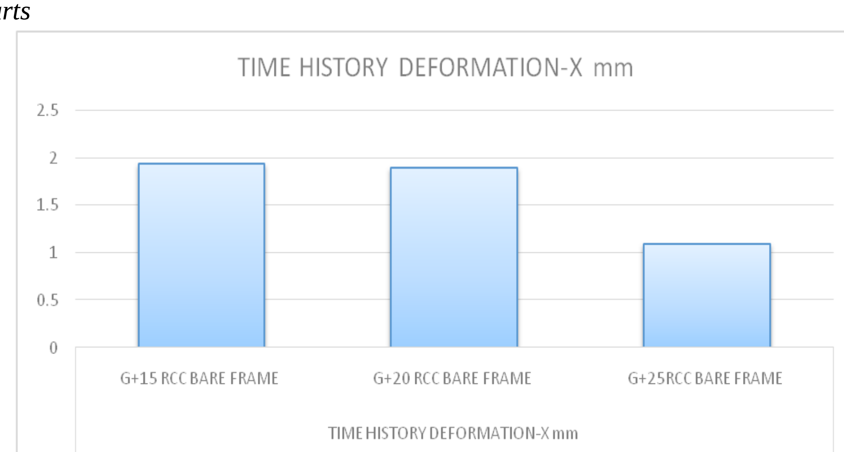

Chart. Time history deformation bar chart for EL CENTRO.

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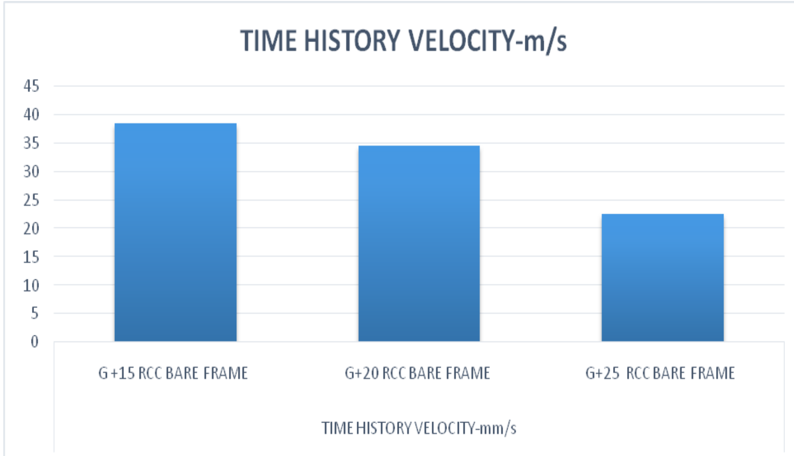

Chart. Time history velocity bar chart for EL CENTRO.

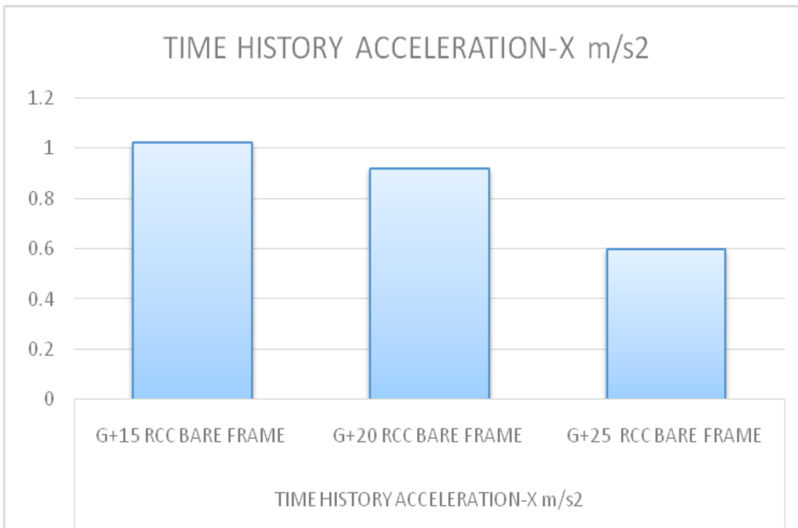

Chart. Time history acceleration bar chart for EL CENTRO

D. Comparative Dynamic Analysis

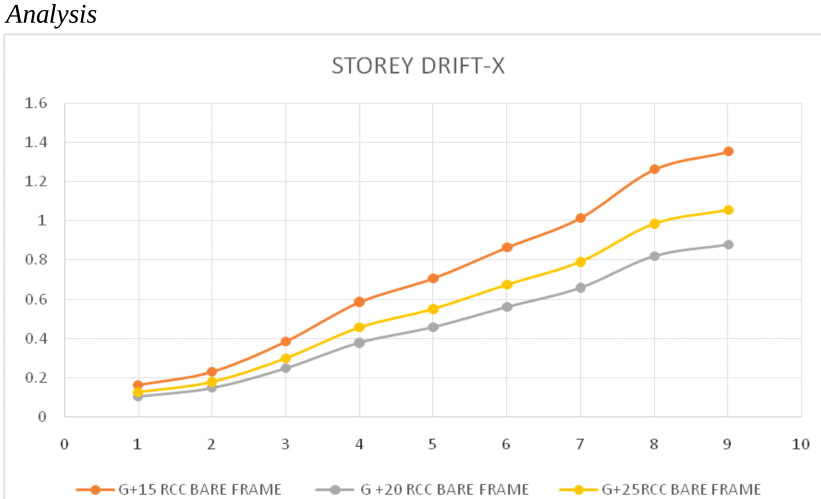

Chart. Storey drift graph for Rcc bare frames in X direction for EL CENTRO

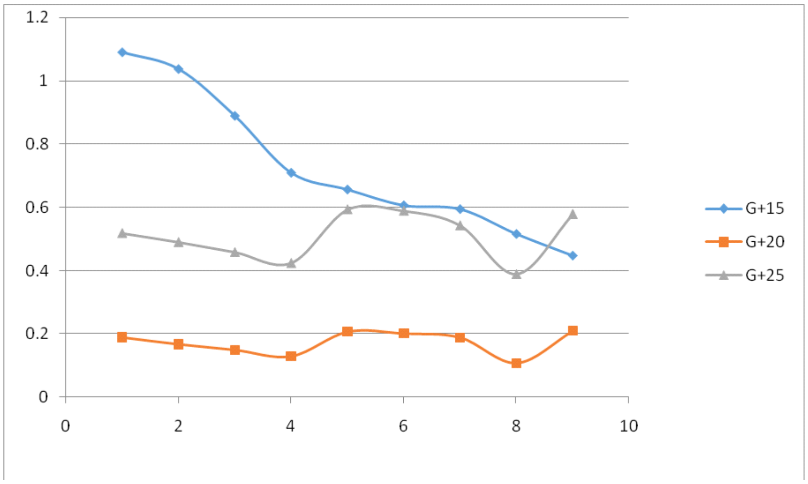

Chart. Storey drift graph for Rcc bare frames in X direction for BHUJ

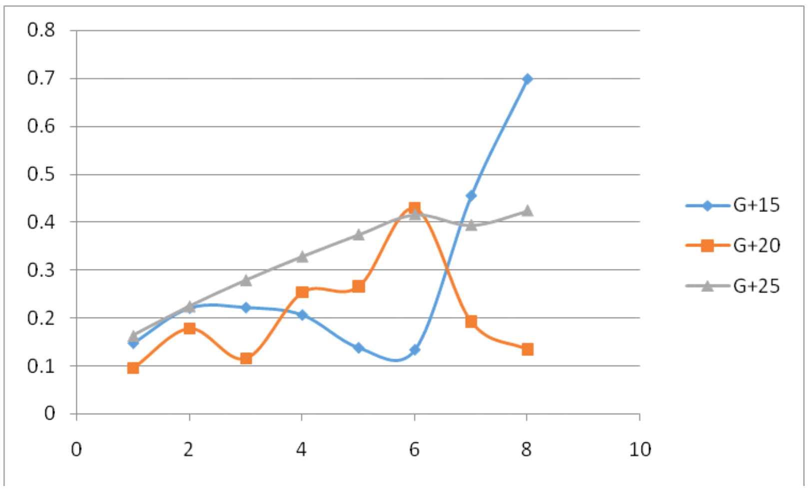

Chart. Storey drift graph for Rcc bare frames in Y direction for BHUJ

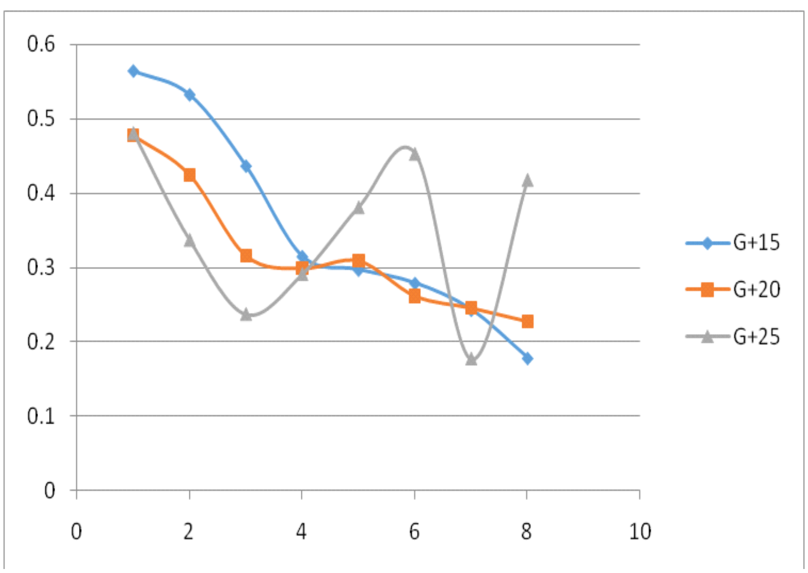

Chart. Storey drift graph for Rcc bare frames in X direction for KOYNA

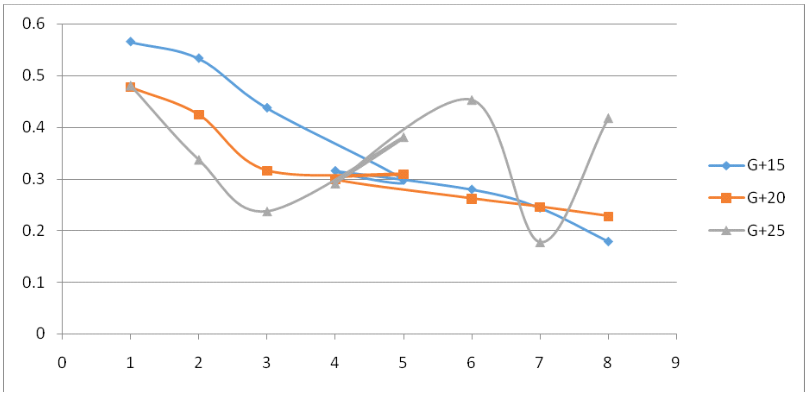

Chart. Storey drift graph for Rcc bare frames in Y direction for KOYNA.

VII. CONCLUSIONS

The main purpose of this study is to analyse plan irregular high rise building by STAAD Dynamic analysis has been carried out to know time period, natural frequency, deformations, displacements and floor responses by using +shaped model. The analysis include participation of 90% of the building mass for every principal horizontal direction of response as per IS 1893(Part-I)-2016 by complete Quadratic Combination (CQC).The time period for mode 1 is 0.3387 sec for mode 2 is0.3315 sec for mode 3 is 0.3215sec and for mode 4 and 5the time periods is 0.3173 sec and 0.2670 sec respectively. In the analysis high performance concrete with modern structural framings such as moment resisting frames are employed. The building is tested for distinct load combinations .

From above results it is observed that,

1) The storey shear force is maximum for the first storey and it decreases to minimum in the top storey.
2) It is observed that time history deformation for G+15 is greater than G+25 Rcc bare frame.
3) It is observed that time history velocity for G+15 is greater than G+20 Rcc bare frame.
4) It is observed that time history acceleration for G+15 is greater than G+20 Rcc bare frame.
5) It is observed that storey drift Rcc bare frame is more than G+15,G+20 than G+25 Rcc bare frame.
6) It is observed that storey drift Rcc bare frame is more than G+15,G+20 than G+25 Rcc bare frame.
7) It is observed that base shear for Rcc bare frame is more than G+15,G+20 than G+25 Rcc bare frame
8) It is observed that Natural frequency for model no 1 is more than model no 2 and model no 3.
9) The stiffness irregular structure experiences lesser base shear than similar regular structures.
10) The mass irregular structures experiences larger base shear than similar regular structures.
11) Vertical irregular structures can be designed accurately and economically for earthquake resistance building using STAAD.pro v8i.

According to THA results, the storey shear force was found to be maximum for the first storey and it decreased to minimum in the top storey in all cases. It was found that mass irregular building frames experience larger base shear than similar regular building frames. The stiffness irregular building experienced lesser base shear and has larger inter storey drifts. In case of mass irregular structure, Time History Analysis yielded slightly higher displacements for upper stories than that in regular building, whereas as we move down, lower stories showed higher displacements as compared to that in regular structures. In regular and stiffness irregular building (soft storey), it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher compared to respective stories in regular buildings.

VIII. FUTURE SCOPE

The importance of the configuration of a building was aptly summarized by Late Henry Degenkolb, a noted Earthquake Engineer of USA, as “If we have a poor configuration to start

With, all the engineer can do is to provide a band-aid-improve a basically poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much.” But with the extensive research work, the ultimate performance can be achieved even with poor configuration.

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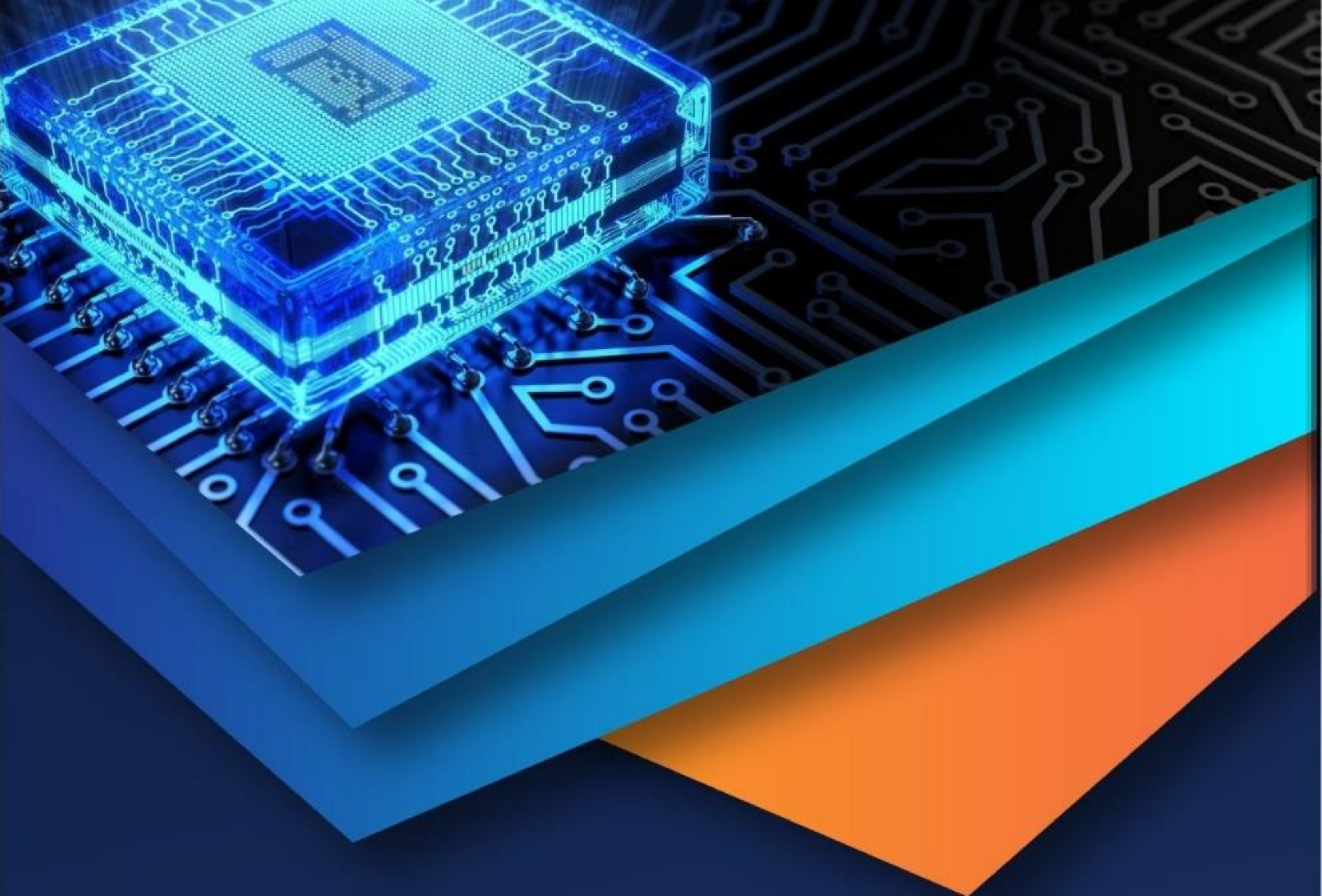

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