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COMPARATIVE STUDY ON SEISMIC ANALYSIS OF IRREGULAR BUILDINGS USING DIFFERENT LOCATION OF SHEAR WALL

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Abstract: Irregularities in buildings are a cause for concern when they are subjected to destructive earthquakes. Buildings often become unstable when their vertical or plan configuration suddenly changes. To prevent failure and reduce the risk potential of irregular structures, proper precautions should be taken to resist lateral loads. One of the most practical and commonly used mechanisms to protect against lateral loads for high-rise buildings in earthquake-prone areas is shear wall systems. It is critical to properly assess the earthquake response of the walls because the properties of these seismic shear walls greatly affect the response of the building. Buildings with shear walls reduce the lateral deflection of the structure, but the effectiveness of the shear wall in terms of lateral strength of the structure depends strongly on the position of the shear wall. The main objective of the current work is to find the appropriate position of shear wall in irregular multistory buildings.

Four different models of irregular buildings were used to study the effectiveness of shear walls. The first model is a bare frame, and the other models are irregular frames with shear walls at different locations. A response spectral analysis is performed in the STAAD Pro software. Based on the results, the optimal model for strategic positioning of the shear wall and minimizing the overall response of the structure is determined by comparing the results of parameters such as projectile drift, axial force, and base shear.

***Index Terms* –** Shear wall; Response Spectrum Analysis; STAAD Pro; Story drift; Base shear; Position of shear wall

I. INTRODUCTION

In the 21st century, infrastructure development in developing countries, especially in India, has increased significantly in terms of the construction of buildings, bridges, industrial facilities, and so on. This infrastructure development is primarily driven by population growth and meeting the needs of the population. Since land is limited, there is a great shortage of land in the city. To solve this problem, tall, slender, multi-story buildings are being constructed. These structures will likely be subjected to massive lateral loads. These lateral loads are due to inertial forces generated by earthquakes, which tend to break buildings in shear and push them in bending. Lateral loads can cause high stresses, sway or vibration. Therefore, it is very important that the structure has sufficient strength for vertical loads and sufficient stiffness to resist lateral forces.

Shear walls are one of the best seismic protection measures for multi-story reinforced concrete buildings. In highly earthquake-prone regions, it is very common engineering practice to use shear walls in structures to resist lateral forces. It has been found to be effective and economical to install a shear wall in the building to achieve its stiffness. When the building is tall, the beams and columns become quite heavy and require a large amount of steel. Therefore, overloading occurs at these joints, and it is difficult to place and vibrate the concrete at these points, and the displacement is quite heavy. Shear walls can form an effective lateral force system if they are placed at advantageous locations in a building. During an earthquake, structures are still damaged for one reason or another. The behavior of a structure during an earthquake depends on the distribution of weight, stiffness, and strength in both the horizontal and vertical planes of the building. Reinforced concrete shear walls are used in buildings to reduce the effects of earthquakes. They can be used to improve the seismic performance of buildings. The design of a building for seismic loading is primarily related to the safety of the structure in the event of a strong earthquake, and it is very important to ensure sufficient lateral stiffness to withstand the lateral loading in a high-rise building. Currently, the main criterion for the design of reinforced concrete structures in earthquake zones is the control of lateral displacements due to the action of shear forces.

Problem Context:

Vertical irregularities in structures are very common in urban areas. In most cases, buildings are vertically irregular at the design stage for architectural and functional reasons. This type of building has historically been found to be more susceptible to earthquakes. Issues related to vertical irregularities have long been at the forefront of research. Numerous studies in the deterministic field have been conducted in this area. Therefore, the present study focuses on evaluating the relative behavior of typical vertically irregular buildings in a probabilistic domain.

This type of buckling is caused by an unexpected decrease in the stiffness or strength of a particular floor. In seismically active areas, building irregularities are likely to be a major concern for good civil engineers. In existing urban infrastructure, there are many irregularly shaped vertical structures. Among them, open first floors and stepped buildings are very common in Indian cities.

For all structures designed to withstand seismic loads, the dynamic characteristics of the loads must be considered. However, for simple regular structures, an analysis using the equivalent linear static method is sufficient. This method is approved in most codes for ordinary buildings of low to moderate height. It starts with an estimate of the basic shear load, which is calculated using the formula provided in the standard and its distribution among the individual layers. Therefore, the static equivalent calculation for low to medium-height buildings without significant coupling of transverse and torsional modes can work well if only the first mode in each direction is considered. Tall buildings (e.g., over 75 m) or buildings with torsional effects where the second or higher mode of vibration may be significant are much less suitable for this method, and more complex methods should be used under these conditions.

About Shear Walls:

In civil engineering, a shear wall is a vertical element of a system designed to resist lateral in-plane forces, usually wind and earthquake loads. In many jurisdictions, the International Building Code and the International Residential Code regulate the construction of shear walls.

A shear wall resists loads parallel to the plane of the wall. Collectors, also known as tension members, transfer shear forces from the diaphragm to the shear walls and other vertical elements of the seismic system. Shear walls are usually light truss or braced wooden walls with shear plates, reinforced concrete walls, reinforced masonry walls, or steel plates.

Plywood is the traditional material used for wood shear walls, but with advances in technology and modern construction methods, other prefabricated options have made it possible to incorporate shear walls into narrow walls that are on either side of an opening. Steel plate and steel-reinforced shear panels instead of plywood in shear walls have proven to be more earthquake resistant.

Types of Shear Wall

Based on the type of material used, shear walls are classified into the following types.

Reinforced Concrete Shear Wall

Concrete Block Shear Wall

Steel Shear Wall

Plywood Shear Wall

Mid-Ply Shear Wall

Geometry of shear wall

The cross-section of the shear wall is oblong which means that one dimension of the cross-section is greater than the other. In addition to commonly used rectangular cross sections, U and L-shaped sections are also utilized. Thin-walled hollow shafts of RC around the elevator core of the building also act as a shear wall.

Fig.1: Various shapes of shear wall

Methods of analysis

The response of structures to earthquakes is in general of the following characteristics

- Complex
- Three-dimensional
- Non-linear
- Dynamic

Hence the full treatment of response of structures subjected to earthquakes should regard all the aforementioned characteristics. However, owing to various limitations such as technological along with a limited understanding of the problem following four types of procedures have been developed namely:

Equivalent Static Analysis

Pushover Analysis

Response Spectrum Analysis

Time History Analysis

Response spectrum analysis: (RSA) is a linear-dynamic statistical analysis technique that calculates the contribution of each natural mode of vibration to estimate the maximum seismic response that a basically elastic structure will likely experience. By measuring pseudo-spectral acceleration, velocity, or displacement as a function of the structural period for a specific time history and damping level, response-spectrum analysis sheds light on dynamic behaviour. The peak response for each realization of the structural period can be represented as a smooth curve by enclosing the response spectrum.

Response-spectrum analysis links the choice of structural type to dynamic performance, which is helpful for design decision-making. Longer structures undergo greater displacement, and shorter structures have greater acceleration. Structural performance objectives should be taken into account during preliminary design and response-spectrum analysis.

II LITERATURE REVIEW

[1] Mohan and Prabha (2011)

studied the behaviour of RCC buildings with the Shear Wall**.** They focus on two multi-storey buildings, one with six stories and the other with eleven, which they modelled using the software package SAP 2000 for India's earthquake zone V. Six distinct types of shear walls were evaluated, each with a different shape, to see how efficient they were at resisting lateral forces. They also looked at how the height of the building affects the shear wall's structural response. According to the research, square-shaped shear walls are the most effective; while L-shaped shear walls are the least effective.

[2]Aainawala & Pajgade (2014)

studied a G+12, G+25, G+38 building with a regular plan. The structures were built using ETAB software, and four distinct models were investigated with different shear wall positions in different zones and for varied heights in order to determine the ideal shear wall location in buildings. Models were examined, and dynamic analyses were carried out for G+ 38 models in all four zones, comparing lateral displacement, storey drift, concrete quantity required, steel, and total cost.

[3] Niveditha & Sunil (2018)

investigated the behaviour of regular and irregular buildings with and without shear walls Under seismic motion. ETABS 2016 was used to model and analyze the buildings. Several characteristics taken into account were lateral displacement, stiffness, and storey drift. Buildings were analyzed using the equivalent static approach and the response spectrum method. The following conclusions were reached: lateral displacement is smaller in regular and irregular buildings with shear walls than in regular and irregular buildings without shear walls. As the storey height increases, the stiffness of each level decreases. The stiffness of the bottom floor is greater than that of the upper storey. The lateral displacement in the X direction is greater than in the Y direction in both the equivalent and response spectrum approaches.

[4] Patel et al. (2021)

used the seismic coefficient approach to investigate the behaviour of multistorey buildings with plan irregularities. The results of several irregular C, H, T, and L-shaped structures were compared in order to obtain a better seismically resistant result for residential buildings. For each form of C, H, T, and L building, the behaviour is examined using three distinct types of soils: Hard, Medium, and Soft. After the structure has been analyzed, displacements, storey drift, and base shear data were computed and compared for each example. Results showed that the base shear of the C & H form has the highest shear, in comparison to the conventional model. The base shear for the L and T shapes is the same, as is the case for the C and H shapes; this is due to the building's orientation and degree of irregularity.

III OBJECTIVE

The objective of present work is to study the behaviour of RCC building using Response Spectrum Analysis method. The other objectives of present work are

- To model and analyze the shear wall building using STAAD Pro software.
- To study the behaviour of frames with different positions of shear walls in seismic zones III & IV using response spectrum analysis method as per IS 1893 (Part-I): 2002.
- To analyze and compare the different models for parameters like story drift, lateral displacement and base shear.

IV METHODOLOGY

The present study is concerned with analyzing seismic behavior of Irregular buildings. In such buildings percentage of irregularity and shape of buildings with same plan area of same heights in same storey are usually observed. In the present study namely Response spectrum method are used to study the seismic response of irregular buildings using STAAD.Pro software. To investigate a multistoried RC outlined structure considering earthquake intensities III and IV Zone by response spectra method and track down the base shear an incentive for various constructions. Response spectra method for RC outline with the uncovered and diverse situation of shear wall is completed utilizing reaction response spectra method according to IS 1893 (Part I): 2002 by utilizing STAAD-PRO programming. For this examination, various sorts of models are thought of and comparison of seismic performance is carried out.The various parameters are considered for analysis such as base shear, maximum displacement, and storey drift.

Response Spectrum Method of analysis shall be performed using the Design Spectrum - $Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g}$

Modelling of buildings using Staad.pro v8i

- Modelling the geometry of building
- Assigning member properties and material
- Assigning supports
- Assigning loadings
- Analyzing building models
- View results of analysis

Project description

For analysis a G+14 stories high Irregular building modelled in Staad Pro as a space frame. The RC Irregular building does not represent any real existing building. The Irregular building with span more along Z direction than along the X direction. The structure ascends to 45m along Y direction and ranges 36 m along X direction and 36 m along Z direction. The buildings are located in seismic zone III & IV. The soil is medium stiff and entire irregular building is supported by fix support. The structure is analysed by Response

Spectrum Analysis, which is a straight powerful investigation. Static analysis is embraced since it gives preferred outcomes over static investigation. The particulars of the model are given in table 1 and the arrangement and the model of the structure is displayed in the following figures. In the entire course work X and Z are taken as the horizontal axes and Y as the vertical axes. Shear walls are the simplest way of reducing the response of irregular buildings which gave rise to five models for the analysis-

- Model 1 -BFB- Bare frame RCC Irregular building.
- Model 2 -SW1- Framed Irregular building with Shear wall at the exterior side along X-direction.
- Model 3 -SW2- Framed Irregular building with Shear wall at the exterior side along Z-direction.Model 4 -SW3- Framed Irregular building with Shear wall at the exterior side along X and Z-direction.
- Model 5 -SW4- Framed Irregular building with Shear wall at the exterior side around the corners.

Model data

Table 1: Details of building

SPECIFICATION	DATA
Model	G+14
Total Building Height	45m
No. of bays along X & Z direction	9
Bay Length along X & Z direction	4m
Floor to Floor Height	3m
Column size	0.60m X 0.60m
Beam size	0.50m X 0.60m
Slab Thickness	0.125m
Thickness of shear wall	0.130 m
Inner Wall Thickness	0.150m
Grade of Concrete	M 25
Grade of Steel	Fe 500
Density of Brick	20 N/mm^3
Unit weight of RCC	25 N/mm^3
Seismic Zone	Zone III & Zone IV
Zone Factor corresponding to seismic zone	0.16 ,0.24 (as per table 2 of IS:1893(part-1-2002)
Importance Factor	1.0 (as per table 6 of IS:1893(part-1-2002)
Response reduction factor	5 (as per table 7 of IS:1893(part-1)-2002)
Type of frame	Special RC moment resisting frame (as per Table-7; IS 1893:2002)
Damping Ratio	5%

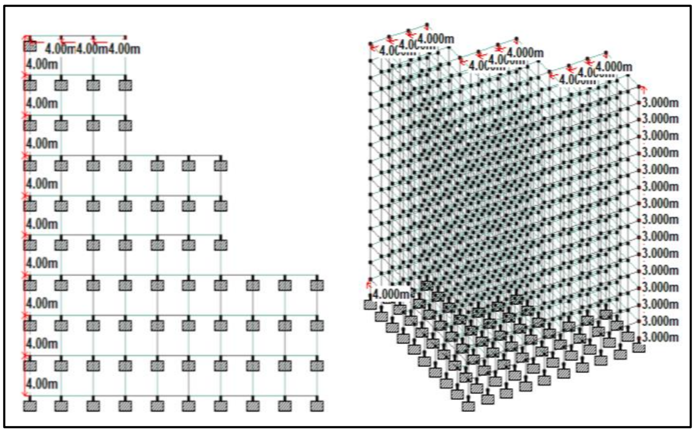

Fig.2: Plan and 3D view of model 1

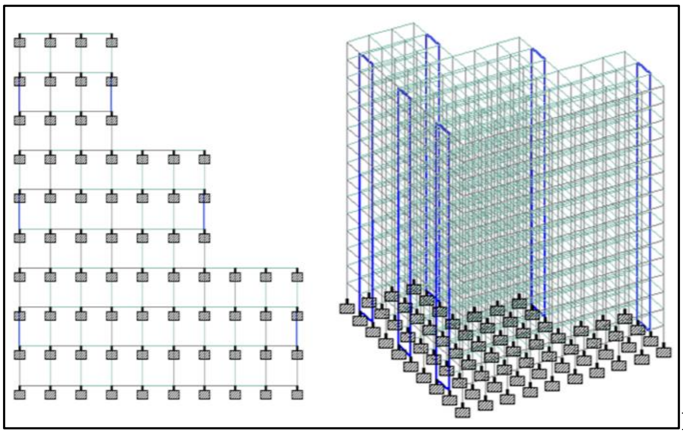

Fig.3: Plan and 3D view of model 2

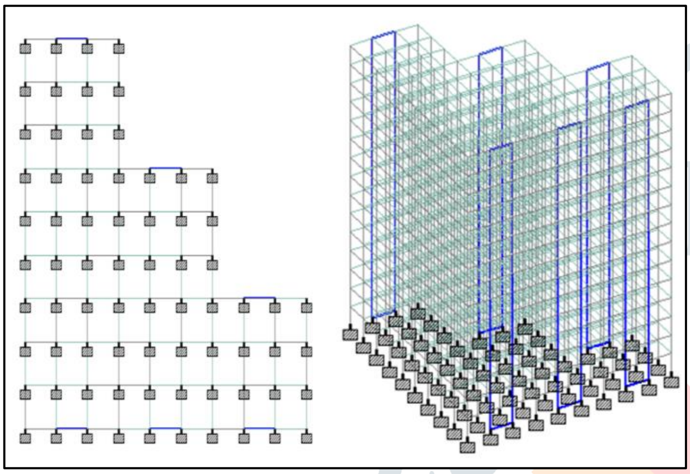

Fig.4: Plan and 3D view of model 3

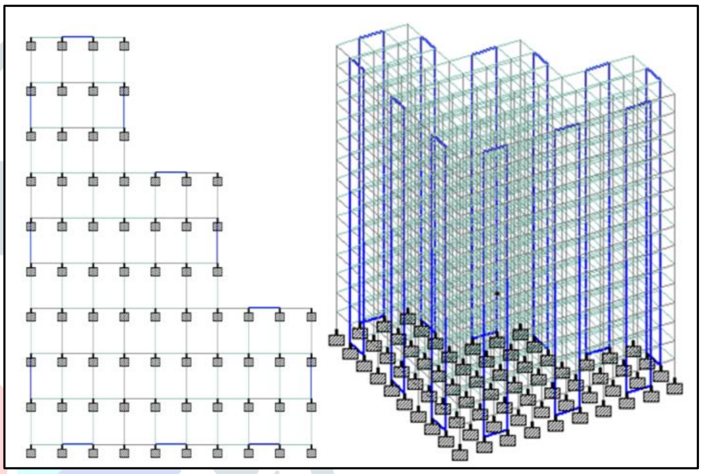

Fig.5: Plan and 3D view of model 4

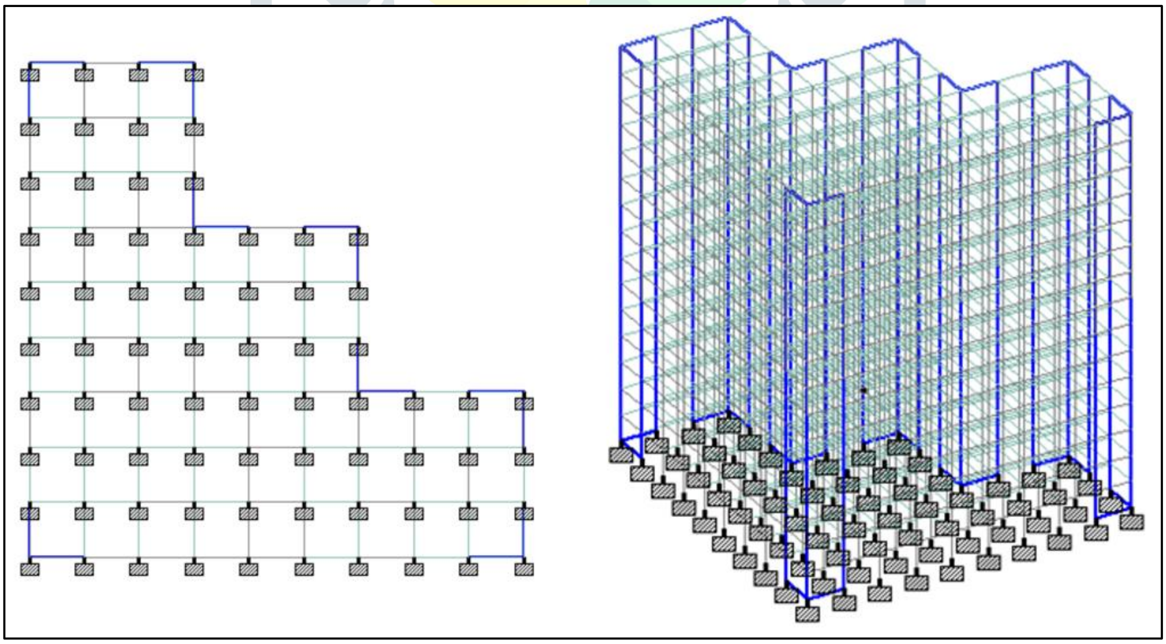

Fig.6: Plan and 3D view of model 5

V RESULT AND DISCUSSION

The study examines the seismic performance of irregular multi-storey buildings to give an idea about the location for providing the shear wall which was based on response spectrum analysis. Five buildings are analyzed for zone III and zone IV. To study the effectiveness of all these buildings, the storey drift, peak, base shear, and node displacement are worked out.

Fig.7: Base shear graph for different models for zone III

Fig.8: Base shear graph for different models for zone IV

The base shear graph of different models in zone III & IV shows that on average there is 12% increase in the value of base shear in zone IV with respect to zone III. Results show that model 4 shows 37% and model 5 shows 39% less values of base shear as compared with the bare frame.

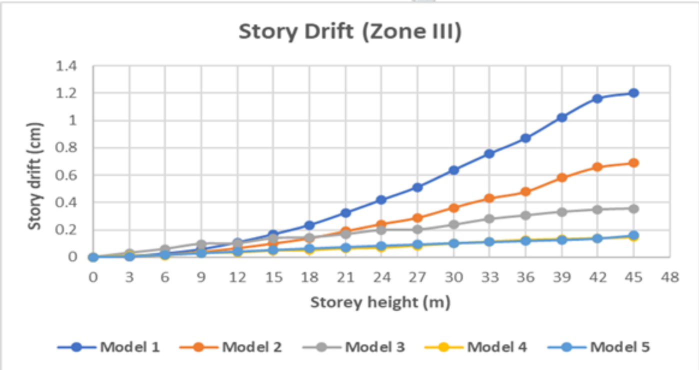

Fig.9: Storey drift vs storey height for zone III

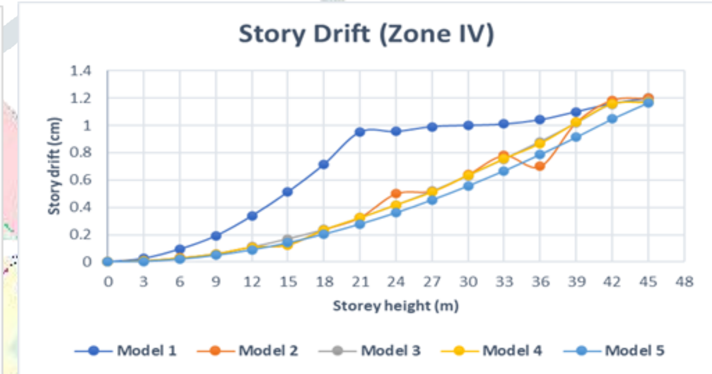

Fig.10: Storey drift vs storey height for zone IV

As per clause 7.11.1 of IS:1893-2002 (part-1), the storey drift in any storey due to the minimum specified design lateral force, with a partial load factor of 1.0, shall not exceed 0.004 times the storey height. Here for 3.0m storey height and a load factor of 1.0 maximum drift will be 12mm.

The value of storey drift is increasing with increase in storey height.It is observed from the result tables and graphs that storey drift for model 2 and model 3 shows nearly similar values.

It is observed that storey drift is maximum for model 1 i.e., bare frame without shear wall as compared with other models in all zones. Model 4 and model 5 shows 70%,model 2 shows 30% while model 3 shows 11% less values of storey drift when compared with bare frame.

While comparing within zones, storey drift is around 55% more in zone IV as compared to zone III.

In all the models the values are well within the permissible limits as per clause 7.11.1 of IS:1893-2002 (part-1).

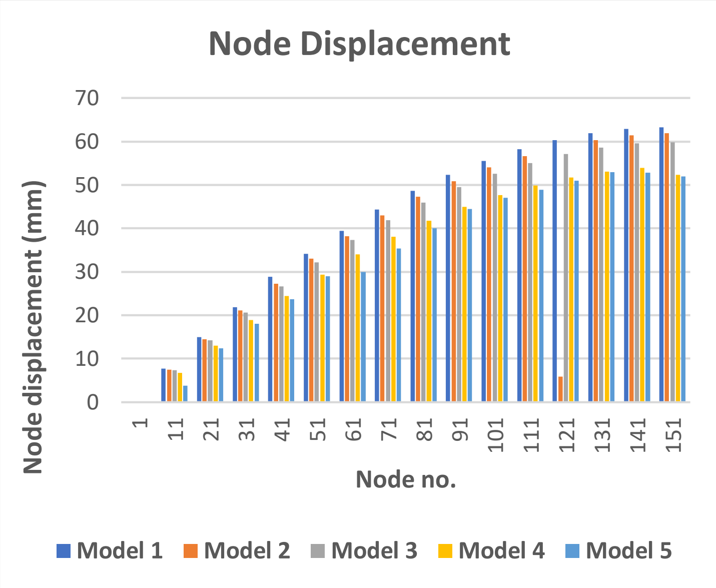

Fig.11: Node displacement vs node no. for zone III

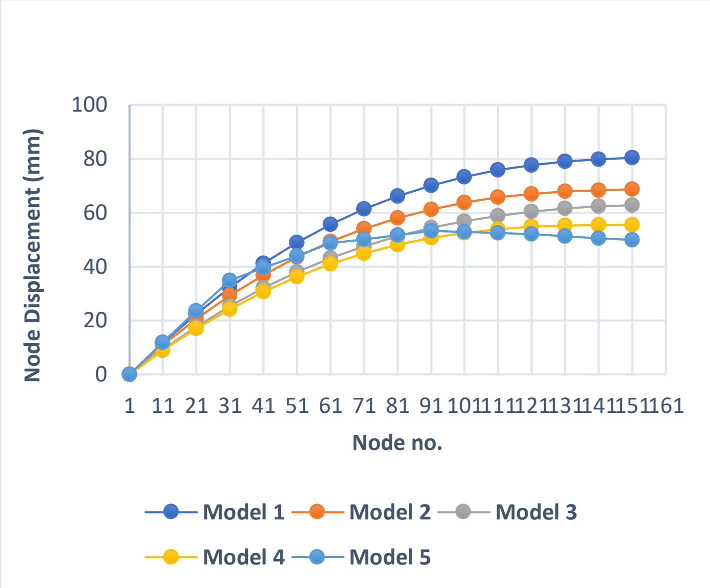

Fig.12: Node displacement vs node no. for zone IV

As the height of the building increases the value of displacement also increases in the models in both zones. Maximum displacement is found in top storey of the models.

The values of displacement for all models are around 25% more for zone IV as compared to zone III.

Model 2,3,4 & 5 shows nearly 9%,11%,14% & 19% respectively, less values of displacement as compared to bare frame in zone III.

VI CONCLUSION

- From the above observations it can be concluded that in seismically active zones shear wall should be provided to reduce the adverse impact of earthquake on structures.
- Changing the position of shear wall affects the attraction of forces. Rectangular Shear walls provided in outermost perimeter i.e., X-Z directions and at corner of the building shows better result as compared to other locations of shear wall.
- Among all the models, the frame without shear walls showed maximum value for all parameters in both zones. After the introduction of the shear wall in models all the parameters are reduced when compared with bare frame.
- It is also observed that in model 2 & model 3 the values of parameters were slightly increased when compared to model 4 & model 5, but still the structure is safe under permissible limits.
- So, providing shear walls at adequate locations substantially reduces the displacements due to earthquakes.

VII FUTURE SCOPE

1. Analysis can be carried out using Time History Analysis.
2. Seismic analysis of irregular frames for different types of soil for different zones could be done.
3. Comparative study by using different shapes of shear walls.

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