THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Study of an Irregular Plan with Different Orientation of Shear Wall in a High Rise Structure

Shivanand C. Ghule
Assistant Professor, Department of Civil Engineering,
The Oxford College of Engineering, Bangalore, Karnataka, India
Sudeep H. C.
Assistant Professor, Department of Civil Engineering,
Yellamma Dasappa Institute of Technology, Bangalore, Karnataka, India
Rahul Ravindra Naik
UG Students, Department of Civil Engineering,
Yellamma Dasappa Institute of Technology, Bangalore, Karnataka, India
Rajesh H. B.
UG Students, Department of Civil Engineering,
Yellamma Dasappa Institute of Technology, Bangalore, Karnataka, India
Mukul S.
UG Students, Department of Civil Engineering,
Yellamma Dasappa Institute of Technology, Bangalore, Karnataka, India
Prithviraj B. R.
UG Students, Department of Civil Engineering,
Yellamma Dasappa Institute of Technology, Bangalore, Karnataka, India

Abstract:
Failure of reinforced concrete structures during the past earthquakes has taught us the importance of evaluation of the seismic capacity of the existing buildings. Presence of irregularities is considered as a major deficiency in the seismic behaviour of structures. Introduction of bracings and stiff shear walls are the popular methods of strengthening the buildings against their poor seismic performance. The usefulness of shear walls in the structural planning of multi-storey buildings has long been recognized. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. In this work dynamic analysis of an irregular plan with different orientation of shear wall location in the plan is carried out using ETAB software. Also attempt made to study behaviour of structure with openings in shear wall.

Keywords: *Shear wall, dynamic analysis, earthquake, irregular plan*

1. Introduction
In High rise structure with Asymmetric horizontal configuration, lateral loads & torsion are of importance, Lateral loads are premier one which will increase rapidly with increase in height. The structural system designed to carry vertical load may not have the capacity to resist lateral load or even if it has, the design for lateral load will increase the structural cost substantially with increase in number of storey. To achieve better performance in these high rise structures to overcome lateral load and torsion problems, special systems to resist these need to be adopted. Shear walls are one of the very effective solutions to sustain these lateral forces and they provide required stiffness and strength and good drift control and are simple to construct.

2. Objective of the Project
The objective of this study is to gain insight into the behaviour of plan irregular structure without and with shear wall in different locations of multi-storey building under various combinations of loads by static & dynamic analysis. The investigation on the behaviour and response of structure considered are carried out by using the finite element models in ETAB v9.7.4. The goals that are to be achieved:

- The effect of irregular plan on structural response under different loadings.
- The effect of openings in the shear wall on the performance of structure.
- Dynamic analysis of framed structures using Response Spectrum Method by CQC method using ETAB software has been investigated.
- Study the parameter like displacement, inter-storey drift and time period for all the models considered.

Support Condition	Fixed at base
Density of concrete	25 kN/m^3 (From Clause 19.2.1, IS 456-2000)
Grade of concrete	M 25
Grade of steel	Fe 415
Characteristic compressive strength of concrete (f_{ck}) for M25 grade	25 N/mm^2 (From Table-2, IS 456-2000)
Modulus of Elasticity of concrete	=5000$\sqrt{f_{ck}}$ (From Clause 6.2.3.1, IS 456-2000) = 5000x$\sqrt{25}$ = 25 x 10^3 N/mm^2
Poisson's ratio for concrete	0.2
Density of steel	7850 Kg / m^3
Modulus of Elasticity of steel	200 KN/mm^2 (From Clause 5.6.3, IS 456-2000)
Poisson's ratio for steel	0.3
Density of brick	2000 Kg / m^3

Table 1: General input data for analysis

3. Problem Formulation

A 30-storeyed (G+29) reinforced concrete building with irregular plan shape "L" with and without shear wall has been considered for the present study. The building considered for the study is asymmetric The plan area of building is 30m×30m with ground floor 5m in height & remaining all storey height is 3m each.

Dynamic analysis is carried out for all the models by response spectrum method.

Total 9 models are considered for the analysis, out of that 7 models were studied for different orientation of shear wall in plan and 2 models were studied for effect of opening in shear wall.

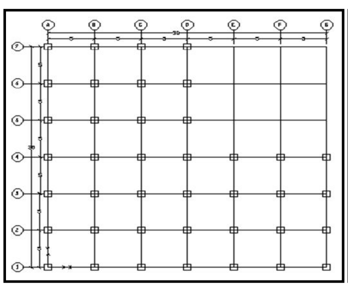


Figure 1: Model-1(M1)

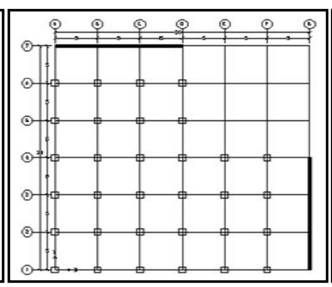


Figure 2: Model-2(M2)

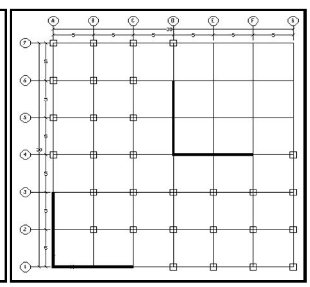


Figure 3: Model-3(M3)

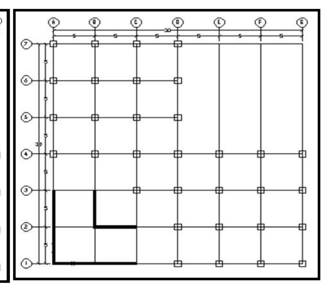


Figure 4: Model-4(M4)

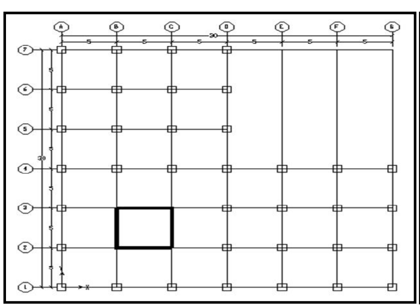


Figure 5: Model-5(M5)

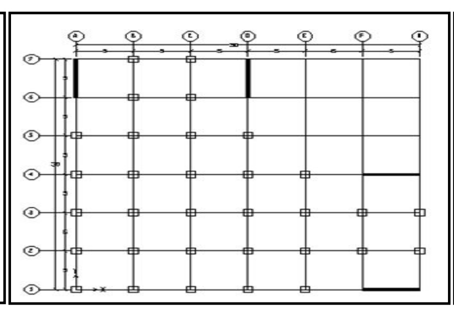


Figure 6: Model-6(M6)

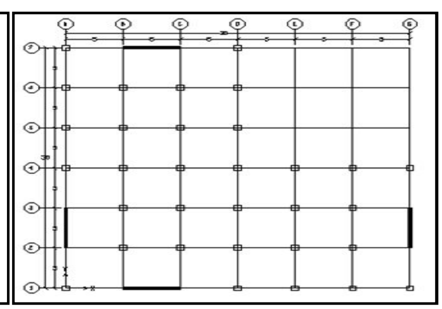


Figure 7: Model-7(M7)

Member	Size (mm)
Column	800x800 (BASE to Storey 10) 600x600 (Storey 11 to storey20) 500x500 (Storey 21 to Storey 30)
Beam	400x300 (Up to Storey 20) 300x300 (21 Storey to Storey 30)
Slab	150
Shear wall thickness	300

Table 2: Member sizes

Basic wind speed	50 m/s
Terrain Category	4
Life of structure	50 years
Class of structure	C
Risk coefficient, k_1	1
Topography, k_3	1 (Flat with upwind slope < 3 degree)

Table 3: Wind data

Zone factor, Z	0.36 (For Zone 5)
Importance Factor, I	1.0
Soil type	II (Medium)
Response reduction factor R	5 (Ductile shear wall with SMRF)
Percentage of imposed load considered during seismic load	25 %
Damping ratio	5%
Fundamental natural period(Time period)	0.5 seconds in X-direction & Y-direction
Eccentric ratio	0.05
Modal combination	Complete Quadratic Combination (CQC)
Directional combination	Square Root of the Sum of the Squares (SRSS)

Table 4: Earthquake data

4. Result and Discussions

4.1. For Different Orientation and Location of Shear Wall

Model	Displacement (mm)	% Reduction in displacement w.r.t to Bare frame (M1)
M1	751.1	-
M2	229.8	69.4
M3	243.4	67.5
M4	408.0	45.6
M5	464.0	38.2
M6	648.7	13.6
M7	553.6	26.3

Table 5: Maximum displacement values

4.1.1. Displacement

Dynamic analysis is carried out for model M1 to M7 by response spectrum method. The maximum displacement values for respective models are tabulated in the Table 5.

For better understanding purpose the displacement values of each storey of all the models are plotted in the below Figure.8

- It is observed that the displacement values of bare frame (M1) is more when compared with the models with shear walls (M2 to M7).
- In model M2, the maximum displacement is reduced by more than 69% when compared to bare frame model M1 due to the presence of shear wall at the end of ‘L’ section.
- Similarly for model M3, the reduction in displacement is found 67% this is mainly due to “L” shear wall at junction of two flange portion which provides rigidity at the corner of building where stress concentration will be more.
- Similarly for model M4 where the two parallel “L” shear wall at junction of two flange portion is provided and reduction in displacement found is 45% and for M5 tube type of shear wall provided and reduction in displacement is 38%.

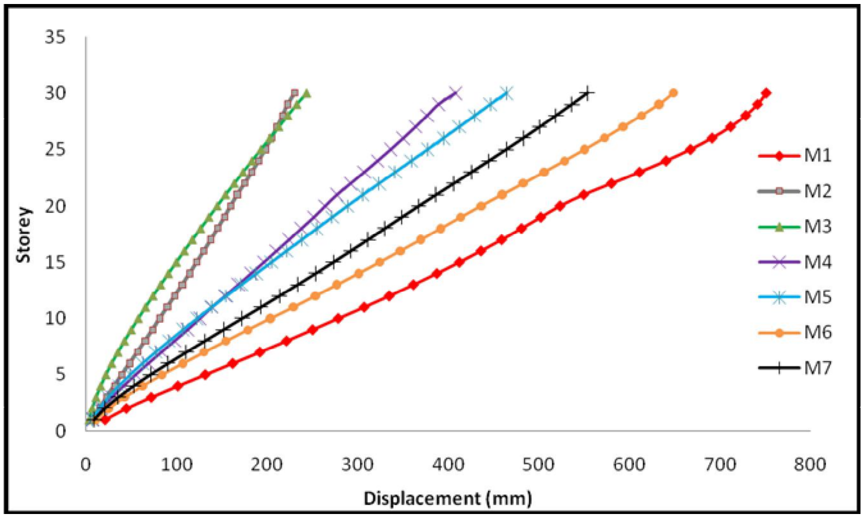


Figure 8: Comparison of displacement values for all models

4.1.2. Inter-Storey Drift

Model	Maximum Inter-Storey drift	% Reduction in Inter-storey drift w.r.t to Bare frame (M1)
M1	0.016495	-
M2	0.004695	71.5
M3	0.005898	64.2
M4	0.011014	33.2
M5	0.008022	51.3
M6	0.013903	15.7
M7	0.009265	43.8

Table 6: Inter-storey drift values

The maximum Inter-storey drift values for respective models are tabulated in the Table 6 for better understanding purpose the Inter-storey drift values of each storey of all the models are plotted in the below Figure.9.

- Performance of the Inter-storey drift is observed better in model M2 & M3 and reduction is found 60 to 70% less compared to bare frame due to stiffness provided by the shear wall in both X & Y direction.
- Model M6 provides less Inter-storey drift resistance out of all other model 15%.
- M5 & M7 also provide better inter-storey drift resistance.

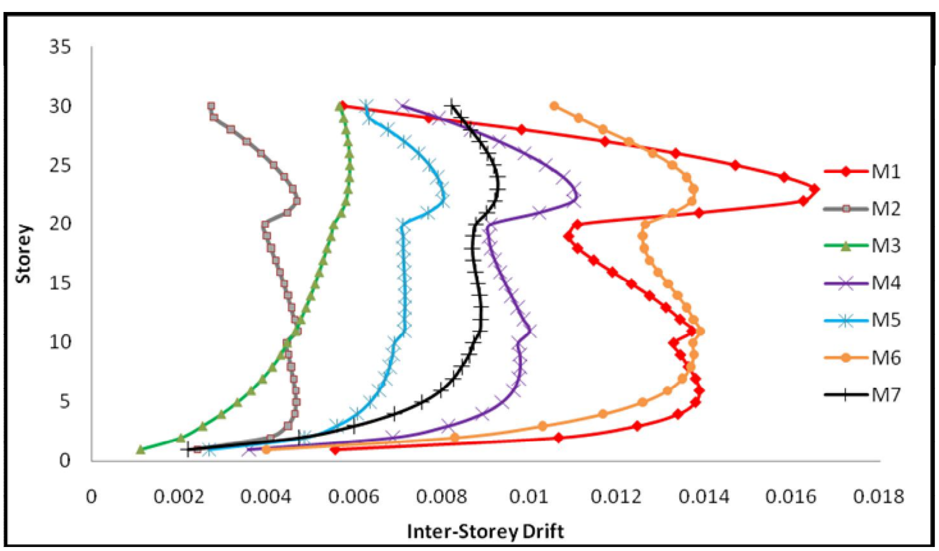


Figure 9: Comparison of Inter-storey drift values

4.1.3. Time Period

From Table 7 (below) and Figure.10 (below) it can be seen that time period value decreases by the addition of shear wall when compared to bare frame (M1).

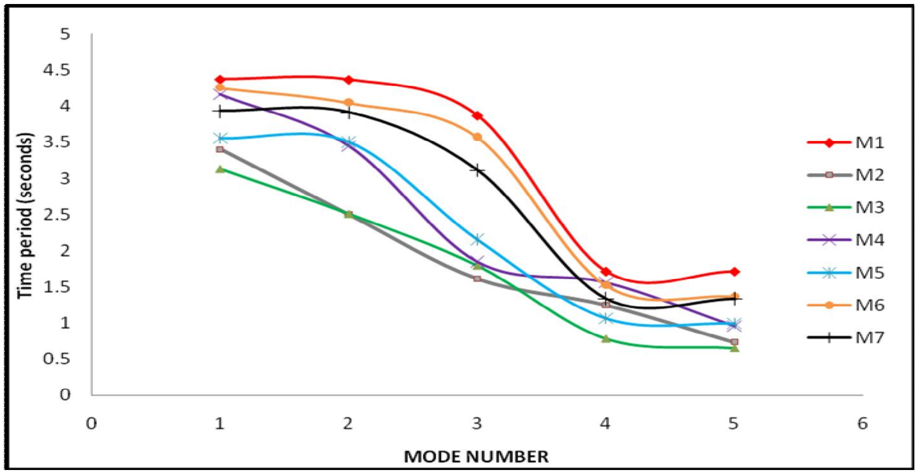


Figure 10: comparison of time period values for different modes

Model	Maximum time period (seconds)	% Reduction in time period value w.r.t to Bare frame (M1)
M1	4.37	-
M2	3.40	22.1
M3	3.13	28.3
M4	4.16	4.8
M5	3.55	18.7
M6	4.25	2.7
M7	3.93	10.0

Table.7: Maximum time period values

Time period is inversely proportional to stiffness of the structure.

That is $T = 2\pi\sqrt{\frac{m}{k}}$

Where T=time period

k= stiffness

m=mass

➢ Stiffness of the structure increases with the provision of shear wall. Hence time period which is inversely proportional to stiffness decreases with the provision of shear wall.

4.2. Result Discussion for Shear Wall with Openings

Sometimes openings are required in the wall for door or window, it is necessary to study the behaviour of structure under such openings. Openings are considered horizontally centered in the shear wall.

To study the effect of openings in shear wall, Model M2 plan is considered, 2 different opening Sizes as given in Table.8 are considered for study.

Details		Model designation
Without openings	Solid shear wall	M2
With Opening size (m) Width x Height	1.2 x 2.0	M8
	2.0 x 2.0	M9

Table.8: Building model with openings

Model	Displacement (mm)	% Increase in displacement w.r.t to solid frame (M2)
M2	229.8	-
M8	268.7	16.9
M9	277.4	20.7

Table 9: Maximum displacement values

4.2.1. Displacement

- Model M9 shows large displacement compared to solid frame M2 & M8 since the opening size provided is more in M9(26% opening) compared to M8(16% opening)
- Increase in displacement values are proportional to increase in opening size.
- Figure.11 it can be seen that displacement increases with provision of opening through shear wall when compared to solid frame (M2).

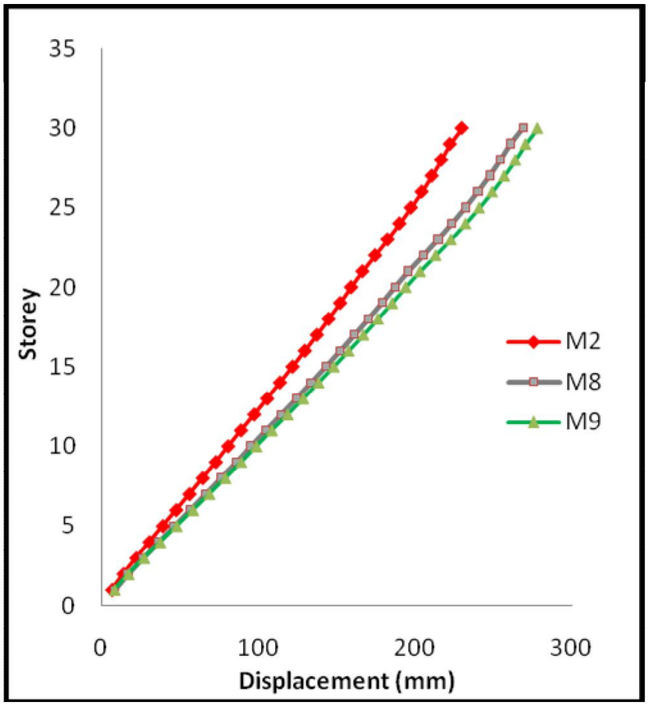


Figure 11: Comparison of displacement values

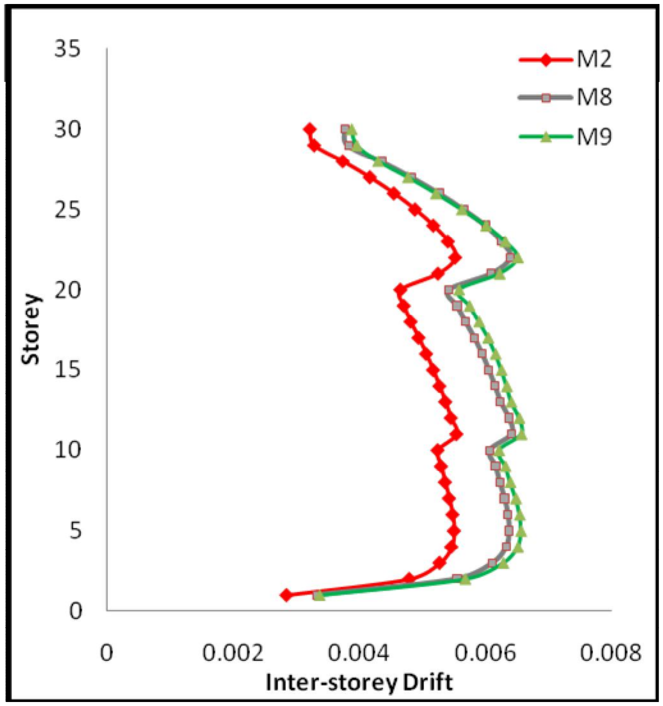


Figure 12: Comparison of Inter-storey drift values

Model	Inter-storey drift	% Increase in Inter-storey drift w.r.t to solid frame (M2)
M2	0.004695	_
M8	0.005433	15.7
M9	0.005562	18.4

Table 10: Maximum Inter-storey drift values

4.2.2. Inter-Storey Drift

Inter-storey drift values of each storey of all the models are plotted in the above Figure. 12

- It is observed that the Inter-storey drift values of solid frame (M2) are less than the models with openings (M8 & M9).
- From the above graphs, it is clear that as the opening size increase not only stiffness of frame decreases, this in turn also increases inter-storey drift due to torsion.
- Model M9 shows maximum increase in inter-storey drift among the models that is 18%.

Model	Maximum time period(seconds)	% Increase in time period value w.r.t to solid frame (M2)
M2	3.40	-
M8	3.59	5.6
M9	3.51	3.2

Table 11: Maximum Time period values

4.2.3. Time Period

- From below figure.13 it can be seen that time period value increases by the addition of openings in shear wall when compared to solid frame (M2).
- Time period which is inversely proportional to stiffness, by provision of window and door openings in the shear wall, the stiffness of frame effects.
- The decrease in stiffness of the frame depends on opening size provided in the shear wall, more the opening size, more the reduction in the stiffness of frame which results in increase in time period.

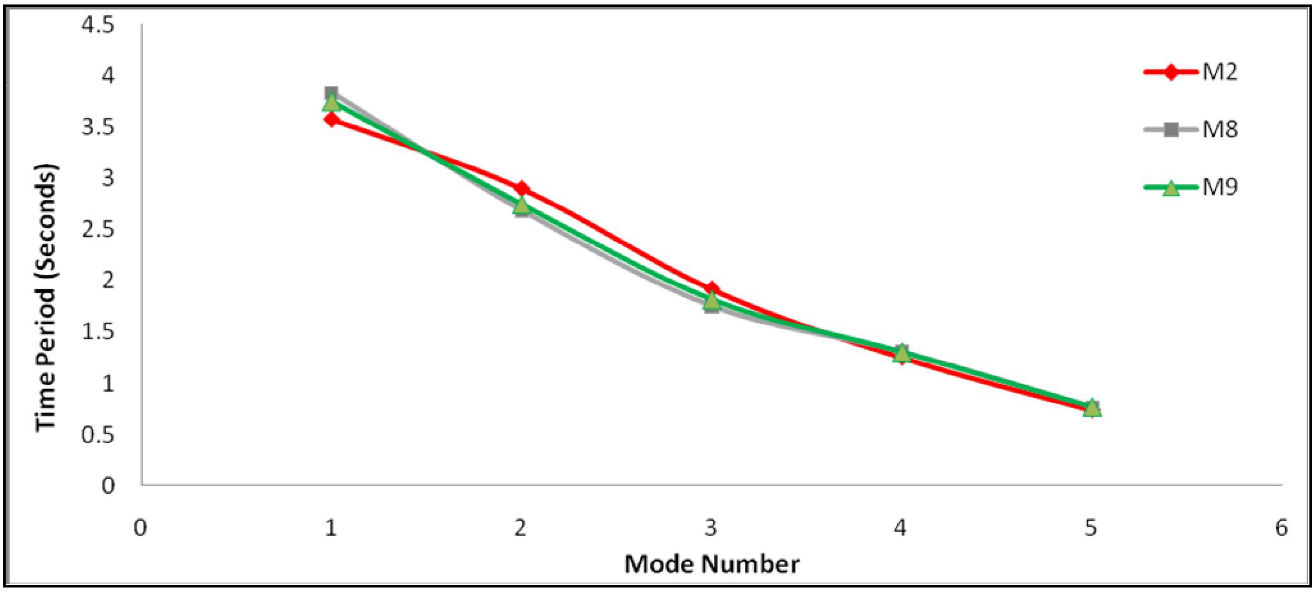


Figure 13: Time period values for different modes (opening)

5. Conclusions

In the present study, 7 models are analyzed for obtaining the optimum orientation and location of shear wall & another 2 models are analyzed for the study of effect of opening in shear wall on the performance of structure. The parameter considered for the analysis is displacement, inter-storey drift and time period. All the models are created and analyzed in ETAB v9.7.4. Based on the study following conclusions are drawn.

- Shear wall frame interaction is very effective in resisting horizontal forces resulting from earthquake and wind forces in high rise structure. By providing shear walls in proper orientation and location in the building plan, the damages to structure can be minimized.
- Most effective location of shear wall is along the outer periphery of the building especially at the corners and shear walls are very effective in contributing towards reduction of displacement, inter-storey drift and also torsion.
- Stiffness of building increases due to adding of shear walls.
- Behaviour of structures is affected by the size of the openings in shear wall. It is also observed that larger the area of opening in the shear wall of structure larger the displacements conceded by the structure and this trend increases with increasing story level.
- It is also understood that opening in shear wall placed in the plane of loading is more critical than that of opening in shear wall placed out of plane of loading.
- The stiffness as well as response of frame-shear wall structure is affected by the size of openings in the shear wall frame.
- It is observed that introduction of shear wall in structure results in the decrease of time period values and when openings are provided in shear wall, time period increases.
- It is advisable to say that before introducing opening in shear wall proper analysis should be made.

6. References

i. Dhiman Basu and Sudhir K. Jain, "Seismic Analysis of Asymmetric Buildings with Flexible Floor Diaphragms", published in Journal of structural Engineering, ASCE, August 2004, pp 1169 -1176

ii. Dr. S.K. Dubey , P.D. Sangamnerkar, "Seismic Behavior of Asymmetric RC Buildings", published in International Journal of Advanced Engineering Technology E-ISSN 0976-3945, IJAET, Volume II, Issue IV, October-December, 2011, pp 296-301

iii. Dr. B. Kameshwari et al. "Dynamic Response of High Rise Structures Under the Influence of Discrete Staggered Shear Walls" published in International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462, Volume 3, No.10 October 2011, pp 7789-7798

iv. Rucha S. Banginwar, M. R. Vyawahare, P. O. Modani, "Effect of Plans Configurations on the Seismic Behaviour of the Structure By Response Spectrum Method" published in International Journal of Engineering Research and Applications (IJERA), ISSN: 2248-9622, Vol.2, Issue 3, May-June 2012, pp.1439-1443

v. Anantwad Shirish, Prof. M.R.Wakchaure, Rohit Nikam, "Effect of Plan Irregularity on High-rise Structures" published in IJAIR, ISSN: 2278-7844, 2012, pp 143 - 147

vi. Burak.B. and Comlekoglu. H, "Effect of Shear Wall Area to Floor Area Ratio on the Seismic Behavior of Reinforced Concrete Buildings" published in journal of structural Engineering, 10.1061/(ASCE)ST.1943-541X.0000785, Dec.7, 2012

vii. Ravikumar C M, Babu Narayan K S, Sujith B V, Venkat Reddy D,"Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings" published in Architecture Research 2012, DOI: 10.5923/j.arch.20120203.01, 2(3), pp 20-26

viii. Bahador Bagheri, Ehsan Salimi Firoozabad, and Mohammadreza Yahyaei, "Comparative Study of the Static and Dynamic Analysis of Multi-Storey Irregular Building" published in International Science Index, Vol:6, No:11, 2012 , pp 1855-1859.

ix. Jaime Landingin, Hugo Rodrigues, Humberto Varum, António Arêde and Aníbal Costa, "Comparative Analysis of RC Irregular Buildings Designed According to Different Seismic Design Codes" published in The Open Construction and Building Technology Journal, 2013, Vol 7, pp 221-229.

x. Mohammed yousuf, P.M. shimpale, "Dynamic Analysis of Reinforced Concrete Building with Plan Irregularities" published in International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 3, Issue 9, September 2013, pp 110-116

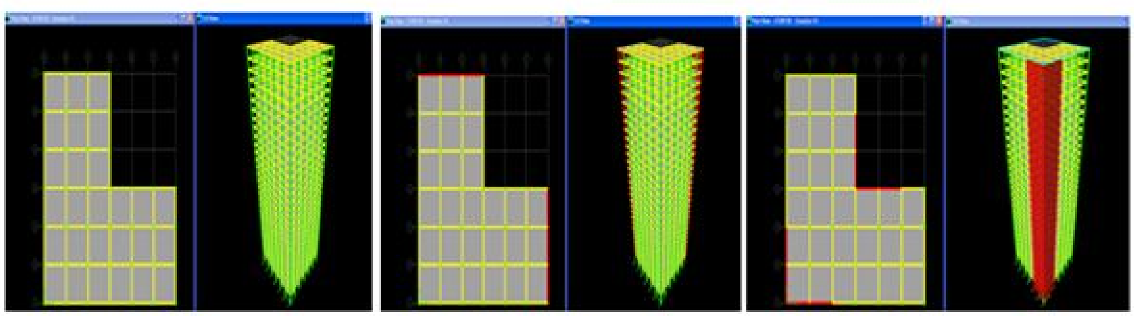
xi. Prof. Wakchaure M. R, Nagare Y U, "Effect of Torsion Consideration in Analysis of Multi Storey frame", published in International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 3, Issue 4, Jul-Aug 2013, pp.1828-1832

xii. Essam M. Awdy, Hilal A. M. Hassan, "Capacity of Open Rectangular Shear Walls" published in International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 1, January 2013 ISSN: 2319-5967 pp- 375-383

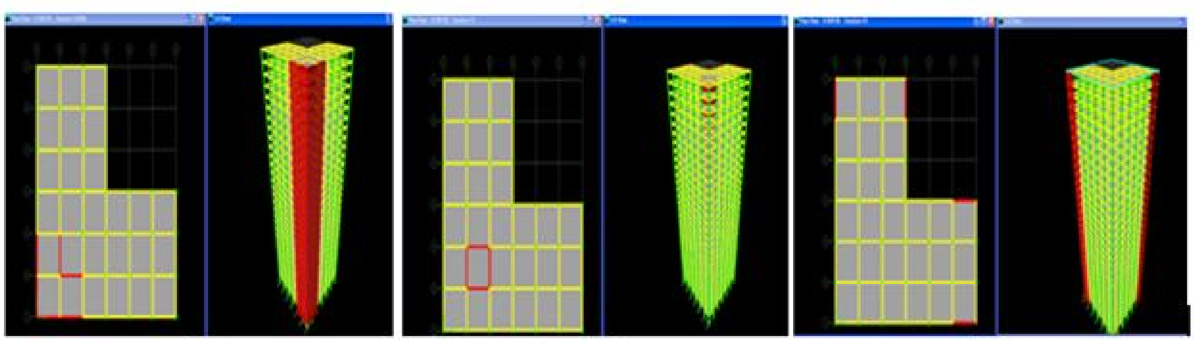
xiii. Le Yee Mon, "Comparative Study on Dynamic Analysis of Irregular Building with Shear Walls" published in International Journal of Science and Engineering Applications, Volume 3, Issue 2, 2014, ISSN-2319-7560, pp 22-30

ANNEXURE

ETAB models



M1 M2 M3



M4 M5 M6

M7 M8 M9