SEISMIC PERFORMANCE OF BUILDING FRAMES OF VARIOUS PLAN GEOMETRY WITH DIFFERENT INCIDENT ANGLE OF EARTHQUAKE FORCES

[1]Smrutee K. Shinde, [2]Dr. Mahesh G. Kalyanshetti
[1]P.G.Student, [2]Associate Professor
Department of Civil Engineering,
Walchand Institute of Technology, Solapur, Maharashtra, India

Abstract: The need of seismic analysis is to determine the behavior of structure during earthquake. Earthquake forces can act in any direction on the structure and also seismic performance depends on plan geometry of structure. Thus there is a need of identifying the incident angle and the shape of the structure which produces worst effect. In the present study three buildings of G+5, G+10 and G+15 of different plan geometry 'L' shape, 'Plus' shape, 'T' shape and 'Square' shape are considered for the analysis. The incident angles considered are'0^0', '30^0', '45^0' and '60^0'. The analysis is carried out by using ETAB software. The equivalent static method is considered for the analysis. The parameters considered for the analysis is Beam Bending Moment, Roof Displacement and Storey Drift. Based on the result obtained most effective shape of the building and the worst incident angle are identified.

IndexTerms **-Seismic Response, Equivalent Static Force Method, Incident Angle, Seismic Zone.**

I.INTRODUCTION

All over the world, there is much need of construction of high-rise buildings due to increase in population and urbanization. These multi-storey structures are unsafe when they are subjected to the earthquakes. Earthquake forces are unpredictable and last only for the small duration but cause severe damage to the structures and harm lives of people. Yearly near 1.5 crore people lose their lives due to the earthquake. The weakness of structures is due to the presence of irregularities in stiffness, strength and mass. Excess mass leads in reduction of ductility of vertical load resisting elements and increase inertia forces and thus increase the tendency towards collapse. Excess mass on upper floors has a more unfavorable effect than those at lower floors. Thus, there is the necessity of designing these structures for earthquake loading so that they sustain moderate to strong earthquake forces.

It is observed that symmetry of the building both in elevation and plan plays important role in the seismic performance. In the event of real earthquake the forces hit the structure in various directions and depending upon the stiffness of the structure in that direction the behavior depends. However the realistic simulation of earthquake is complex. Therefore there is a scope to study unsymmetrical structures and to evaluate their performances in point of overall stability. Performance of structure with different plan geometry having same plan area is observed to be different. Earthquake forces can act in any direction on the structure and therefore different incident angles are to be considered to identify the worst effect.

II.OBJECTIVE

The objective of the present study is to investigate the Seismic Performance of various unsymmetrical building frames using Equivalent Static Force Method. The results are obtained by analytical study using structural analysis software ETAB2016. Following are the objectives of proposed study.

1) To study the Seismic Performance of various building frame.
2) To study the effectiveness of building frames with various plan geometry.
3) To study the performance of building for different incident angle of earthquake forces.
4) To identify the best possible type of building shapes suitable for various earthquake.

III.PROTOTYPE BUILDING FRAME CONSIDERED FOR THE ANALYSIS

In the present work, four building frames are considered which are analyzed and designed as per codal provision. The plan geometry of structures considered are 'L' shape, 'Plus' shape, 'T' Shape and 'Square' shape. Dimensional characteristics are illustrated in Table 1.

Table 1 Geometric and Material Properties of Building Frames

Sr. No	Detail	Description		
1	Structure	OMRF	OMRF	OMRF
2	No. of stories	G+5	G+10	G+15
3	Storey Height	3 m	3 m	3 m
4	Grade of Concrete	M 20	M 20	M 20
5	Grade of Steel	Fe415	Fe415	Fe415
6	Bay width	3 m.	3m.	3 m.
7	Size of Column	0.50m x 0.50m	0.65m x 0.65m (upto 5storey) 0.50m x 0.50m (From 6-10storey)	0.75m x 0.75m (Upto 5storey) 0.65m x 0.65m (From6-10storey) 0.50m x 0.50m (From 11-15storey)
8	Size of Beam	0.4m x 0.3m	0.4m x 0.3m	0.4m x 0.3m
9	Live load	$3kN/m^2$	$3kN/m^2$	$3kN/m^2$
10	Seismic Zone	III	III	III
11	Importance Factor(I)	1	1	1
12	Response Reduction Factor	5	5	5
13	Slab Thickness	0.12m	0.12m	0.12m

IV. TYPICAL DETAIL OF G+15 BUILDING

The various plan geometry considered are shown in Fig no.1 to Fig no.4.

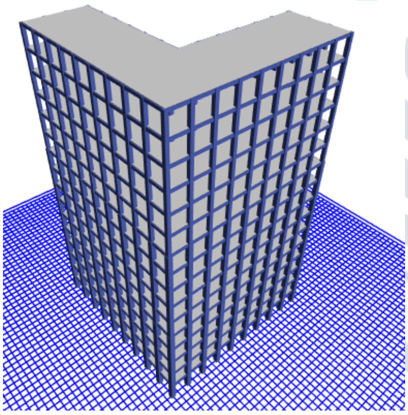

Fig 1(a). 3-D View

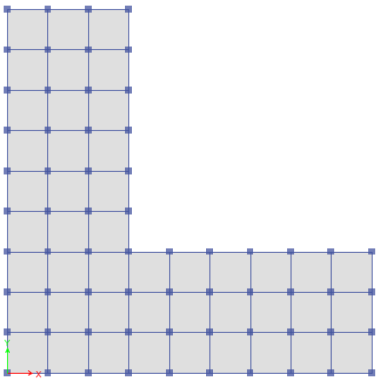

Fig 1(b). Plan View(0^0)

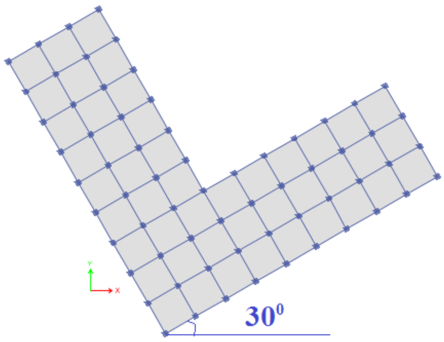

Fig 1(c). Plan View (30°)

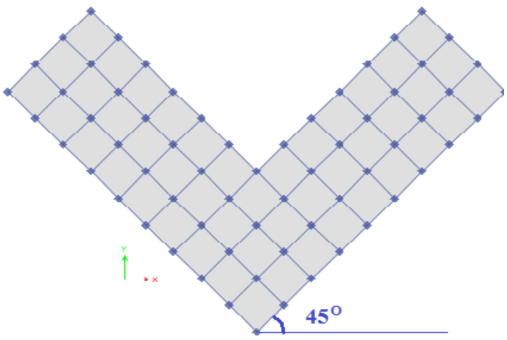

Fig 1(d). Plan view (45^0)

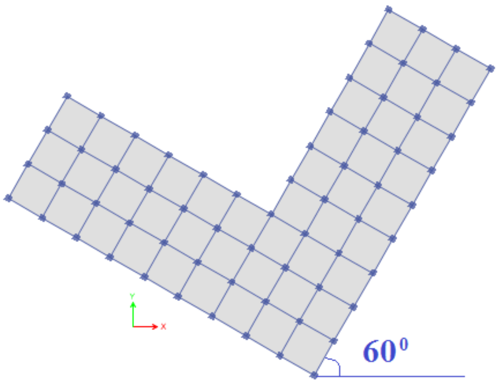

Fig.1(e). Plan view (60^0)

Fig 1. 'L' Shape Building

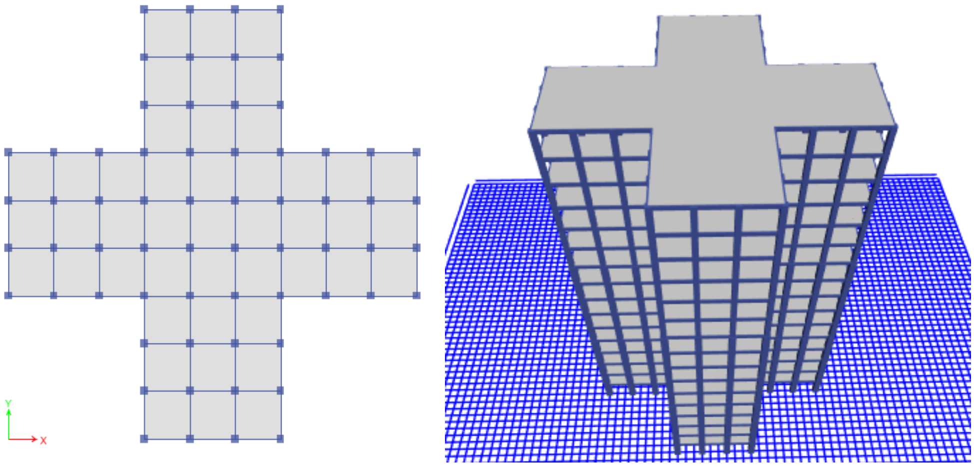

Fig 2(a). Plan View Fig 2(b). 3-D View

Fig 2. ‘Plus’ Shape Building

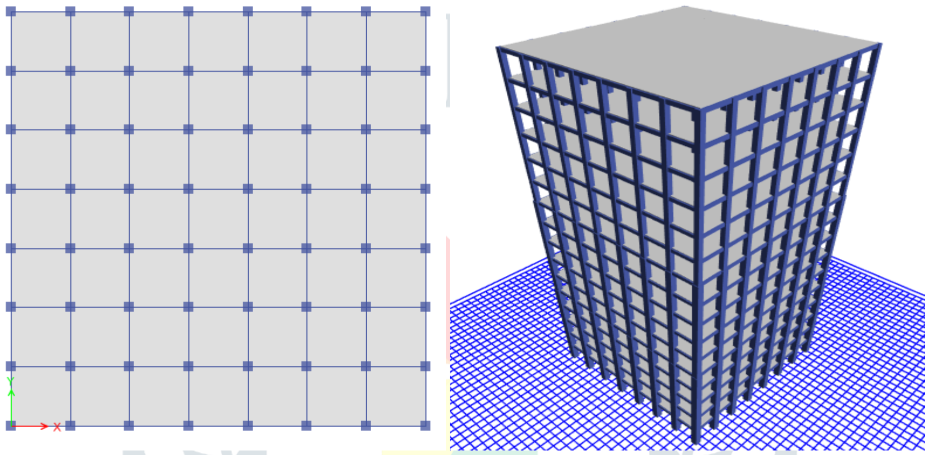

Fig 3(a). Plan View Fig 3(b). 3-D View

Fig 3. ‘Square’ Shape Building

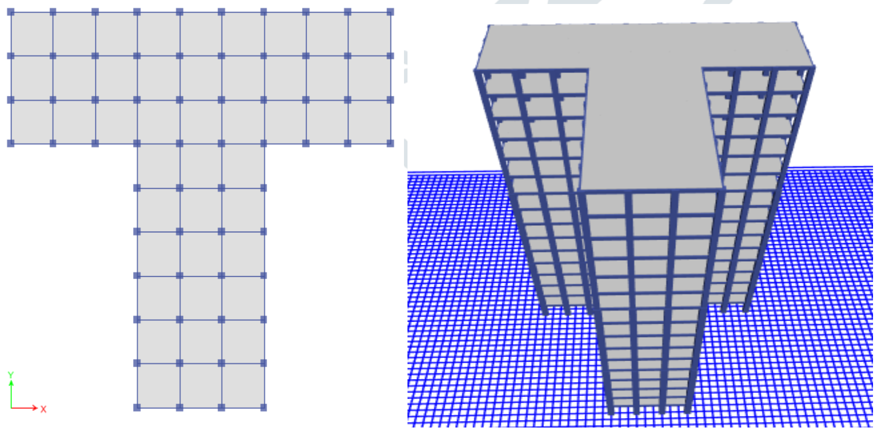

Fig 4(a). Plan View Fig 4(b). 3-D View

Fig 4. ‘T’ Shape Building

V. METHOD OF ANALYSIS:-EQUIVALENT STATIC METHOD

The method of finding design lateral forces is also known as static method or the equivalent static method or the seismic coefficient method. Mass in a building is subjected to an equivalent lateral force. Earthquake (Dynamic) force are idealised as equivalent static force. Design base shear is determined by following expression:

$$V_b = Ah*W$$

where, V_b= Total design lateral force at the base of a structure,

W= Seismic weight of a building
Ah= Design horizontal seismic coefficient for a structure

$$Ah = \frac{(ZISa)}{(2Rg)}$$

where, Z= Zone factor given in table 2,

Table 2 : Seismic Zone Factor

Seismic Zone	II	III	IV	V
SeismicIntensity (Z)	Low 0.10	Moderate 0.16	Severe 0.24	Very Severe 0.36

I= Importance factor (In accordance with IS 1893)
R= Response reduction factor (In accordance with IS 1893)
Sa/g= Average Response Acceleration Coefficient (In accordance with IS 1893)

VI. RESULTS

The analysis of all building frames with various plan configuration is carried out using equivalent static method in accordance with IS 1893. The results are also obtained for various incident angles i.e. 0^0, 30^0, 45^0, and 60^0.The responses studied are Beam Bending Moment, Roof Displacement and Storey Drift. These variation are presented in Fig no.5 to Fig no.13.

VI. I RESPONSE OF G+5 BUILDING FRAME

The variation of Beam Bending Moment, Roof Displacement and Storey Drift for various shape building for various incident angles is presented in fig no.5 to fig no.7.

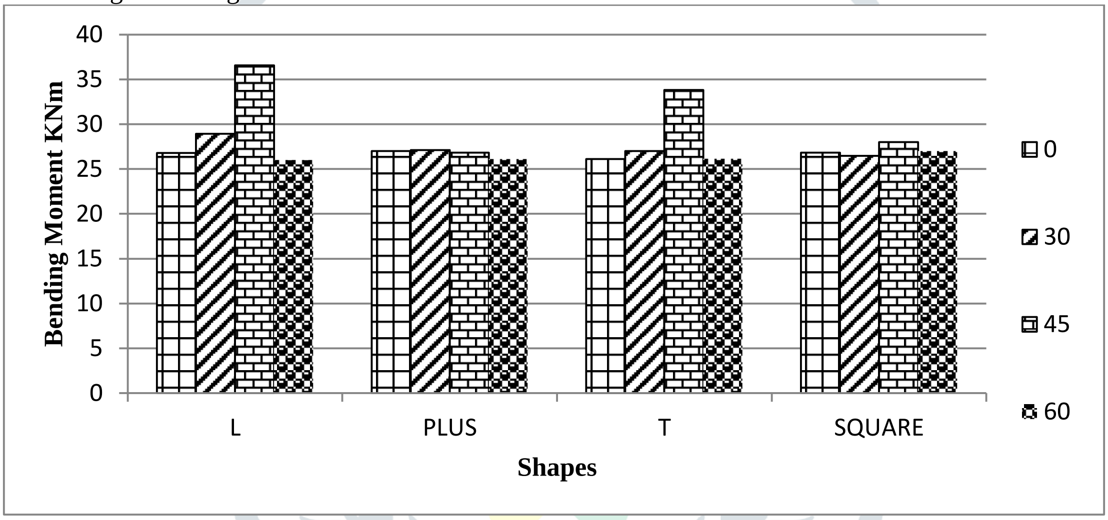

Fig. 5 Variation of Beam Bending Moment

- The BM is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.
- With increase in the incident angle, the BM goes on increasing from 0^0 to 30^0 by 9 to 10% and from 30^0 to 45^0, it increases by almost 25 to 30%. Further increase in the incident angle from 45^0 to 60^0 decreases the BM by 30%. Same trend is observed for 'T' shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as 'Plus' shape and 'Square' shape.

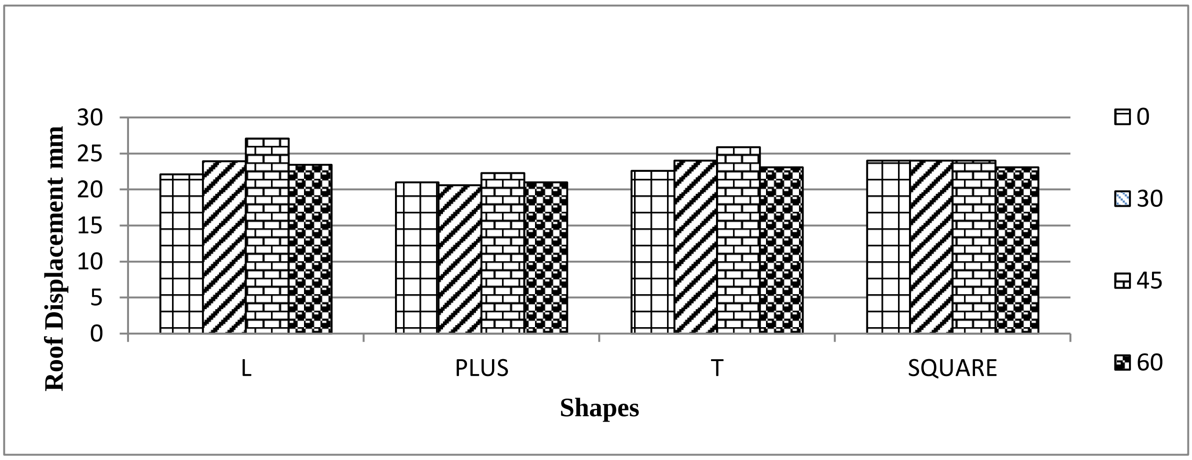

Fig. 6 Variation of Roof Displacement

- The Roof Displacement is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.
- With increase in the incident angle, the Roof Displacement goes on increasing from 0^0 to 30^0 by 8 to 10% and from 30^0 to 45^0, it increases by almost 12 to 15%. Further increase in the incident angle from 45^0 to 60^0 decreases the Roof Displacement by15to 17%. Same trend is observed for 'T' shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as 'Plus' shape and 'Square' shape.

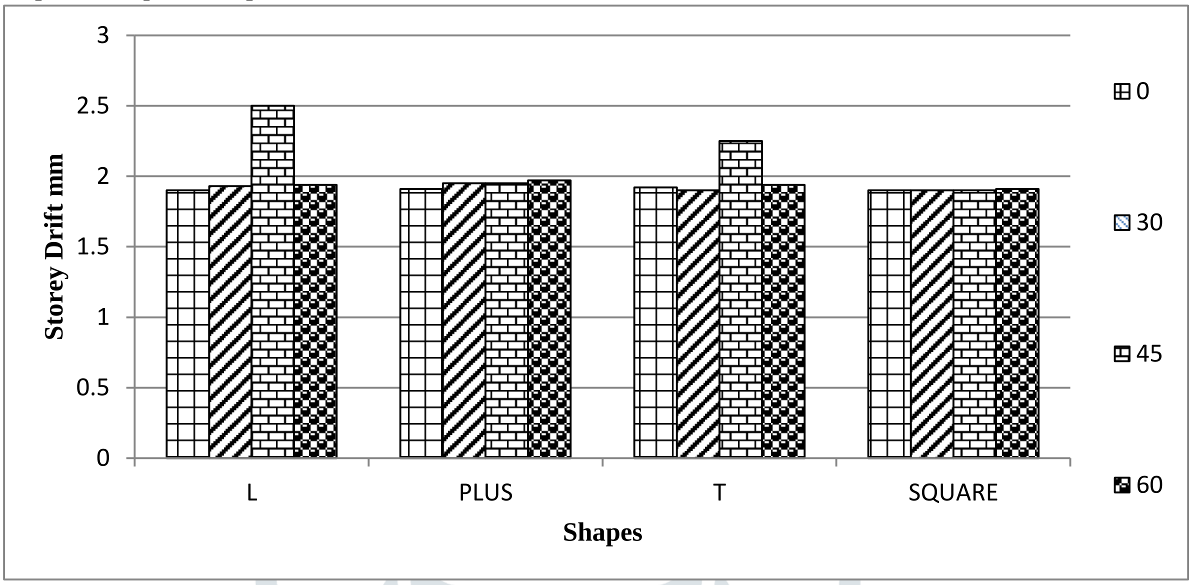

Fig. 7 Variation of Storey Drift

- The Storey Drift is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.
- With increase in the incident angle, the Storey Drift goes on increasing from 0^0 to 30^0 by 2 to 5% and from 30^0 to 45^0, it increases by almost 30 to 35%. Further increase in the incident angle from 45^0 to 60^0 decreases the Storey Drift by 20to 25%. Same trend is observed for 'T' shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as 'Plus' shape and 'Square' shape.

VI. II RESPONSE OF G+10 BUILDING FRAME

The variation of Beam Bending Moment, Roof Displacement and Storey Drift for various shape building for various incident angles is presented in fig no.8 to fig no.10.

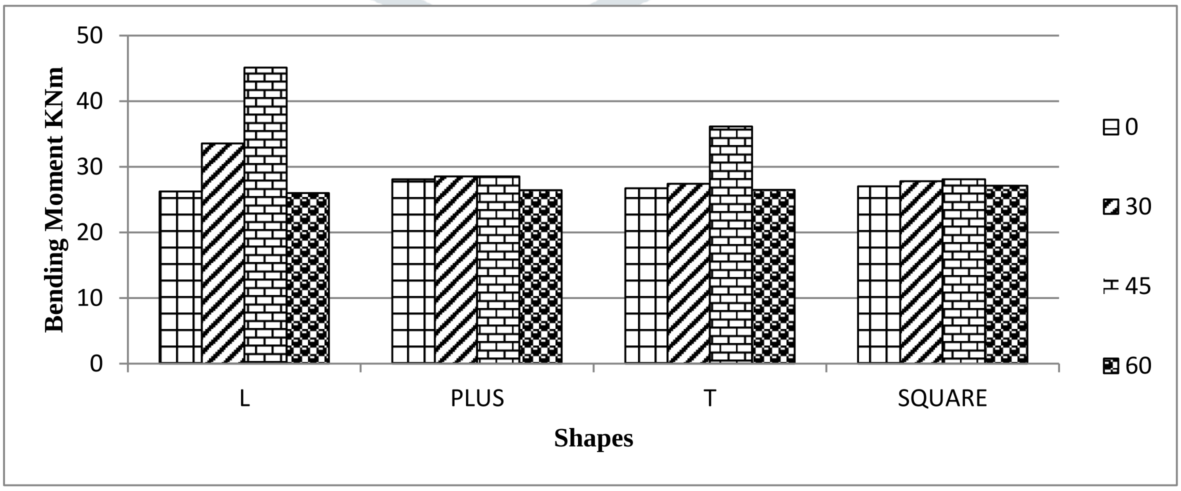

Fig. 8 Variation of Beam Bending Moment

- The BM is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.

- With increase in the incident angle, the BM goes on increasing from 0^0 to 30^0 by25 to 27% and from 30^0 to 45^0, it increases by 34 to37%. Further increase in the incident angle from 45^0 to 60^0 decreases the BM by 40to 45%. Same trend is observed for ‘T’ shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as ‘Plus’ shape and ‘Square’ shape.

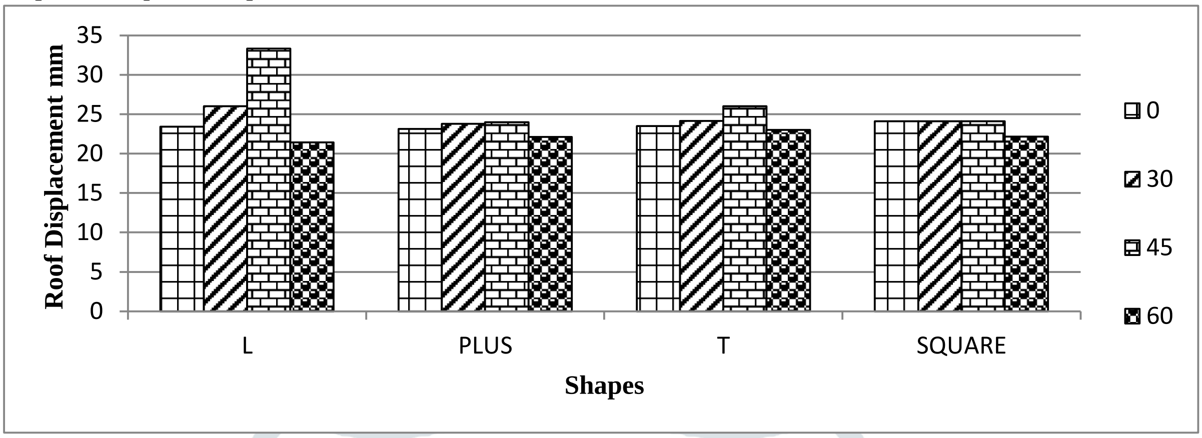

Fig. 9 Variation of Roof Displacement

- The Roof Displacement is observed to be higher in case of unsymmetrical building frame i.e. ‘L’ shape and ‘T’ shape. Whereas in case of ‘Plus’ shape and ‘Square’ shape it is observed to be lesser.
- With increase in the incident angle, the Roof Displacement goes on increasing from 0^0 to 30^0 by 11 to 15% and from 30^0 to 45^0, it increases by almost 25 to 30%. Further increase in the incident angle from 45^0 to 60^0 decreases the Roof Displacement by 35to 40%. Same trend is observed for ‘T’ shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as ‘Plus’ shape and ‘Square’ shape.

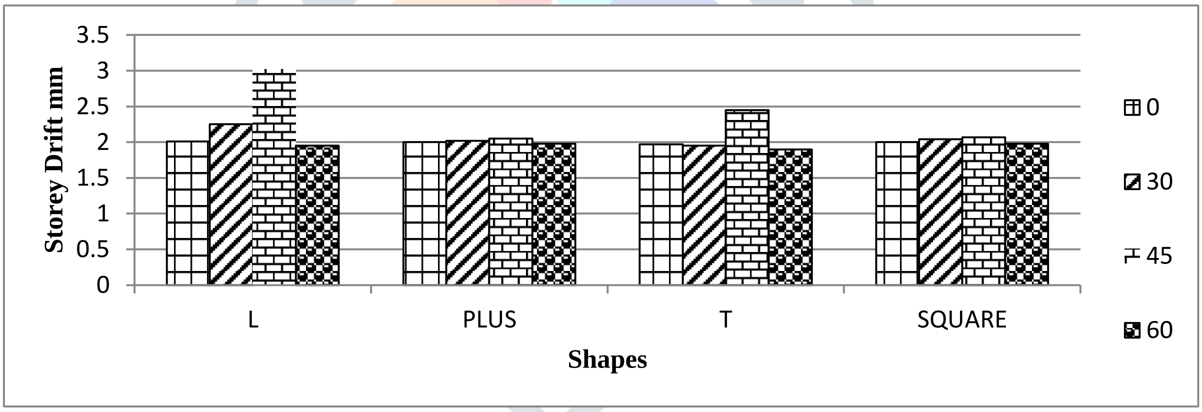

Fig. 10 Variation of Storey Drift

- The Storey Drift is observed to be higher in case of unsymmetrical building frame i.e. ‘L’ shape and ‘T’ shape. Whereas in case of ‘Plus’ shape and ‘Square’ shape it is observed to be lesser.
- With increase in the incident angle, the Storey Drift goes on increasing from 0^0 to 30^0 by11 to 15% and from 30^0 to 45^0, it increases by almost 33 to 38%. Further increase in the incident angle from 45^0 to 60^0 decreases the Storey Drift by 35to 40%. Same trend is observed for ‘T’ shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as ‘Plus’ shape and ‘Square’ shape.

VI. III RESPONSE OF G+15 BUILDING FRAME

The variation of Beam Bending Moment, Roof Displacement and Storey Drift for various shape building for various incident angles is presented in fig no.11 to fig no.13.

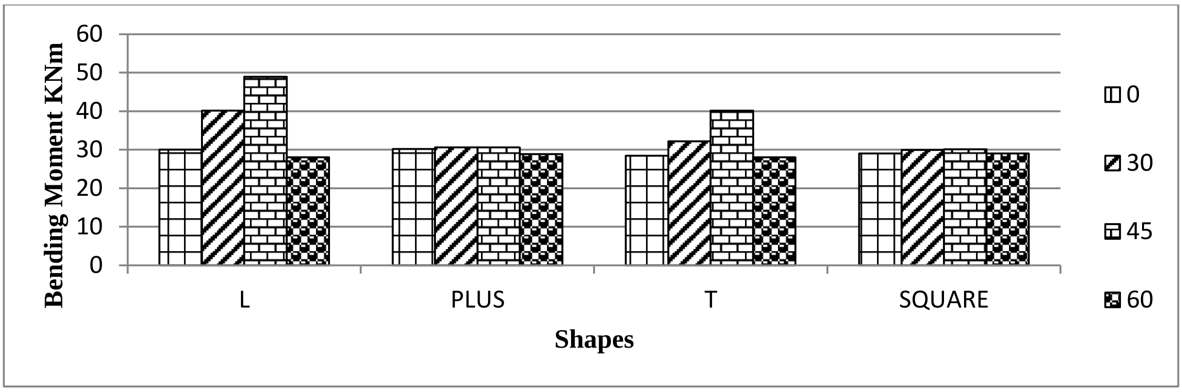

Fig. 11 Variation of Beam Bending Moment

- The BM is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.
- With increase in the incident angle, the BM goes on increasing from 0^0 to 30^0 by 32 to 34% and from 30^0 to 45^0, it increases by 22 to 25%. Further increase in the incident angle from 45^0 to 60^0 decreases the BM by 41 to 45%. Same trend is observed for 'T' shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as 'Plus' shape and 'Square' shape.

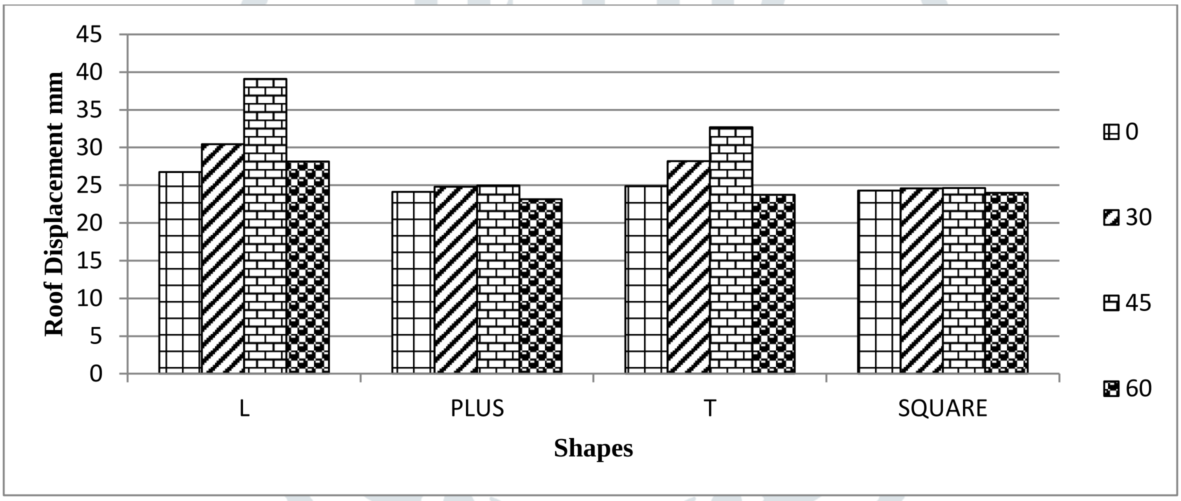

Fig. 12 Variation of Roof Displacement

- The Roof Displacement is observed to be higher in case of unsymmetrical building frame i.e. 'L' shape and 'T' shape. Whereas in case of 'Plus' shape and 'Square' shape it is observed to be lesser.
- With increase in the incident angle, the Roof Displacement goes on increasing from 0^0 to 30^0 by 13 to 15% and from 30^0 to 45^0, it increases by almost 27 to 30%. Further increase in the incident angle from 45^0 to 60^0 decreases the Roof Displacement by 26 to 30%. Same trend is observed for 'T' shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as 'Plus' shape and 'Square' shape.

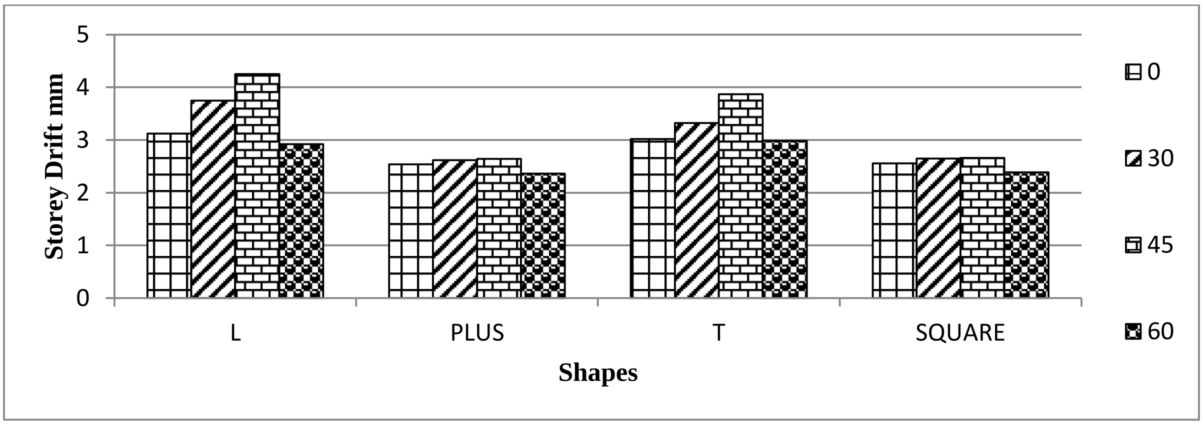

Fig. 13 Variation of Storey Drift

- The Storey Drift is observed to be higher in case of unsymmetrical building frame i.e. ‘L’ shape and ‘T’ shape. Whereas in case of ‘Plus’ shape and ‘Square’ shape it is observed to be lesser.
- With increase in the incident angle, the Storey Drift goes on increasing from 0^0 to 30^0 by 19 to 21% and from 30^0 to 45^0, it increases by almost 25 to 30%. Further increase in the incident angle from 45^0 to 60^0 decreases the Storey Drift by 31to 35%. Same trend is observed for ‘T’ shape.
- Variation in the incident angle is observed to be ineffective in case of symmetric building frames such as ‘Plus’ shape and ‘Square’ shape.

VII. COMPARISION OF BUILDINGS OF VARIOUS STORIES

It is observed that ‘L’ Shape building frame produces higher Beam Bending Moment, higher Roof Displacement, and higher Storey Drift. Also out of the four incident angle, at an angle of 45^0 the responses are observed to be greater. The variation of Beam Bending Moment, Roof Displacement and Storey Drift for various shape building for 45^0 incident angle is presented in fig no.14 to fig no.16.

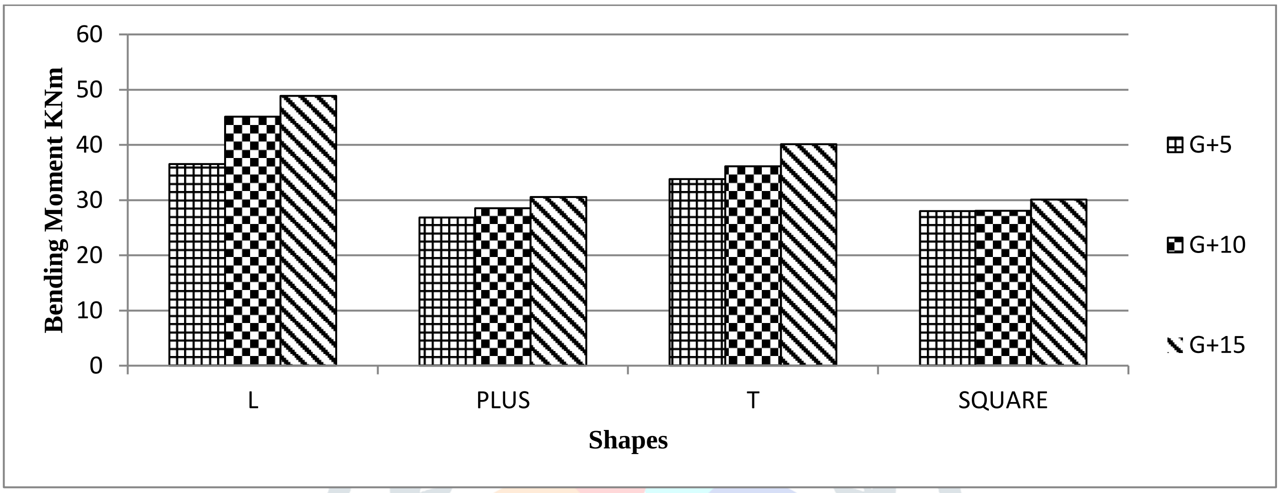

Fig. 14 Variation of Beam Bending Moment

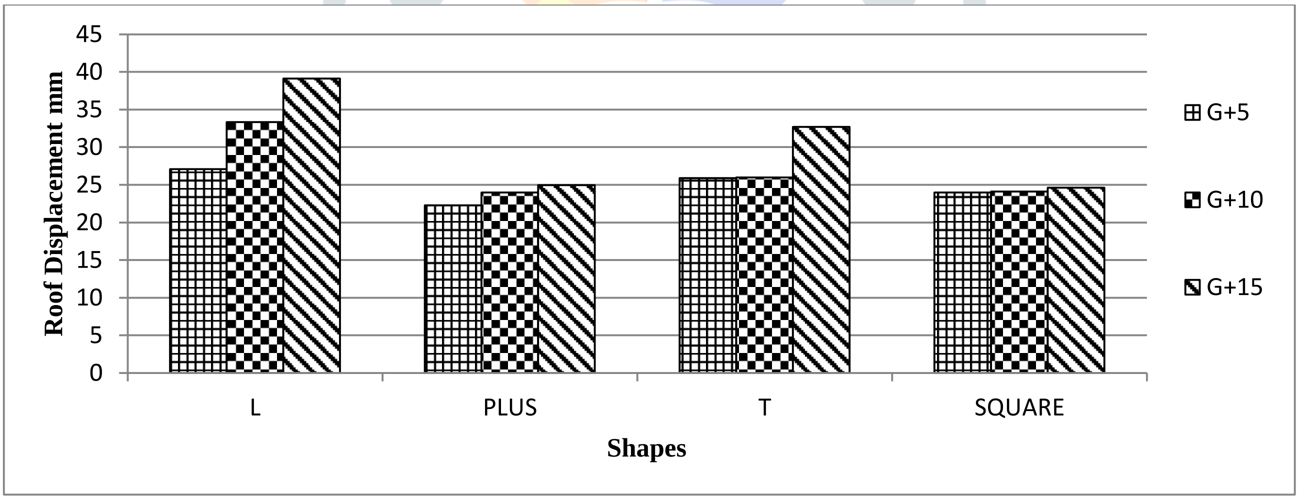

Fig. 15 Variation of Roof Displacement

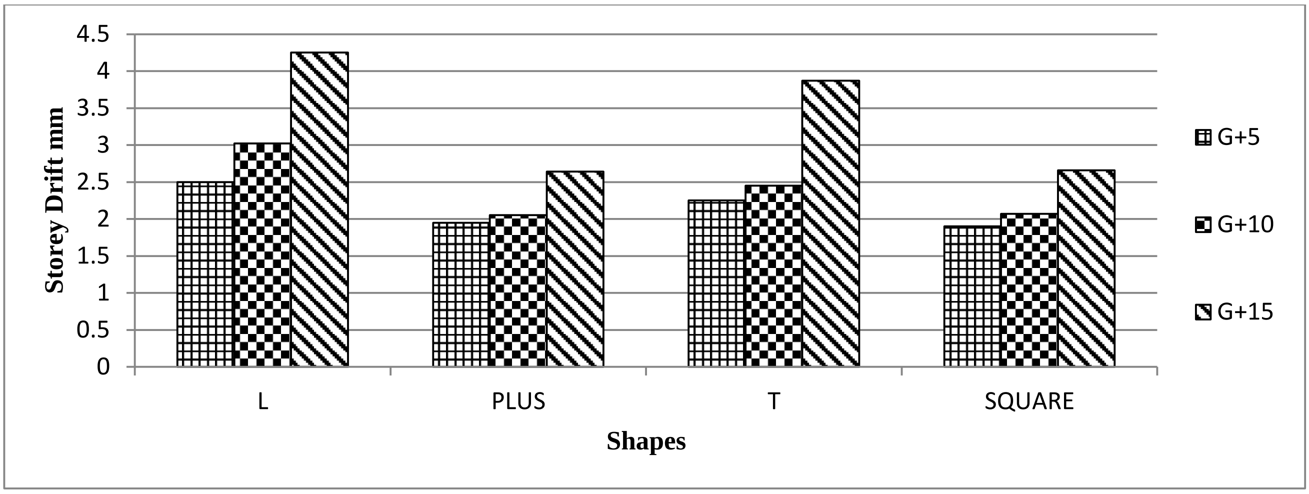

Fig. 16 Variation of Storey Drift

- The Beam Bending moment, Roof Displacement and Storey drift goes on increasing with increase in the number of storey.
- The rate of increase in the Beam Bending Moment, Roof Displacement and Storey Drift are observed to be higher for 'L' Shape building as compared to 'Plus 'Shape' , 'T' Shape and 'Square' Shape.

VIII.CONCLUSION

The study is carried out on four building frames having "L" Shape, "Plus" Shape, "T" Shape and "Square" Shape with different plan geometry.The parameters considered for the analysis is Beam Bending Moment, Roof Displacement and Storey Drift. Based on the result obtained most effective shape of the building and Beam Bending Moment, Roof Displacement and Storey Drift on different models are determined by using Equivalent Static Method. Following are the conclusion

1. The study reveals that the structure behaves differently for different plan geometry and for different incident angle of earthquake forces.
2. The parameters are observed to be higher in case of 'L' shape building frame indicating that unsymmetrical structure are less effective in resisting the earthquake forces. Also it is observed that symmetric building (Plus shape, Square shape) derives better resistance to earthquake forces. Hence symmetric structures are recommended which derives more strength and stability.
3. The incident angle of earthquake force plays an important role in the seismic performance of the structure. It is observed that unsymmetrical structure ('L' shape, 'T' shape) are more sensitive to incident angle. Study reveals that inclination from 0° to 30° increases the response by almost 22-25% and from 30° to 45°, it increases by 30to 32%. Further increase in the inclination from 45° to 60° decreases the responses. Thus it is concluded that the buildings are subjected to severe effect when the incident angle is around 45°. So stability of the structure along the diagonal is to be verified to ensure overall safety and stability of structure.
4. From G+5 to G+10, Beam Bending Moment, Roof Displacement and Storey Drift increase upto12-15% whereas from G+10 to G+15, eam Bending Moment, Roof Displacement and Storey Drift increase by17- 22. The rate of increase is mild from G+5 to G+10; from G+10 to G+15 it is steeper.

IX. ACKNOLEDGMENT

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X.REFERENCES

1) Ms. Medini Deshpande , Dr. M.G.Kalyanshetti and Dr. S.A.Halkude, Performance Of Multi Storied Building For Various Locations Of Shear Wall. International Journal Of Latest Trends In Engineering and Technology. Vol.(8) Issue(3)
2) SA Halkude, MG Kalyanshetti, VD Ingle, Seismic Analysis Of Buildings Resting On Sloping Ground With Varying Number Of Bays And Hill Slopes. International Journal OF Engineering Research And Technology, Volume: 02 Issue:12 2013
3) Dr. M.G.Kalyanshetti, Mr. Amit Wale, Seismic Performance Of Building Frame Considering Soil Structure Interaction (SSI). International Journal of Research In Engineering Technology, Volume: 07 Issue:08 August 2018
4) J Narla Mohan, A. Mounika Vardhan M.Tech (Structural Engineering), Department of Civil Engineering, Vishwa Bharati College of Engineering. Analysis of G+20 RC Building in Different Zones Using ETABS. International Journal of Professional Engineering Studies. Volume VIII /Issue 3 / MAR 2017

5) Mohaiminul Haque, Sourav Ray, Amit Chakraborty, Mohammad Elias, Seismic Performance Analysis of RCC Multistoried Buildings with Plan Irregularity. American Journal of Civil Engineering
6) Dileshwar Rana, Prof. Juned Raheem, Seismic Analysis of Regular and Vertical Geometric Irregular RCC Framed Buildings. International Research Journal of Engineering and Technology, Volume: 02 Issue:04 July 2015
7) T. Prasanthi ,Asst. prof. P. M. Lavanya ,To study of seismic analysis and design for different plan configuration in structural behavior of multistory RC framed building. IJIRT Volume: 03 Issue:10March 2017
8) R.Deccan Chronicle, Mohammed Anwarullah, Abdul Rashid, Dr. P. Siva Prasad ,Analysis and Design of High-Rise RC Structure in Different Seismic Zones. International Research Journal of Engineering and Technology (IRJET) ,Volume: 05 Issue: 03 March 2018
9) Jamandla Ramakrishna,Shyamla Sunil Pratap Reddy, Syed Viqar Malik, Seismic Analysis of Four Storey Build Using Equivalent Static Method. Global Journal Of Engineering Science And Researches
10) Abrar Ahmed, Prof. Shaik Abdulla, Prof. Syed Arfat, Seismic Analysis On Building With Horizontal And Vertical Irregularities. International Journal of Advance Engineering and Research Development, Volume: 04 Issue:09September 2017
11) Dr. K. Subramanian and M. Velayutham, Influence of Seismic Zone Factor and the International Codal Provisions for Various Lateral Load Resisting Systems in Multistory Buildings.
12) P. Pravin Venkat Rao, L. M. Gupta ,Effect of Seismic Zone and Story Height on Response Reduction Factor for SMRF Designed According to IS 1893(Part-1):2002
13) IS 1893 (part 1), Indian Standard Criteria for Earthquake Resistant Design of Structures (Bureau of Indian Standards, New Delhi, 2002
14) IS: 456, (2000), Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi
15) IS: 875 (Part 2): Code of Practice for Design Loads (Other than Earthquake) For Buildings and Structures. Part 2: Imposed Loads (Second Revision) (1987).
16) IS: 13920, (1993), Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces, Bureau of Indian Standards, New Delhi.
17) Chopra A.K., (2012), Dynamics of Structures – Theory and Application to Earthquake Engineering, Fourth Edition, Prentice Hall Inc.USA.