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ANALYSIS OF SYMMETRIC & ASYMMETRIC SHAPED G+6 STORIED RC FRAME STRUCTURE FOR EARTHQUAKE LOADING USING STAAD Pro.

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Abstract - *Structural analysis is mainly used for finding out the behavior of a structure when subjected to some action. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. since all these loads are dynamic including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency. Structural design of buildings for seismic loads is very important for structural safety during major ground motions. The recent earthquakes, in which many reinforced concrete structures have been severely damaged or collapsed, indicated the need for evaluating the Seismic performance buildings. In particular, the seismic rehabilitation of concrete structures in high seismicity areas is a matter of growing concern, so damage qualification of buildings must be identified and an acceptable level of safety must be determined. The aim of this paper is to study the seismic behavior of building of symmetrical and asymmetrical structure using STAAD Pro.*

Key Words: Earthquake Analysis, Static and Dynamic Loads, Seismic Coefficient Method, Response Spectrum Method, Time History Analysis etc.

1.INTRODUCTION

Today is the era of Performance Based Engineering philosophies in seismic design of Civil Engineering structures. Qualitative seismic design provisions require Structural Engineers to perform both static and dynamic analysis for the design of structures. However, given that seismic prediction is still far from becoming a reality but, it is very important to modify the prediction of the seismic behavior of existing structures. This is the reason why studies of Seismic Vulnerability of Buildings have been developed to evaluate the expected damage in the different types of buildings.

At present people are facing problems of land scarcity, cost of land. The population explosion and advent of industrial revolution led to the exodus of people from villages to urban areas i.e. construction of multi-storied buildings has become inevitable both for residential and as well as office purposes. The high raised structures are not properly designed for the resistance of lateral forces. It may cause to the complete failure of the structures. The earthquake resistance structures are designed based on the some factors. The factors are natural frequency of the structure, damping factor, type of foundation, importance of the building and ductility of the structure. The structures designed for ductility need to be designed for less lateral loads as it has better moment distribution qualities. This aspect is taken care of by response reduction factor R for different type of structure. For high performance, the building is designed as an SMRF. It needs to be designed only for lesser forces than it is designed as an OMRF.

1.1 Methods of Seismic Analysis

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. In the past the buildings were designed just 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 prevalent.

There are different types of earthquake analysis methods. Some of them used in the project are:

I. Equivalent Static Analysis
II. Response Spectrum Analysis
III. Time History Analysis

I. Equivalent Static Analysis: - All design against seismic loads must consider the equivalent linear static methods. It is to be done with an estimation of base shear load and its distribution on each story calculated by using formulas given in the code. Then the displacement demand of model must be checked with code limitation. Equivalent static analysis can therefore work well for low to medium-rise buildings. The equivalent static analysis procedure consists of the following steps:

a) Estimate the first mode response period of the building from the design response spectra.
b) Use the specific design response spectra to determine that the lateral base shear of the complete building is consistent with the level of post-elastic (ductility) response assumed.
c) Distribute the base shear between the various lumped mass levels usually based on an inverted triangular shear distribution of 90% of the base

shear commonly, with 10% of the base shear being imposed at the top level to allow for higher mode effects.

II. Response Spectrum Analysis: - The representation of the maximum response of idealized single degree freedom system having certain time period and damping, during past earthquake ground motions. The requirement that all significant modes be included in the response analysis may be satisfied by including sufficient modes to capture at least 90% of the participating mass of the building in each of the building's principal horizontal directions. Modal damping ratios shall reflect the damping inherent in the building at deformation levels less than the yield deformation. The peak member forces, displacements, story forces, story shears, and base reactions for each mode of response shall be combined by recognized methods to estimate total response. Modal combination by either the SRSS (square root sum of squares) rule or the CQC (complete quadratic combination) rule is acceptable. The maximum response plotted against the un-damped natural period and for various damping factors, and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement.

III. Time History Analysis: - It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a specific ground motion time history. Recorded ground motion data base form past natural earthquakes can be a reliable source for time history analysis. The steps involved in time history analysis are as follows:

a) Calculation of Modal matrix,
b) Calculation of effective force vector,
c) Obtaining of Displacement response in normal coordinate,
d) Obtaining of Displacement response in physical coordinate,
e) Calculation of effective earthquake response forces at each storey,
f) Calculation of maximum response.

2. RESEARCH METHODOLOGY

The methodology adopted to achieve the aims and objectives of the study, details of the methods used, and the analysis procedures applied to investigate various methods.
The reported work has aimed at the development and verification of a systematic methodology for process planning and optimization for most efficient method of analysis. The aims and objectives of this study are as follows:

a) To check the relative displacement of symmetric and asymmetric shaped building by static and dynamic analysis,
b) Determination of storey displacements and displacement of center of mass by using both static and dynamic analysis,
c) Finding out maximum displacements of building at different stories in both X and Z direction for all methods of analysis,
d) Also to check the seismic behavior of symmetric and asymmetric building in different seismic zone,
e) To check the accuracy and exactness of Time History analysis and Seismic Coefficient Method or Equivalent Static Analysis with respect to different conditions & aspects.

2.1 Scope of the Study: -

The scope of this study is as follows:

a) RC building is considered.
b) Linear elastic analysis is to be done on the structures.
c) Column is modeled as fixed to the base.
d) Loading due to infill wall was taken into account.

2.2 Load and Load Combination: -

Loads are a primary consideration in any building design because they define the nature and magnitudes of hazards are external forces that a building must resist to provide a reasonable performance (i.e., safety and serviceability) throughout the structure's useful life. The anticipated loads are influenced by a building's intended use (occupancy and function), configuration (size and shape) and location (climate and site conditions). Ultimately, the type and magnitude of design loads affect critical decisions such as material collection, construction details and architectural configuration. Thus, to optimize the value (i.e., performance versus economy) of the finished product, it is essential to apply design loads realistically. In the present project works following loads are considered for analysis.

a) Dead Load (IS 875 Part 1:1987)
b) Live Load (IS 875 Part 2:1987)
c) Earthquake Loads by Seismic Coefficient Method (IS 1893 Part I:2002)

In addition to the above mentioned loads, dynamic loads in form of Response Spectrum method can also be assigned. STAAD Pro. also uses IS 1893 – 2002 (Part 1) parameters mentioned below to evaluate seismic output parameters in form of design seismic coefficient, base shear storey shear and mass participation factor.

a) Seismic Zone Coefficient,
b) Response Reduction Factor,
c) Importance Factor,
d) Soil Site Factor,

e) Type of Structure,
f) Damping Ratio (Obtain Multiplication Factor for Sa/g),
g) Depth of Foundation below ground level in the present study above mentioned parameters are kept constant and discussed in the seismic analysis results.

2.3 Geometry and Modelling:-

In the present scenario, because of the wide range of geometry possible, the accumulated understanding is still limited, thus there is a need of an attempt to investigate the behavior of soft storey in building frame which will be used as general guidelines for the performance study of soft storey subjected to earthquake loading. For this study, building models of a 7 storey (G+6) are considered. The plan dimensions of asymmetric structure is 15 m × 10 m and symmetric structure is 10 m ×10 m and a floor height of 3 m each in all the floors.

Table -1: Structural Data of Symmetric Structure

Type of structure	RC Framed G+6 Residential Building
Plan dimensions	10 m X 10 m
Floor height	3 m
Bay width in longitudinal direction	5m
Bay width in transverse direction	5m
Size of beams	250 mm X 550 mm
Size of columns Upto G+3 G+4 to G+6	 230 mm X 600 mm 230 mm X 450 mm
Thickness of slab	200mm
Seismic zone	I & II, III, IV and V
Soil condition	Medium
Density of concrete	25 kN/m^3
Importance Factor	1
Damping Ratio	0.05
Response Reduction Factor	5

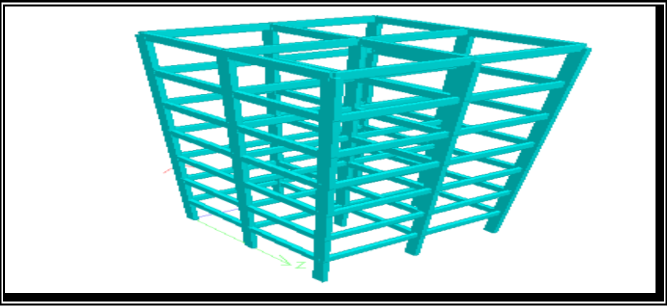

Fig -1: Rendered View of Symmetric Structure

Table -2: Structural Data of Asymmetric Structure

Type of structure	RC Framed G+6 Residential Building
Plan dimensions	15 m X 10 m
Floor height	3 m
Bay width in longitudinal direction	5m
Bay width in transverse direction	5m
Size of beams	250 mm X 550 mm
Size of columns Upto G+3 G+4 to G+6	 230 mm X 600 mm 230 mm X 450 mm
Thickness of slab	200mm
Seismic zone	I & II, III, IV and V
Soil condition	Medium
Density of concrete	25 kN/m^3
Importance Factor	1
Damping Ratio	0.05
Response Reduction Factor	5

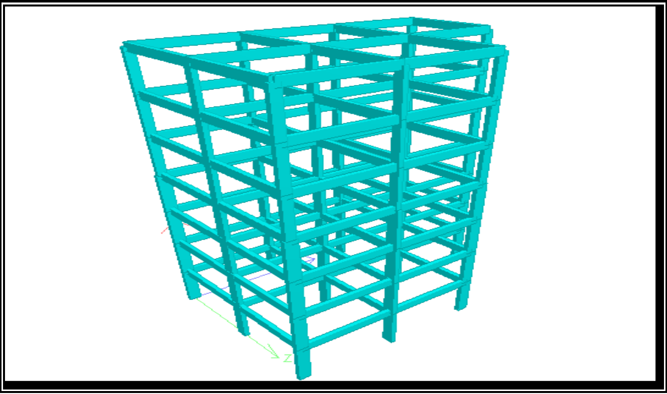

Fig -2: Rendered View of Asymmetric Structure

2.4 Load Calculations:-

Dead load:- As per IS 875 Part I (1987), "Indian Standard Code of Practice for Design Loads (Other Than Earthquakes) For Building and Structures Part 1: Dead Loads –Unit Weights of Building materials and stored materials", Second Revision, Bureau of Indian Standards (BIS), New Delhi, 1987.

Thickness of slab = 0.200m

Density of concrete = 25kN/m^3

Self Weight of slab = Density of concrete x Thickness of slab

= 25 x 0.200
= 5 kN/m^2

Floor Finish at floor level = 0.5 kN/m^2

Total Slab Weight at floor level= 5.5 kN/m^2

Live load: - As per IS 875 Part II (1987), "Indian Standard Code of Practice for Design Loads (Other Than Earthquakes) For Building and Structures Part 2: Imposed Loads", Second Revision, Bureau of Indian Standards (BIS), New Delhi, 1987.

Live Load Intensity specified (Residential building) = 2 kN/m^2

Design Lateral Force: - As per IS 1893:2002 (Part I), buildings and portions thereof shall be designed and constructed, to resist the effects of design lateral force as a minimum. The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level, shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action. The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression:

$$V_B = Ah \times W$$

Where,

Ah = Design horizontal acceleration spectrum using the fundamental natural period T, and

W= Seismic weight of the building.

Design Spectrum: - As per IS 1893:2002 (Part I), for the purpose of determining seismic forces, the country is classified into four seismic zones as shown in Fig. 1. (Provided that for any structure with T <0.1 s, the value of A_h will not be taken less than Z/2 whatever be the value of I/R.) The design horizontal seismic coefficient Ah for a structure shall be determined by the following expression.

$$Ah = (Z/2)\ (I/R)\ (Sa/g)$$

Where,

Z= Zone factor given in Table 2 of IS 1893 (Part 1):2002 is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone,

I= Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance [Table 6 of IS 1893 (Part 1):2002],

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. The values of R for buildings are given in Table 7 of 1893 (Part 1):2002,

S_a/g = Average response acceleration for rock or soil sites as given by Fig. 2 and Table 3 based on appropriate natural periods and damping of the structure.

After assigning sectional properties, support conditions, static and dynamic loading along with combination of loading following dynamic results are tabulated and compared.

3. RESULT AND DISCUSSION

The results obtained from analysis gives encourage to the use of the new approach in design of asymmetrical structure.

Table 3: Distribution of Base Shear at Storey Level of Symmetric Structure

Distribution Of Base Shear (kN)	Zone I & II	Zone III	Zone IV	Zone V
Q_1	0.97	1.56	2.34	3.52
Q_2	3.90	6.26	9.39	14.11
Q_3	8.78	14.09	21.12	31.74
Q_4	15.62	25.05	37.58	56.44
Q_5	23.73	38.05	57.07	85.72
Q_6	34.17	54.78	82.19	123.44
Q_7	41.63	66.75	100.14	150.39

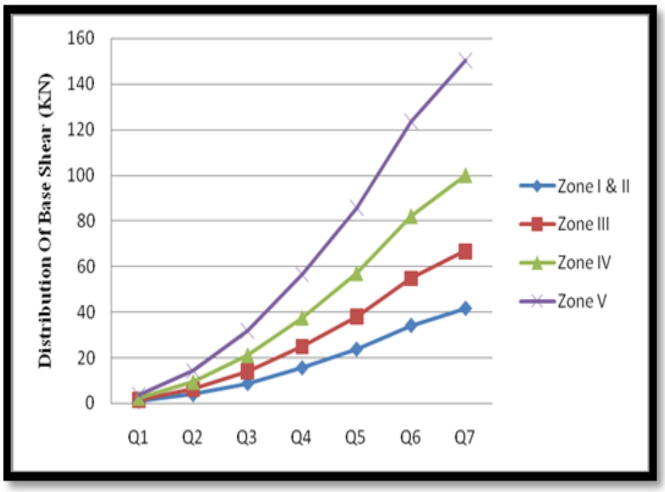

Chart 1: Comparison of Base Shear at Storey Level of Symmetric Structure

Table 4: Distribution of Base Shear at Storey Level of Asymmetric Structure

Distribution Of Base Shear (kN)	Zone I & II	Zone III	Zone IV	Zone V
Q_1	1.34	2.14	3.21	4.82
Q_2	5.36	8.56	12.87	19.31
Q_3	12.07	19.31	28.997	43.46
Q_4	21.46	34.34	51.51	77.27
Q_5	32.61	52.19	78.28	117.43
Q_6	46.97	75.15	112.73	169.09
Q_7	57.27	91.64	137.46	206.19

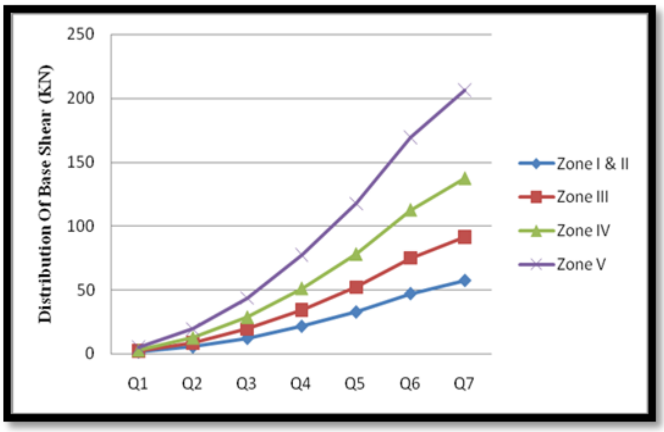

Chart 2: Comparison of Base Shear at Storey Level of Asymmetric Structure

I. Displacement

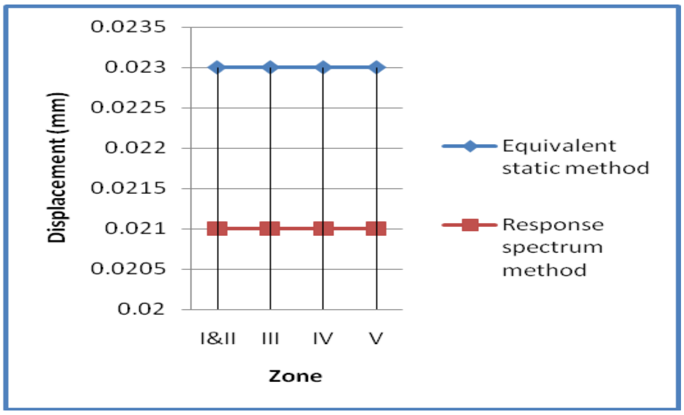

Chart - 3: Comparison between Equivalent Static method and Response Spectrum Method by Displacement for Asymmetric Structure

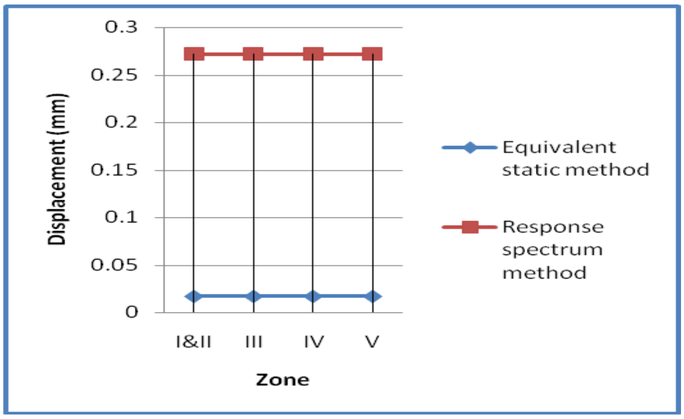

Chart - 4: Comparison between Equivalent Static method and Response Spectrum Method by Displacement for Symmetric Structure

II. Moment

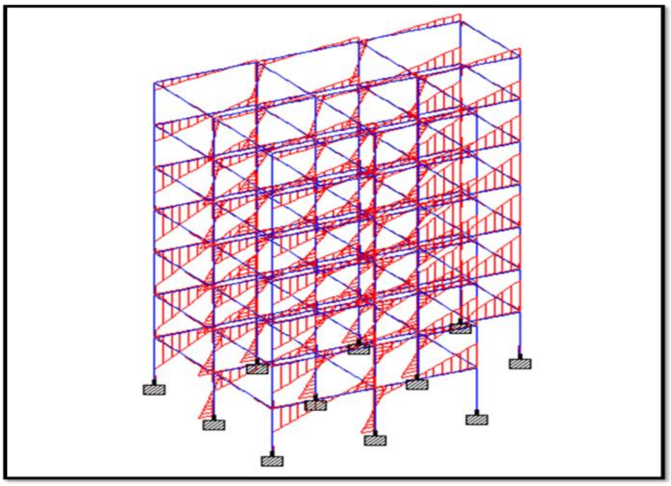

Fig -3: Bending Moment Diagram of Asymmetric Structure

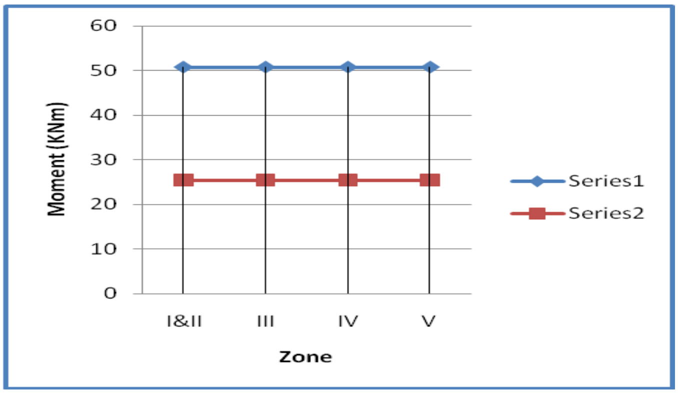

Chart - 5: Comparison between Equivalent Static method and Response Spectrum Method by Moment for Asymmetric Structure

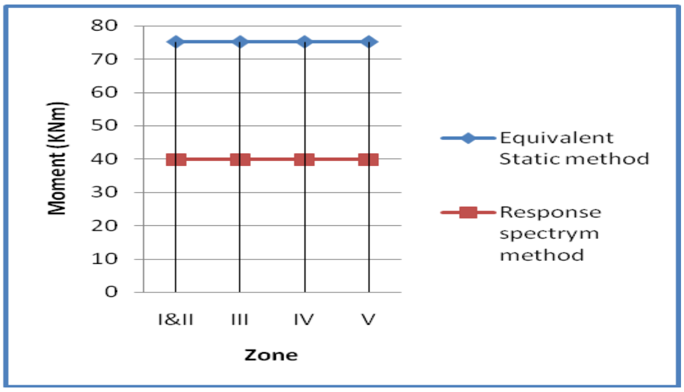

Chart - 6: Comparison between Equivalent Static method and Response Spectrum Method by Moment for Symmetric Structure

III. Reactions

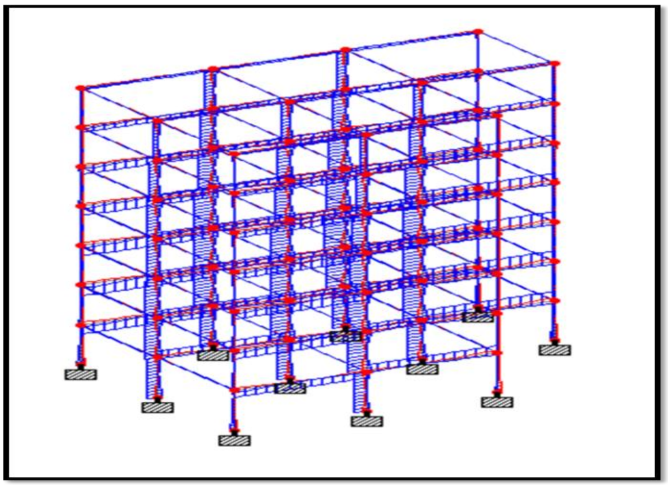

Fig -4: Reaction Diagram of Asymmetric Structure

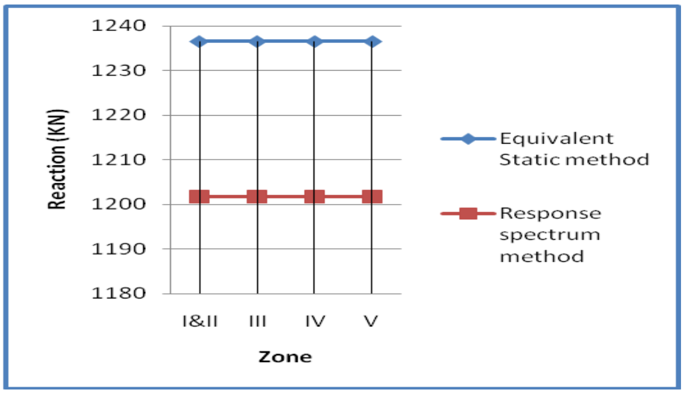

Chart - 7: Comparison between Equivalent Static method and Response Spectrum Method by Reaction for Asymmetric Structure

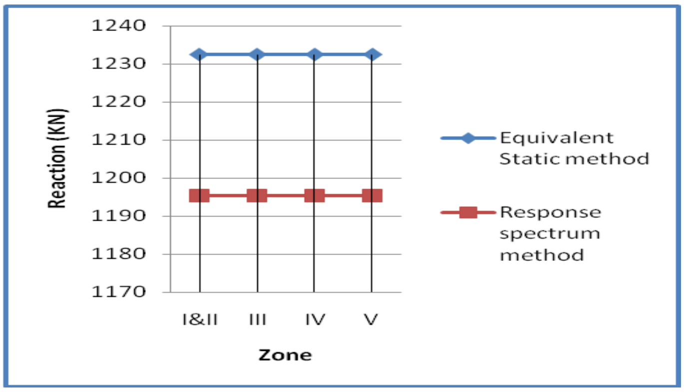

Chart - 8: Comparison between Equivalent Static method and Response Spectrum Method by Reaction for Symmetric Structure

3.1 Time History Analysis:-

The results obtained from Time History Analysis are:-

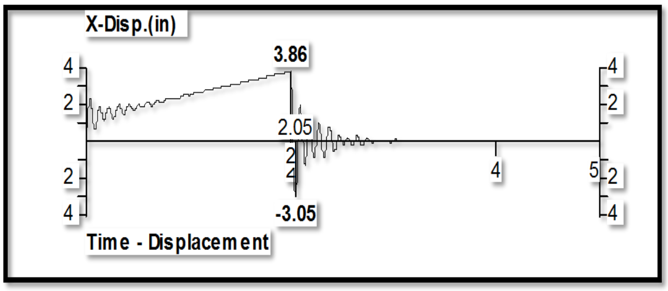

Chart 9: Time History Displacement along X for Asymmetric Structure at Zone I & II - Node 78

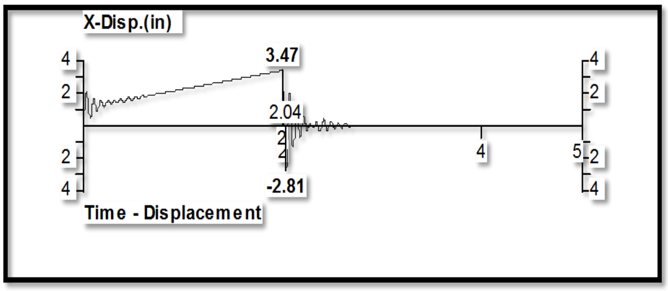

Chart 10: Time History Displacement along X for Symmetric Structure at Zone I & II - Node 78

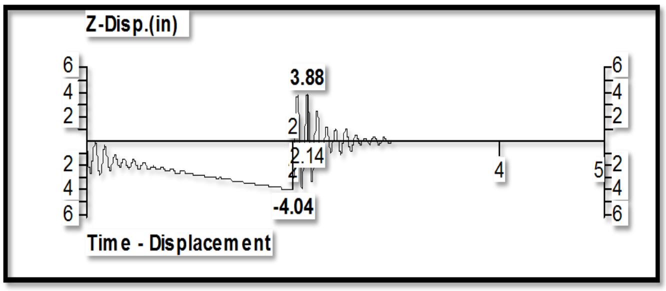

Chart 11: Time History Displacement along Z for Asymmetric Structure at Zone I & II - Node 78

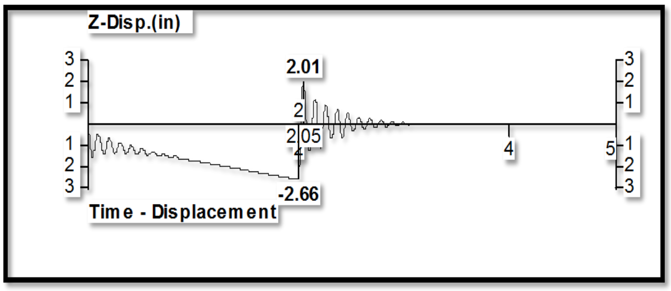

Chart 12: Time History Displacement along Z for Symmetric Structure at Zone I & II - Node 78

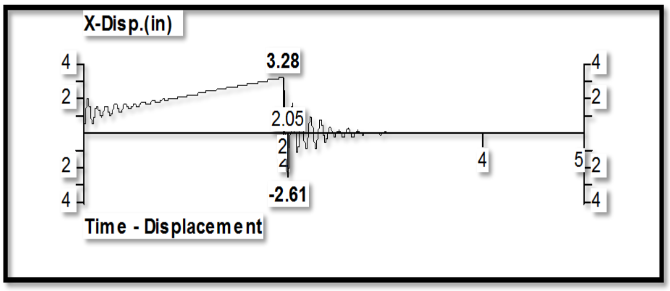

Chart 13: Time History Displacement along X for Asymmetric Structure at Zone I & II - Node 45

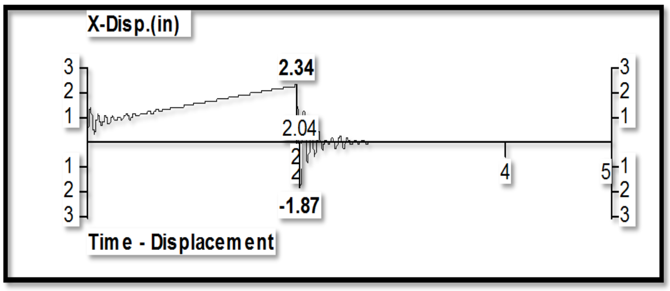

Chart 14: Time History Displacement along X for Symmetric Structure at Zone I & II - Node 45

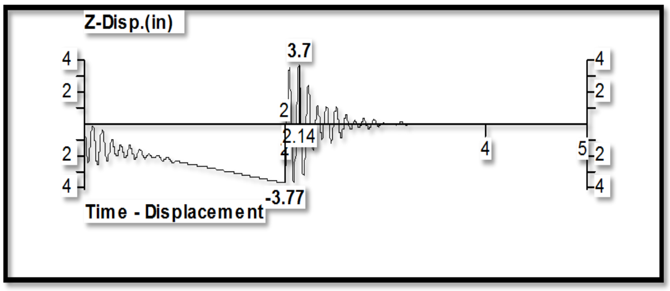

Chart 15: Time History Displacement along Z for Asymmetric Structure at Zone I & II - Node 45

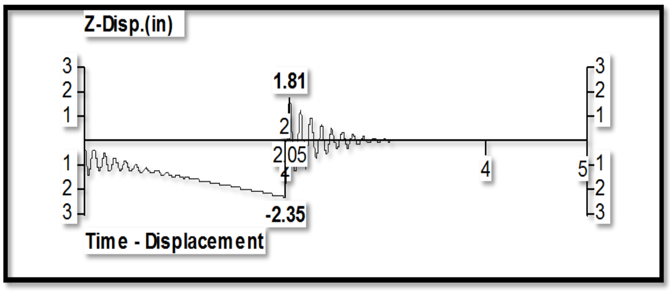

Chart 16: Time History Displacement along Z for Symmetric Structure at Zone I & II - Node 45

4. CONCLUSIONS

The static analysis only produces storey shear in the direction of loading. Static analysis gives higher values for maximum displacement of the stories in both X and Z direction. Base shear values obtained by manual analysis are slightly higher than software analysis. Static analysis is not sufficient for high rise buildings and it's necessary to provide dynamic analysis. Base shear value is more in the zone V for both symmetrical and asymmetrical structure. Irregular shapes are severely affected during earthquakes especially in high seismic zones. Base shear is calculated by using IS 1893-2002 method for all models and illustrate the comparison of base shear using Equivalent Static Method. The lower base shear is getting in symmetric shape building and the higher base shear is getting in asymmetric shape building. The irregular shape building undergoes more deformation and hence regular shape building must be preferred. Time period does not depend on the zone value. Maximum displacement for irregular structure and minimum for regular structure. There is slightly change in displacement, moments and reaction upto G+6 structure in both asymmetric and symmetric. Equivalent Static Analysis gives higher values as compared to Response Spectrum Method.

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