Seismic Strengthening of Irregular Geometrical Configured RCC Multi Storeyed building using shear wall

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Abstract - *This study aims to model and analyze G+14 RCC building with different geometrical configurations and provision of shear wall at different location for zone IV and V. The various parameters like Lateral displacement, Storey drift, Drift ratio, Base Shear are compared for building models developed by using SAP2000 with and without shear wall models. The provision of shear wall in multistoried building in zone V improved lateral load carrying capacity and also other parameters are enhanced in comparison with building in zone IV.*

***Key Words*: Shear wall; Lateral displacement; Story Drift; Base shear; Modal time period; Displacement Reduction Factor(DRF)**

[1]. INTRODUCTION

Due to tremendous increase in the construction of high rise irregular geometrical residential and commercial buildings, the effect of lateral loads like earthquake load has gain more attention as every designer is facing problem of providing sufficient strength and stability against earthquake. A normal building should possess four main attributes having simple in plan and regular configuration, adequate lateral strength, its stiffness and ductility. Buildings having normal regular geometry in plan and in elevation, suffer much less damage than the irregular configuration. A building shall be considered as an irregular as per IS 1893-2002, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements. The dynamic loads includes many loads such as wind, waves, traffic, earthquakes, and blasts. Any structure either regular or irregular can be subjected to dynamic loading. Structural symmetry might be a major reason of poor performance of buildings under extreme seismic loading; asymmetry contributes significantly to increase lateral deflections, increased member forces and ultimately the buildings tends to collapse.

Shear walls are the vertical elements of the horizontal force resisting system. When shear walls are designed and constructed properly, they will have the sufficient strength and stiffness to resist the horizontal forces. Mainly the Shear walls start at the foundation level and are continuous throughout the building height. The thickness of the shear wall should be as low as 150mm, or as high as 400mm in high rise buildings.

Shear walls are generally provided along both length and width of buildings. Shear walls are like vertically aligned wide beams that carry the earthquake loads down to the foundation.

[2]. LITERATURE REVIEW

P S Kumbhare, A C Saoji, and Babasaheb Naik, 'Effectiveness of Reinforced Concrete Shear Wall for Multi-Storeyed Building', *International Journal of Engineering Research & Technology*, 1.4 (2012), 4–8.*[1]* studied on the medium high rise building (G+10) by considering two system that was frame system and dual system. And four models has been taken for the earthquake analysis. Model one was bare frame structural system and other four models are dual type structural system. Analysis has carried out by using ETABS. The comparison of these models for different parameters like shear force, Bending Moment, Displacement, Storey Drift and has been presented by replacing column with shear wall. Five models were analyzed through ETABS and equivalent static analysis or linear static analysis has been done and the results obtained in terms of the storey drift, displacement, shear force and bending moment and after analyzing the results the conclusion obtained was that frame system should be more economical than the structural dual system for medium rise building in high seismic zone.

Sharath Irappa Kammar and Tejas D Doshi, 'Non Linear Static Analysis of Asymmetric Building with and without Shear Wall', *International Research Journal of Engineering and Technology*, 2.3 (2015), 1838–41.*[2]* done the detailed study for the performance level and behaviour of structure in presence of shear wall for plan irregular building with re-entrant corners has been done keeping in mind the parameters considered were Base shear, Displacement and performance levels of the structure. Nonlinear static Pushover analysis was used for study. Now from the studies the results obtained from the pushover analysis depicts that the performance point of the models without shear wall should have the base shear less compared to model with shear wall as the shear wall resists the earthquake forces to the greater extent .The base shear of the building increased with the addition of the shear wall as the load resisting capacity increases. The addition of shear wall significantly reduces the displacement in the structures when compared with the structures without shear wall. Results obtained from the above study it has been observed that the buildings with re-entrant corners were more prone to earthquake damage causing Torsional effect.

Margrette Mary James and George M Varghese, 'Seismic Performance of Dual System Structures : A Review', *Journal of Structural Technology*, 1.1 (2016), 1–7.[3] studied four different types of multistoried buildings and in that the different positions of shear walls has been decided to avoid the design base shear in dual wall systems. And the buildings are analysed through the software ETABS. The response parameters for different types of buildings are lateral displacement, mode period; base shear and storey acceleration are also evaluated. Equivalent static force method, Response spectrum method and Time history analysis were considered for different models and results drawn and conclusion made from the studies that Provision of shear walls in zone V was not enough to keep maximum displacements within permissible limits. There has been increase in column reinforcement of about 0.6 to 1% without shear wall model and 0.2 to 0.6% with shear walls having different positions, hence the presence of shear walls has significant contribution to column reinforcement. When compared to symmetric buildings base shear was more in asymmetric buildings. About 16% reduction in the lateral displacements was found when the shear walls were introduced along with the flat slab.

Shyam Bhat M, N A Premanand Shenoy, and Asha U Rao, 'Earthquake Behaviour of Buildings With and without Shear Walls', *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 2013, 20–25.[4] depicted a 50-story building with a 3.5-meters height for each story, regular in plan was modelled assuming fixed at base and analyzed through stad.pro taking 4 models considering framed section, buildings with shear walls one on each side, on corners and at centre. Lateral displacements, displacements reduction and base shear of the four models should be made based on the graphs and result obtained is that the top displacement of the model 1 is high compared to all other models. The top displacement of model 1 is high compared to other models. The top displacement of the floors can be much reduced by providing shear walls along the corners. The roof or upper displacement of model 2 is 3% less compared to model 1, model 3 is 18% less compared to model 1, model 4 is 24% less compared to model 1 in zone 2 likewise in zone 3 4 and 5 respectively.

A Neuenhofer, 'Lateral Stiffness of Shear Walls with Openings', *Journal of Structural Engineering*, 132.11 (2006), 1846–51 <https://doi.org/10.1061/(ASCE)0733-9445(2006)132:11(1846)>.[5] has investigated the study on the accuracy of a simplified hand method recommended in several design guidelines for practising structural engineers for calculating the lateral stiffness of shear walls with openings. He has conducted the parametric study in which the location of the wall and size of the opening, as well as the aspect ratio of the wall were varied. And the comparison should be made between the hand developed results and the results obtained from the software MATLAB. He has conducted the three parametric studies based on the opening of the shear wall. First case was horizontally centered fixed-size opening at variable vertical location second case was horizontally centered opening of varying height and third was of shear wall with varying aspect ratio and single horizontally and vertically centered opening. Results from the study undertaken above indicate hand method consistently underestimates the impact of the opening on the reduction of stiffness, thus producing a lateral stiffness larger than that obtained from the detailed finite-element analysis. The manual calculations gave the remarkably poor results for the walls with small aspect ratios in comparison with software MATLAB. Finite-element analysis was still not easy and practicing structural engineers often lack the experience to apply the finite element class.

[3] METHOD OF ANALYSIS

3.1 Equivalent Static Method

In Equivalent static analysis method it is based on the assumption that the structure responds in its fundamental mode. The response is being read from a design response spectrum giving the natural frequency of the structure. The Equivalent static method works well for low to medium-rise buildings without significant lateral–torsional modes, in which only the first mode in each direction is of significance. The applicability and the reliability of this method has been extended in many building and design codes by applying modification factors accounting for higher buildings with some higher modes, and for lower levels of twisting. Accounting effects during yielding of the structure, many codes applied modification factors reducing in the design forces.

3.2 Response Spectrum Method

The Response Spectrum Analysis approach depicts the multiple modes of response of a building to be taken into account (in the frequency domain). The response of a structure shall be defined as a combination of many special irregular shapes that in a vibrating string correspond to the harmonics. Computer and software analysis can be used for determination of the modes for a structure. For every single mode, a response should be read from the design spectrum, depending on the modal frequency and the modal mass, and then combined to provide a desired estimate of the total response of the structure. The result obtained from the response spectrum analysis method using the response from a ground motion is typically different from that calculated directly from a linear dynamic analysis using the ground motion, however the phase information is lost in the process of generating the response spectrum. In different cases where structures are too irregular, too tall or of significance to a community in disaster response, the response spectrum approach is no longer available, and more complex and detailed analysis is often required, such as non-linear static analysis or non-linear dynamic analysis.

Different types of Combinations methods are as follows:

- Absolute - peak values are added together
- Square root of the sum of the squares (SRSS)
- Complete Quadratic Combination (CQC)

[4] STRUCTURAL MODELLING AND ANALYSIS

The structural analysis of G+14 storied reinforced concrete asymmetrical building is done with the help of SAP2000 software. The location of the building is situated in in seismic zones IV and V. All columns in all models are pinned at the base for simplicity. The plan area is 398.83m^2. The floor to floor height is 3m. Live load on floor is taken as 3 KN/m^2 and on roof is 1.5 KN/m^2. Floor finish on the floor is 1kN/m^2. Thickness of slab is 125mm. Shear wall thickness is of 250 mm on all the beams. The seismic weight is calculated conforming to IS 1893-2002(Part-I). The unit weight of concrete is taken as 24 KN/m^3. The grade of concrete for column, beam and slab is considered as M-25.The building is special moment resisting frame considered to be situated in seismic zone IV and V having medium soil and intended for residential use.

Five models were prepared on the basis of the plan area shown in Fig.1 and Fig.2, analysis of the models was done through the SAP 2000 software. The Static and Dynamic analysis was done based on the load cases and combinations and the results obtained in form of graphs were obtained for further study.

Table 1: Building Preliminary Data

Number of Stories	G+14
Plan(29.83*13.87)	398.83m^2
Floor to Floor height	3m
Length of bay in X-direction	18
Length of bay in Y direction	15
Size of inner and outer Beam	(500*500) and (450*500)mm^2
Size of inner and outer column	(700*700) and (500*500)mm^2
Thickness of Slab	125mm
Dead Load	11.5 KN/m
Live Load	3 KN/m
Grade of concrete	M20
Grade of reinforcing steel	Fe-415
Clear Cover	25mm
reinforcement	
Seismic Intensity	Severe
Importance factor (I)	1
Zone factor (zone IV & V)	0.24 & 0.36
Damping	5%
Height of building	3m
Response Reduction Factor (R) Special moment Resisting Frames (SMRF)	5
Type of Soil	Medium

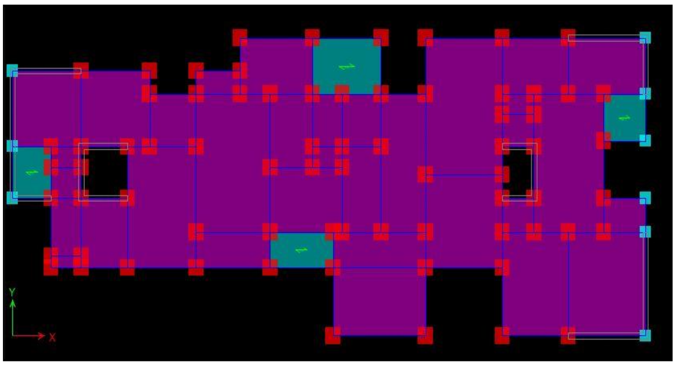

Figure 1: *Plan of Building*

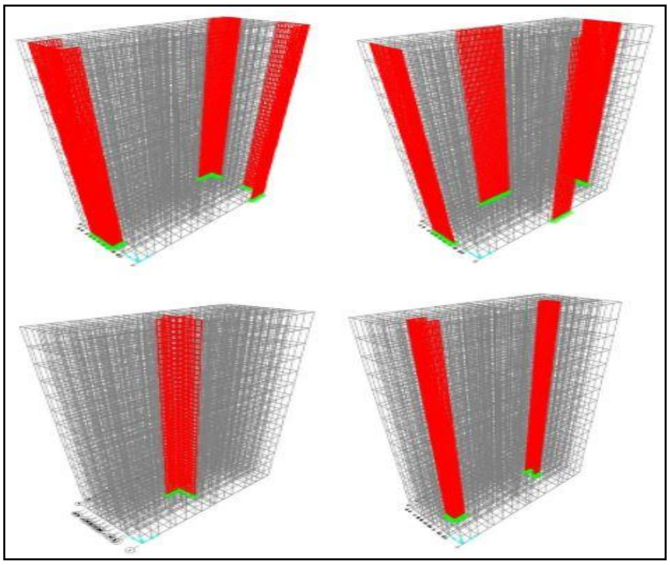

Figure 2: *Building model with shear wall provided along the corners, at centre, across periphery and around core walls*

Five models has been prepared based on the different positioning of shear wall:

Model-I – Model without Shear wall

Model-II – Model with Shear wall along the Corners

Model-III – Model with Shear wall at the Centre

Model-IV – Model with Shear wall across the Periphery

Model-V – Model with Shear wall provided around Core walls (lift)

4.1 LOADS ASSIGNED

The gravity loads on structure incorporates the weight of beams, slabs, columns and walls. The wall loads have been calculated as per the load calculations and assigned as uniformly distributed loads on beams. Rest is automatically considered by software itself. The Earthquake load is considered as per the IS 1893-2002. The loading was considered keeping in mind the zone factor, Response reduction factor, Importance Factor, type of soil.

Scale Factor = Z/2*I/R*Sa/g
= 0.2354 for Zone IV
= 0.3531 for Zone V
Live loads have been assigned as uniform area loads on slab elements as per IS 875(Part-2)
Live load on roof= 1kN/m^2

4.2 LOAD COMBINATIONS

The load combinations considered for the analysis and design is as per IS: 1893-2002.

4.3 ANALYSIS OF THE STRUCTURE

1) Equivalent Static method
2) Response Spectrum Analysis

4.3.1 EQUIVALENT STATIC METHOD

The natural period of the building is calculated by the expressions $T= 0.075 \times h^{0.75}$ *for* bare frame and $T = 0.09h/\sqrt{d}$ for in filled frame as given in IS 1893 (Part 1) -2002, wherein *h* is the height and *d* is the base dimension of the building in the considered direction of vibration. The lateral load calculation and its distribution along the height are done as per IS: 1893 (part 1)-2002. The seismic weight is calculated using full dead load plus 25% of live load.

4.3.2 RESPONSE SPECTRUM ANALYSIS

Response spectrum analysis of all the models are done .The parameters provided are Z=0.24 and 0.36, considering zone factor IV and Zone-V, Importance factor I=1, considering residential building. R=5.0, considering special RC moment resisting frame (SMRF).

[5] RESULTS AND DISCUSSION

From the results obtained from the equivalent static analysis and response spectrum analysis comparison is made for the five models in terms of displacement, storey drift and base shear.Comparison is also done between the linear equivalent static method and dynamic response spectrum method.

5.1 Lateral Displacement

As per the Indian Standard Code IS 1893-2002(Part-I) the permissible lateral displacement should not be more than *0.004* times the overall height of the building. The lateral displacement at the top story is *0.004*45 = 0.18 m or 18 cm* which is more than the displacement in X-direction and is allowable. Analysis of G+14 storied irregular geometrical frame model without shear wall and shear wall provided along the corners, across the periphery, at the centre and across the core walls is done using SAP 2000v19.1 software.

The results of the displacement in X-direction of each floor of different shear wall model situated in zone-IV and zone-V are shown in Fig-3.

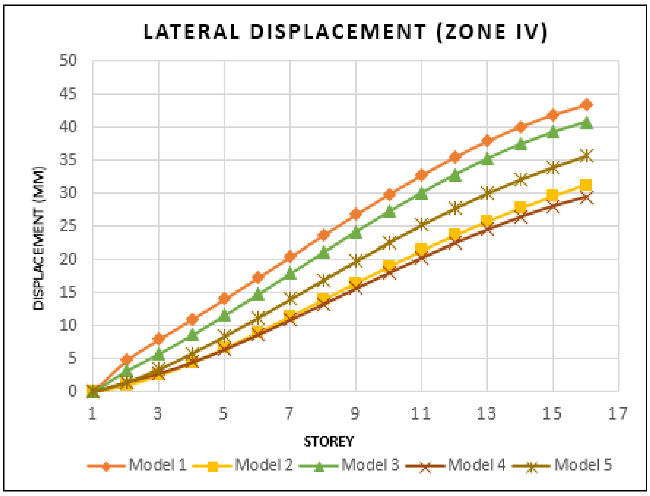

Figure 3: *Lateral Displacement in X-direction in Zone IV*

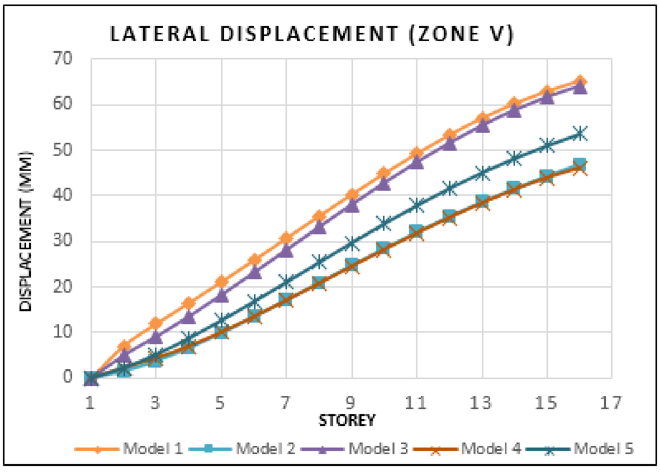

Figure 4*: Lateral Displacement in X-direction in Zone V*

In 1st case, building without shear wall, maximum displacement in 15th Story i.e. at the top floor is 65.17mm is in Zone-V and maximum displacement at the top floor in

Zone-IV is 43.45mm, which does not exceeds the permissible value given in IS 1893:2002 (part-I).

In Shear Wall Location 1 in model-II, where the shear wall is provided along the corners, maximum displacement in 15th Story is 31.25mm in Zone-IV and 46.87mm in Zone-V. It decreases about 34.30% in Zone-IV and 45.29% in Zone-V at the top floor of building compared to building without shear wall.

Displacement in Shear Wall Location 2 in model-III, where the shear wall position is at the centre of the building, it reduces to 40.83mm in Zone-IV and 59.07mm in Zone-V. The percentage reduction in displacement in all the story is 9.69% in Zone-IV and 15.67% in Zone-V as compared to building without shear wall model.

In Shear Wall Location 3 in model-IV, where the provision of the shear wall is across the periphery (outer walls of buildings), it has been observed there is maximum reduction in displacement of 29.48mm in Zone-IV and 44.14mm in Zone-V. Percentage reduction in in Zone IV is 42.00% and in Zone V is 47.28% compared to model without shear wall in X-direction.

In fifth case, Shear Wall Location 4 in model-V, where the shear wall is provided across the core walls (lift or elevators), in 15th story maximum displacement is reduced to 35.70mm in Zone-IV and 51.55mm in Zone-V. Percentage Reduction observed between the models is about 24.56% in Zone-IV and 29.97% in Zone-V as compared to building model without shear wall.

5.2 Storey Drift

Lateral (story) drift is the amount of side sway between two adjacent stories of a building caused by seismic loads. Horizontal deflection of a wall refers to its horizontal movement between supports under earthquake loading. Vertical deflection of a floor or roof structural member is the amount of sag under gravity or other vertical loading. Inter-story Drift is the difference between the roof and floor displacements of any given story as the building sways during the earthquake, normalized by the story height.

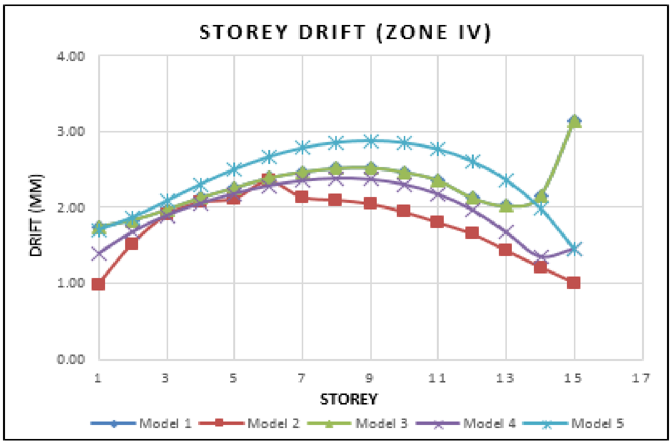

Figure 5: *Storey Drift in X-direction in Zone IV*

As per Clause no. 7.11.1 of IS 1893 (Part 1): 2002, the storey drift in any storey due to specified design lateral force with partial load factor of 1.0, shall not exceed 0.004 times the storey height. Maximum drift permitted = 0.004 x 3000 = 12mm and in our case it is satisfied and as permissible. In first case, building without shear wall, maximum story drift is in 15th Story and it is 3.15mm in Zone-IV and 7.07mm in Zone-V.

In the Fig 5, the storey drift of the models without shear wall and the models with shear wall in zone-IV has been obtained from the graphs and the comparison is made among the shear wall models along X-direction. The Interstory Drift obtained in Zone IV in model-I is 0.99 mm, in model-II is 0.54 mm, in model-III is 0.57 mm, in model-IV is 0.10 mm, in model-V is 0.54 mm. The percentage reduction in the storey drift along X-direction in shear wall models compared to model without shear in Zone-IV along model-II is 23.03%, in model-III is 19.67%, in model-IV is 13.60% and in model-V is 4.63%.

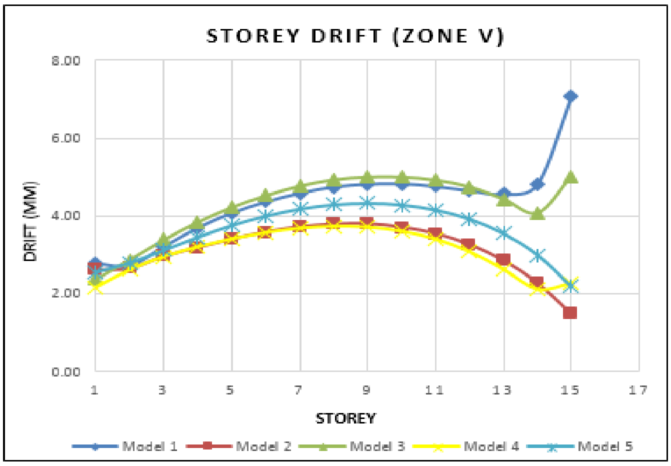

Figure 6: *Storey Drift in X-direction in Zone IV*

In the Fig 6, the storey drift of the models without shear wall and the models with shear wall in zone-V has been obtained from the graphs and the comparison is made among the shear wall models along X-direction. The Interstory Drift obtained in Zone V in model-I is 2.25 mm, in model-II is 0.79 mm, in model-III is 0.94 mm, in model-IV is 0.16 mm, in model-V is 0.81 mm. The percentage reduction in the storey drift along X-direction in shear wall models compared to model without shear in Zone-V along model-II is 28.83%, in model-III is 2.51%, in model-IV is 29.77% and in model-V is 18.51%.

5.3 Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Base shear of the building mainly depends on the value of zone factors.

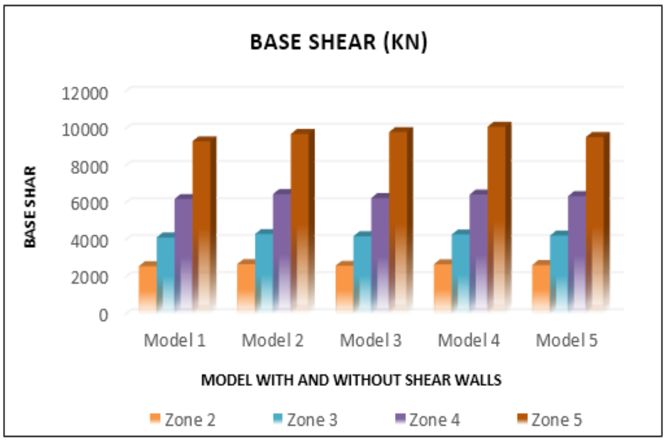

Figure 7: *Base shear in Models with and without S.W. along X-direction*

There has been change in the base shear in all models because of providing shear wall at the corners, center, along the periphery and across the core walls. Due to provision of the shear wall it is but obvious that the stiffness should be more and it resulting in the greater amount of base shear compared to building without shear wall. There has been slight increase in total base shear compared to building without shear wall. This is due to the seismic weight of the structure and weight of the shear wall.

Zone V has the slightly higher percentage increase in the base shear along X-direction compared to Zone -IV in model-IV and model-II. Model-III has lower increase in base shear among all models in zone-IV and zone-V.

5.4 Displacement Reduction Factor (DRF)

For comparing the performance of frames in the linear range of deformation Displacement reduction factor (DRF) has been introduced. It has been defined as the ratio of the maximum lateral displacement in the Base frame (D_{bf}) minus maximum lateral displacement in a frame with lateral load resisting elements called Shear wall (D_{tf}) divided by the maximum lateral displacement in the Base frame (D_{bf}).

$$DRF = \frac{Dbf - Dtf}{Dbf}$$

The larger value of the factor indicated more reduction in lateral displacement and more strength of the elements or the system.

Table 2: *Displacement Reduction Factor (DRF) in Zone-IV*

Storey	Model-II	Model-III	Model-IV	Model-V
1	0.79	0.33	0.69	0.69
5	0.48	0.15	0.50	0.35
10	0.35	0.03	0.38	0.23
15	0.28	0.09	0.32	0.18

Table 3: *Displacement Reduction Factor (DRF) in Zone-V*

Storey	Model-II	Model-III	Model-IV	Model-V
1	0.79	0.29	0.68	0.69
5	0.48	0.10	0.48	0.33
10	0.35	0.04	0.35	0.27
15	0.28	0.02	0.29	0.19

The displacement reduction factor is calculated between the model without shear wall and the four models with shear wall at different positions. Comparison is done to check the best positioning of the shear wall when there is much reduction in the displacement and the strength should be increased.

Due to providing the shear wall it is but obvious that the stiffness should be more and it resulting in the greater amount of base shear compared to building without shear wall.

Model-II and Model-IV has higher percentage reduction ratio compared to other models in Zone-IV and Zone-V among intermediate stories. As far as concern the base frame has higher percentage reduction in the ratio compared to other intermediate frames in Zone-IV and Zone-V.

5.5 Modal Time Period

Modal analysis is the analysis in which the overall mass and stiffness of a structure has a tendency to find the various periods at which it will naturally resonate. The modal time periods of vibration are very important to note in the effect of earthquake, as it is imperative that a building's natural frequency isn't match the frequency of expected earthquakes in the region in which the building is to be constructed. Fundamental natural period T is an inherent property of a building. Any alterations made to the building will change in its time period. Fundamental natural periods T of normal single storey to 20 storey buildings are usually in the range 0.05-2.00 sec. The time period of my building is also in this range and the structure vibrates in its 12 fundamental modes giving the detailed view of the structure.

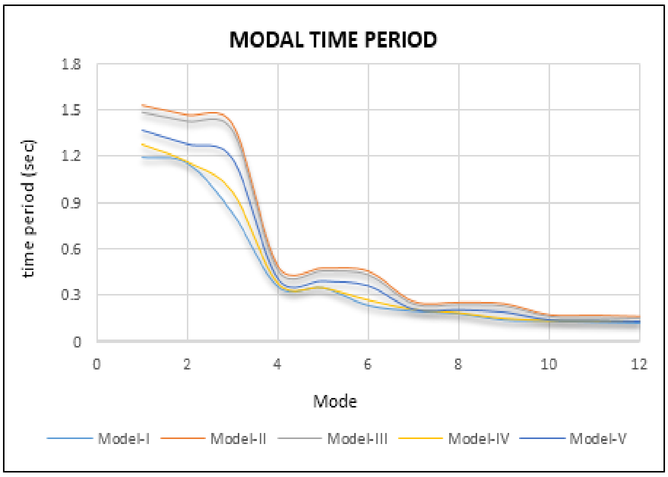

Figure 8: *Time Period of the Building*

The maximum time period of the structure in its fundamental mode is 1.5241 sec in model-I in which there is no provision of shear wall in the building and the minimum time period of the building is 0.1181 sec in model-II i.e. at Shear wall location 1, where the provision of shear wall is along the corners of the building. The modal time period of the building depends on the applied loading conditions, location and frequency. In all the models the time period of the building is nearly same.

[6] CONCLUSIONS

After the linear static and dynamic analysis of G+14 storied irregular geometrical framed building in Zone IV and Zone V with model without shear wall and models with shear wall, the conclusion drawn from the study of the results obtained in form of graphs are as follows:

1) In RSA, minimum displacement in X-Direction is in Shear Wall Location 3 followed by Shear Wall Location 1. Model without Shear Wall has maximum displacement compared to other models.

2) There has been maximum reduction in displacement is observed in Zone-V compared to Zone-IV. Zone-V has the maximum reduction in displacement in model-IV compared to other models.

3) It has been also observed that after providing the shear wall at the corners there has been 50% reduction in the displacement along Y direction compared to model without shear wall.

4) In Shear Wall Location 3 i.e. model-IV has maximum reduction in story drift at bottom floors compared to other models in Zone-IV compared to Zone-V. Model-II and Model-V has maximum reduction in Zone-IV compared to other Zones.

5) Zone V has the slightly higher percentage increase in the base shear along X-direction compared to Zone-IV in model-IV and model-II. Model-III has lower increase in base shear among all models in all four zones.

6) Model-II and Model-IV has higher percentage reduction ratio compared to other models in Zone-IV and Zone-V among intermediate stories.

7) As far as concern the base frame has higher percentage reduction in the ratio compared to other intermediate frames in Zone-IV and Zone-V.

8) Model-III has lower reduction factor among top stories in zone-IV and zone-V.

9) The maximum time period of the building is in model-I i.e. without shear wall model and minimum time period is in model-II and model-IV.

Hence, from the above studies and analysis conducted among five models, the most efficient location of shear wall is in ***model-II*** *i.e. shear wall provided along the corners* and ***model-IV*** *i.e. shear wall provided across the periphery*.

[7] REFERENCES

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