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Seismic Behavior of Symmetrical & Unsymmetrical Structure with Cantilever Section

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Abstract*— This project performance of the torsionally balanced and torsionally unbalanced structure also called as symmetrical and unsymmetrical structure. In this project the effort is made to study the effect of eccentricity between centre of mass (CM) and centre of stiffness (CR) on the performance of the buildings. Two buildings of storey (G+12) are used in this paper, likes Symmetrical with cantilever section and Unsymmetrical with cantilever section. The performance of a multi-storey framed building during study earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. During earthquake there is strong earth shaking, hence earthquake resistant design of structures is required. As now day's unsymmetrical structures with cantilever sections are used to utilize area and available space in very efficient way. So, it is required to study the seismic behavior of unsymmetrical structures with cantilever section. In such type of structures, the centre of mass of the buildings does not correspond with the centre of resistance. This leads to inordinate edge deformation and shear forces in the unsymmetrical structure compared to symmetrical structure. Hence, by reducing the difference between the centre of mass and centre of stiffness, torsion effects can be minimized. The Dynamic response of the building during the times of seismic irregularities depends on the stiffness characteristics of the building. The objective study is the comparison of sections used in large span unsymmetrical cantilever structures to minimize the effect of torsion. The study is primarily focused on the deflections of cantilevers of large spans under different loading conditions such as dead load, live load and seismic load. The study also focuses on, to identify an appropriate technique suitable for analysis of large span cantilevers with in unsymmetrical structure.

Keywords*— Cantilevers, seismic, Symmetrical Structure with cantilever section, unsymmetrical Structure with cantilever section, response-spectrum Analysis, ETABS.

I. INTRODUCTION

In the present scenario, the unsymmetrical structure with a large span cantilever section is being constructed which causes irregularities such as soft storey, unsymmetrical layout, torsion irregularity, etc. Therefore, seismic analysis of a large span cantilever in an unsymmetrical structure is important. As during earthquake, there is strong earth shaking therefore to resist this shaking, seismic analysis and design of structures is required. In this report, an attempt has been made to study the seismic behavior of unsymmetrical structure with cantilever sections. In this type of structure, the center of mass of building does not correspond with the center of resistance, due to this there is inordinate edge deformation and shear force in unsymmetrical structures. As larger the eccentricity between the center of stiffness and the center of mass, larger the torsion effects. Hence by reducing the difference between the center of mass and center of stiffness the torsion effects can be minimized. This study also focuses on the deflection characteristics of cantilevers of large span in unsymmetrical structures under different loading conditions. This study also focuses on the deflection characteristics of cantilevers of large span in unsymmetrical structures under different loading conditions. Hence the study of seismic behavior of large span cantilevers is one of a major part of seismic analysis and design of unsymmetrical structures. Unsymmetrical buildings are more vulnerable to damage due to seismic excitation or earthquakes because of the coupled torsional effects and unsymmetrical edge deformation. Eccentric mass due to temporary storage of materials leads to an unsymmetrical distribution of lateral loads causing torsional failures. A loss of symmetry causes torsional effects that might be difficult to detect and have serious consequences. The subject of earthquake-induced torsion in buildings is extremely old, and despite a lot of attention in recent decades, it remains unsolved. This is evidenced not only by the diversity of relevant provisions in many modern codes but also by the literature's inconsistent results. However, in the recent decade, multi-story inelastic building response has become increasingly realistic. Some interesting conclusions have been obtained as a result of this research, correcting prior notions concerning the inelastic response of structures based on one-story simplified model results.

II. OBJECTIVES

The main objective of this research is to study the seismic response of unsymmetrical structures with cantilever sections and analyze the behavior of the structures by adopting a methodology such as response spectrum analysis to minimize the effects caused by seismic forces.

- To study seismic behavior of symmetrical structure & unsymmetrical structure with cantilever section based on material and geometry.
- To study the effect of torsion for symmetric and unsymmetric multi-storied R.C.C. building in a high seismic zone.
- To compare the response parameters such as storey drift, storey shear, displacement, of Symmetrical and conventional building.
- To compare the torsional moment & overturning moment of Symmetrical and unsymmetrical structure with cantilever section.

III. CRITIQUES

The literature review gives information about the study of various types of cantilever structures subjected to seismic loads. It also includes the study of the effects of structure configuration

- According to seismic performance, effect on frame structure, analyzed by FEM (Finite Element Method).

- It is observed that seismic behaviour of the symmetrical and unsymmetrical structure, the storey drift, and storey displacement are more sensitive in unsymmetrical structures.

- The buildings with large span cantilevers are more prone to earthquake damage due to lateral forces, torsion effects, uneven settlement, and weight of the structure.

- Found that steel & other composite structures perform better than conventional reinforced concrete structures under seismic action.

IV. MODELLING

MODEL1: SYMMETRICAL STRUCTURE.

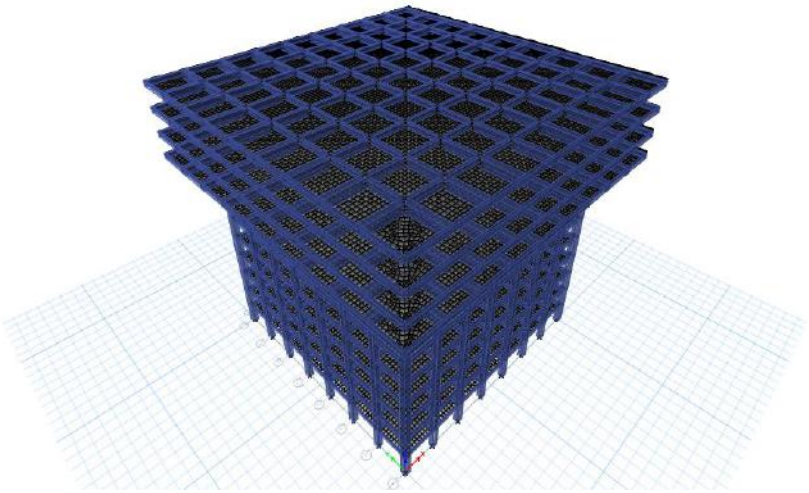

Fig. (7) Isometric view of Symmetrical structure.

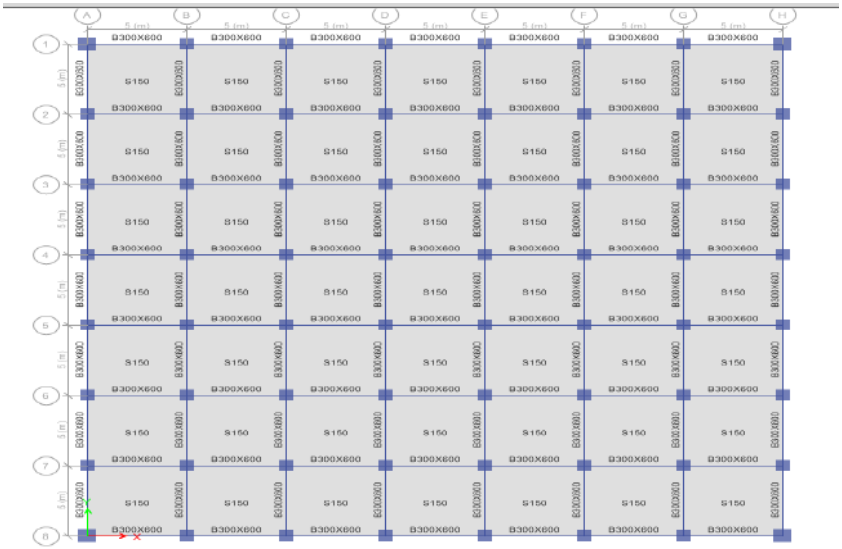

Fig.(8) Isometric view of Symmetrical structure.

MODEL INFORMATION.

TABLE 1
The objectives of research following aspects are:-

Symmetrical structure Model Data		
Seismic zones	III	IV
Total area	1225m^2	1225m^2
No. of stories	12	12
Typical storey height	3.2m	3.2m
Bottom storey height	3m	3m
Grade of concrete	M25	M25
Standard	INDIAN	INDIAN
Is code	IS 456	IS 456
Is code	IS1893 PART-1 (2016)	IS1893 PART-1 (2016)
Material	Concrete	Concrete
Type of Steel (Rebar)	HYSD 500	HYSD 500
Size of Beam	(300X600,300X750) (450X900,750X1000)	(300X600,300X750) (450X900,750X1000)
Size of Column	(750X750,900X900)	(750X750,900X900)
Wind speed	39 m/s	39 m/s
Parapet wall	1m	1m
Software	ETABS	ETABS
Type of building use	Commercial	Commercial
Zone factor	0.16	0.24
Importance factor	1.2	1.2
Response Reduction Factor (RF)	5	5
Dead Load	3.75 kN/m^2	3.75 kN/m^2
Live Load	4 kN/m^2	4 kN/m^2
Floor Finish Load	1.5 kN/m^2	1.5 kN/m^2
Number of Bays along X-direction	7	7
Number of bays along Z-direction	7	7
Bay Width along X-direction	5	5
Bay Width along Z-direction	5	5

TABLE 2
Beam section of both model.

S. NO.	ZONE 3			ZONE 4		
1	Shear force (kN)	Bending moment (kN-m)	Deflection (mm)	Shear force (kN)	Bending moment (kN-m)	Deflection (mm)
	628.2	2060.12	1.924	629.7797	2065.175	1.939

TABLE 3
Column section of both model.

S. NO.	ZONE 3			ZONE 4		
1	Shear force (kN)	Bending moment (kN-m)	Axial force (kN)	Shear force (kN)	Bending moment (kN-m)	Axial force (kN)
	64.255	173.4884	9042.6040	76.6838	207.0462	9158.4377

TABLE 4

TORSION & SUPPORT REACTION.

S NO.	ZONE 3		ZONE 4	
1	Torsion (Kn-m)	SUPPORT REACTION (kN)	Torsion (Kn-m)	SUPPORT REACTION (kN)
	243.454	5879.3689	254.6102	5879.3689

MODEL 2: UNSYMMETRICAL STRUCTURE.

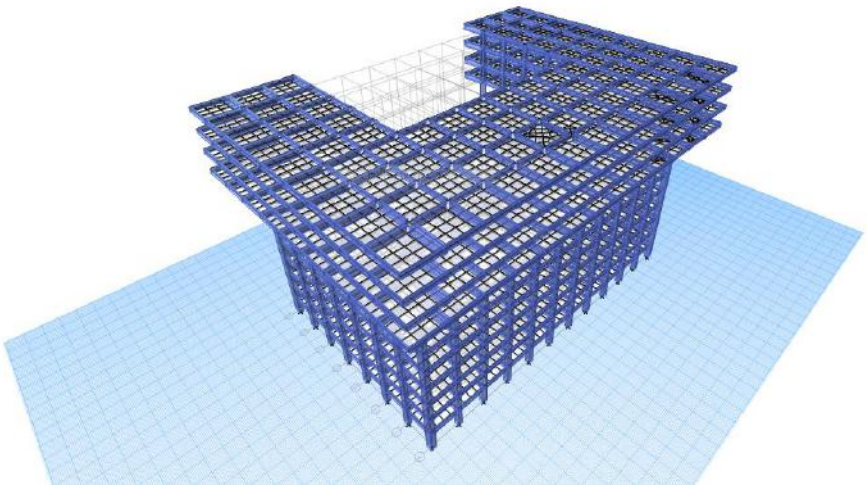

Fig. 9 Isometric view Unsymmetrical building plan.

MODEL INFORMATION.

TABLE 5

The objectives of research following aspects are:-

Symmetrical structure Model Data		
Seismic zones	III	IV
Total area	1225m^2	1225m^2
No. of stories	12	12
Typical storey height	3.2m	3.2m
Bottom storey height	3m	3m
Grade of concrete	M25	M25
Standard	INDIAN	INDIAN
Is code	IS 456	IS 456
Is code	IS1893 PART-1 (2016)	IS1893 PART-1 (2016)
Material	Concrete	Concrete
Type of Steel (Rebar)	HYSD 500	HYSD 500
Size of Beam	(300X600,300X750) (450X900,750X1000)	(300X600,300X750) (450X900,750X1000)
Size of Column	(750X750,900X900)	(750X750,900X900)
Wind speed	39 m/s	39 m/s
Parapet wall	1m	1m
Software	ETABS	ETABS
Type of building use	Commercial	Commercial
Zone factor	0.16	0.24
Importance factor	1.2	1.2
Response Reduction Factor (RF)	5	5
Dead Load	3.75 kN/m^2	3.75 kN/m^2
Live Load	4 kN/m^2	4 kN/m^2
Floor Finish Load	1.5 kN/m^2	1.5 kN/m^2
Number of Bays along X-direction	11	11
Number of bays along Z-direction	7	7
Bay Width along X-direction	5	5
Bay Width along Z-direction	5	5

TABLE 6

BEAM SECTION OF BOTH MODEL

S. NO.	ZONE 3			ZONE 4		
1	Shear force (kN)	Bending moment (kN-m)	Deflection (mm)	Shear force (kN)	Bending moment (kN-m)	Deflection (mm)
	637.16	2143.64	2.054	648.61	2172.4	2.077

TABLE 7
COLUMN SECTION OF BOTH MODEL

S. NO.	ZONE 3			ZONE 4		
1	Shear force (kN)	Bending moment (kN-m)	Axial force (kN)	Shear force (kN)	Bending moment (kN-m)	Axial force (kN)
	55.2	143.5	8532.8	63.1	164.1	8734.2

TABLE 8
AXIAL FORCE, BASE SHEAR & SUPPORT REACTION.

S NO.	ZONE 3			ZONE 4		
1	AXIAL FORCE (kN)	BASE SHEAR (kN)	SUPPORT REACTION (MTON)	AXIAL FORCE (kN)	BASE SHEAR (kN)	SUPPORT REACTION (MTON)
	-3039.87	3039.87	359.385	-4559.81	4559.81	359.385

TABLE 9
TORSION & SUPPORT REACTION.

S NO.	ZONE 3		ZONE 4	
1	Torsion (Kn-m)	SUPPORT REACTION (kN)	Torsion (Kn-m)	SUPPORT REACTION (kN)
	243.454	5879.3689	254.6102	5879.3689

V. ANALYSIS AND DISCUSSION OF SYMMETRICAL STRUCTURE:-

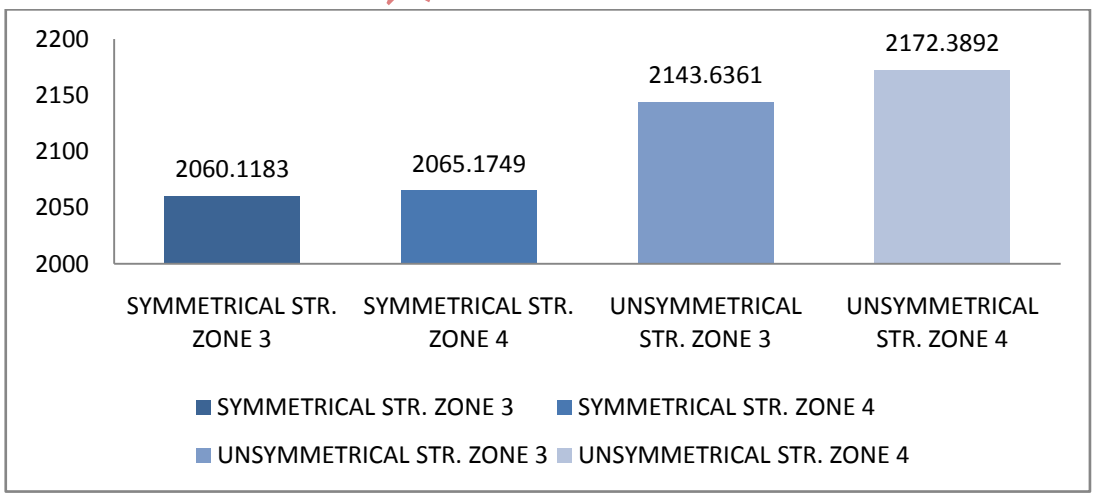

Fig.(10)

The variation of bending moment in beam throughout the span of unsymmetrical structure with respect to the seismic zone is shown in Fig.(10). The bending moment is found to be higher in the case of seismic zone 4, in the unsymmetrical structure when analyzed by dynamic analysis respectively. And also fig.(10) shows that the bending moment in symmetrical structure is less with compare to unsymmetrical structure with their earthquake zones, respectively.

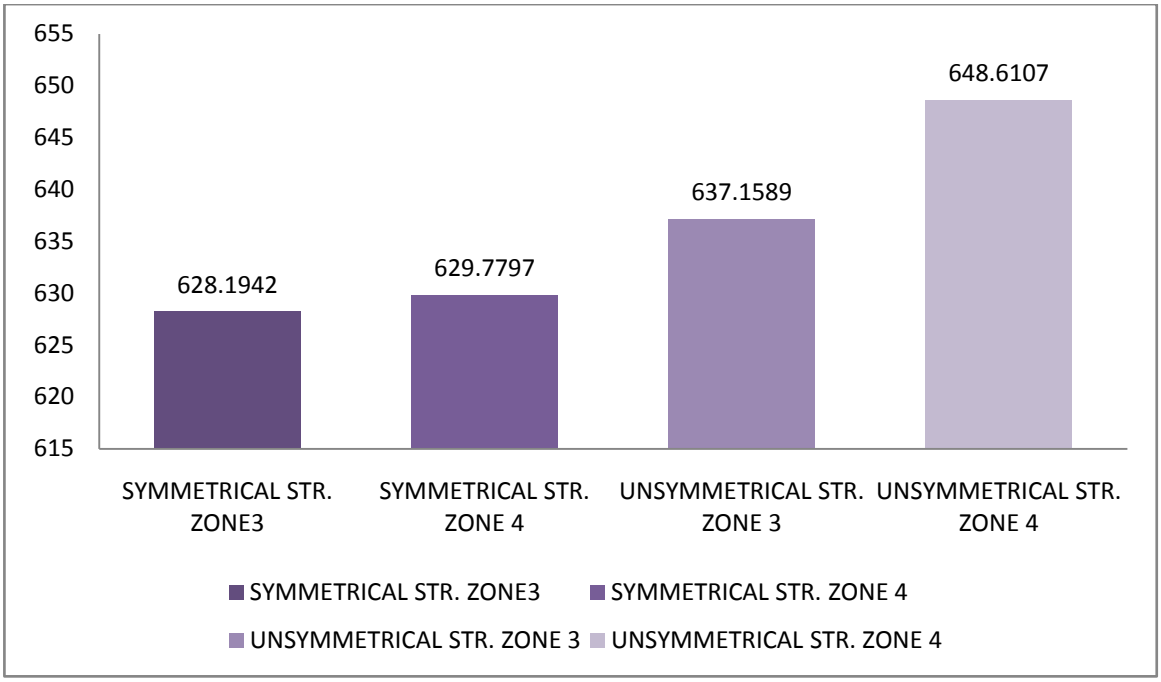

Fig.(11)

The variation of shear force in beam section of symmetrical structure & unsymmetrical structure with respect to the seismic zone is shown in Fig.(11). The shear force is found to be higher in the case of seismic zone 4, in the symmetrical structure & unsymmetrical structure when analyzed by dynamic analysis respectively. And also fig.(11) shows that the shear force in a symmetrical structure is less than an unsymmetrical structure with their earthquake zones, respectively.

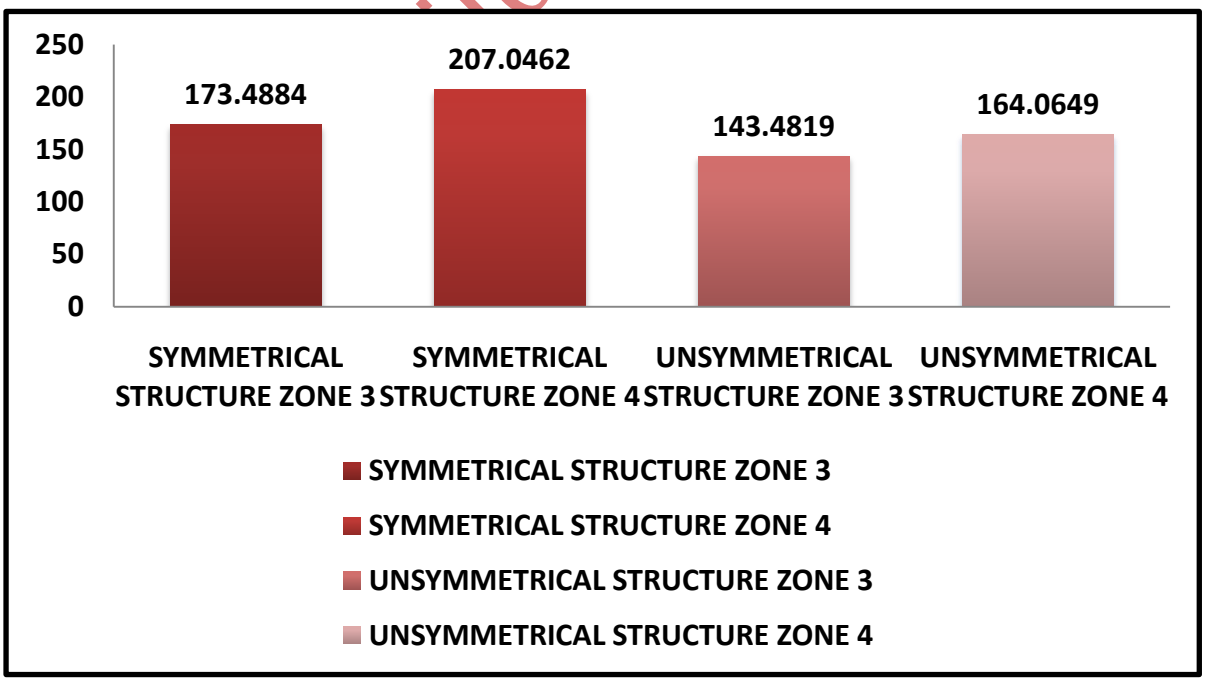

Fig.(12)

The variation of bending moment in column throughout the height of symmetrical structure & unsymmetrical structure with respect to the seismic zone is shown in Fig.(12). The bending moment is found to be higher in the case of seismic zone 4, in the symmetrical structure when analyzed by dynamic analysis respectively.

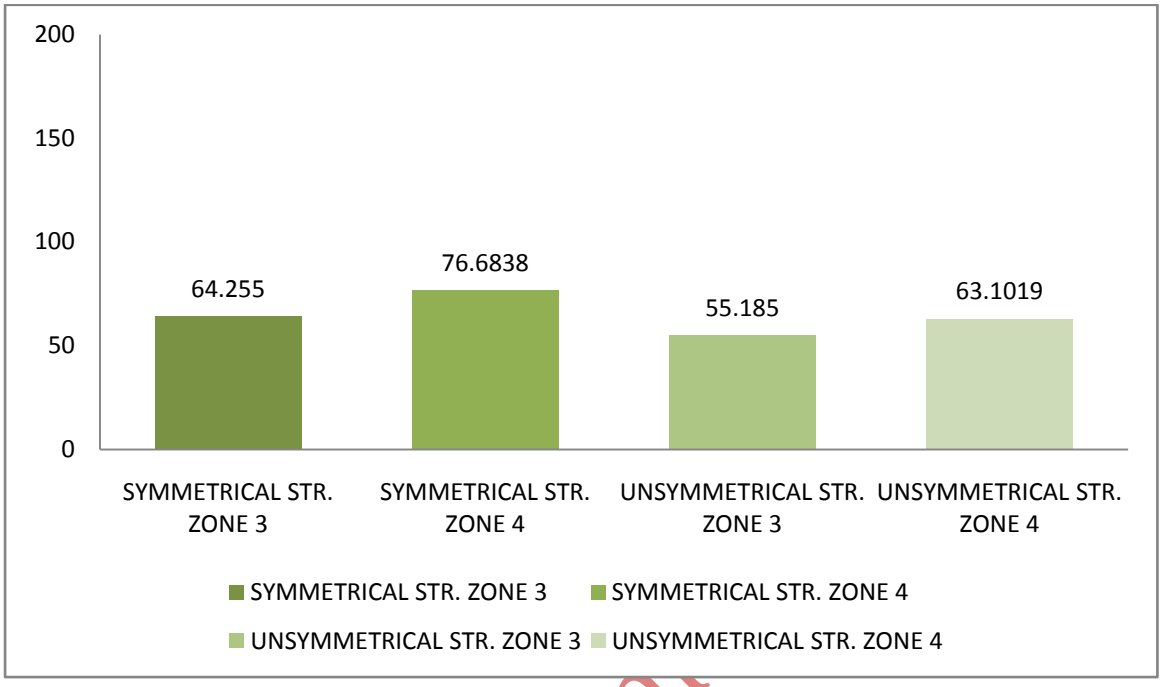

Fig.(13)

The variation of shear force in column section of symmetrical structure & unsymmetrical structure with respect to the seismic zone is shown in Fig.(13). The shear force is found to be higher in the case of seismic zone 4, in the symmetrical structure when analyzed by dynamic analysis respectively.

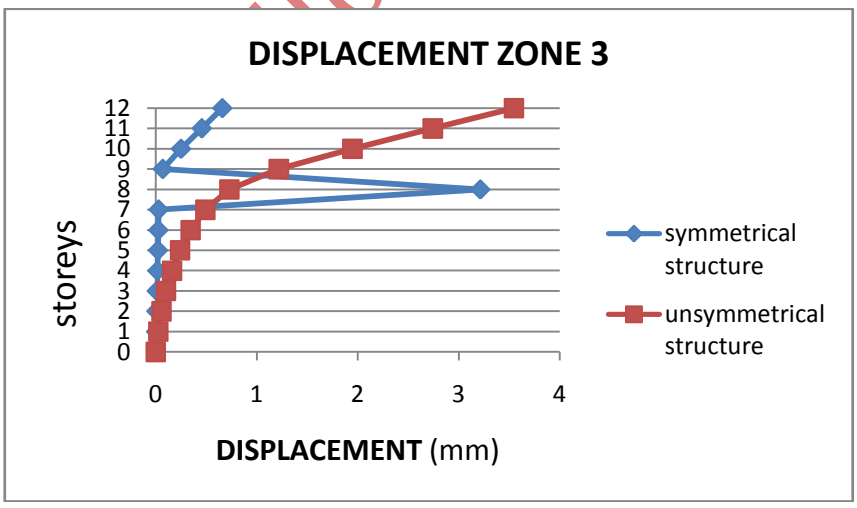

Fig.(14)

The variation of displacement throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (14). The maximum displacement is found to be higher in storey 8 of the structure, in symmetrical structure with seismic zone 3 . And also the maximum displacement is found to be higher in the highest storey of the structure, in unsymmetrical structure with seismic zone 3.

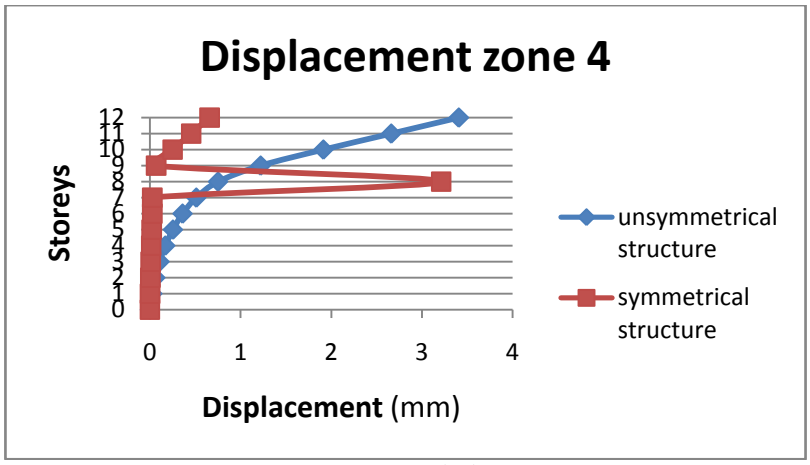

Fig.(15)

The variation of displacement throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig.(15). The maximum displacement is found to be higher in the storey 8 of the structure, in symmetrical structure with seismic zone 4. And also the maximum displacement is found to be higher in the highest storey of the structure, in an unsymmetrical structure with seismic zone 4.

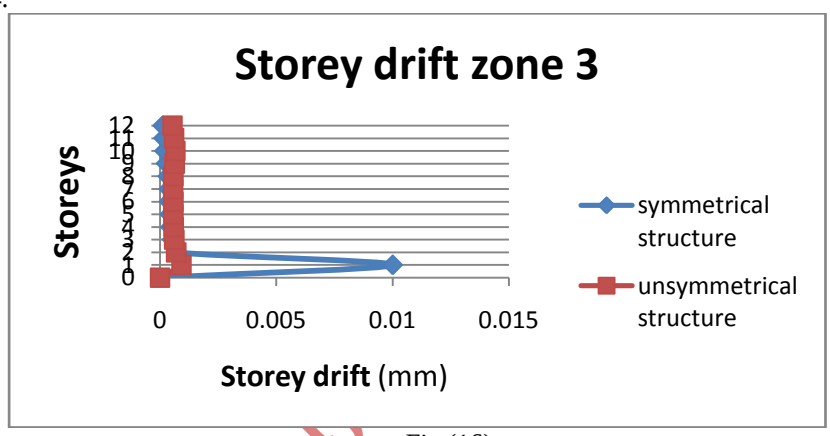

Fig.(16)

The variation of storey drift throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure shown in fig (16). The maximum storey drift is found to be higher in storey 1 of the structure, in symmetrical structure with seismic zone 3.

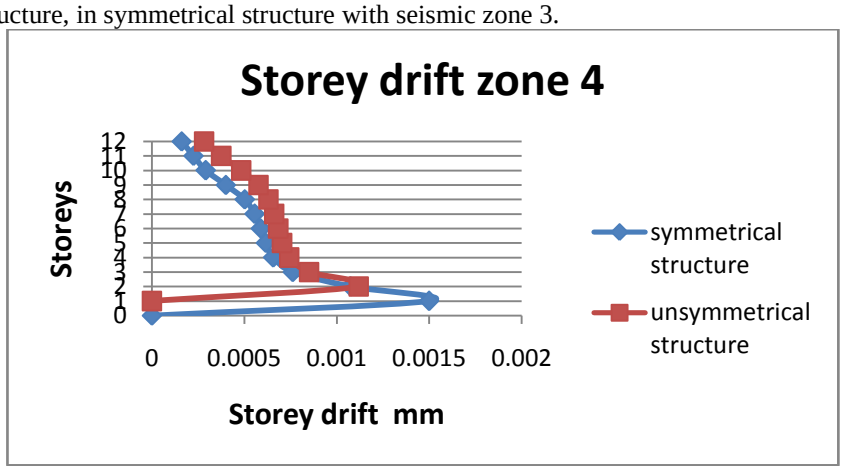

Fig.(17)

The variation of storey drift throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure shown in fig (17). The maximum storey drift is found to be higher in storey 1 of the structure, in symmetrical structure with seismic zone 4.

The variation of overturning moment throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (18). The maximum storey drift is found to be higher in storey 1 of the structure, in unsymmetrical structure with seismic zone 3.

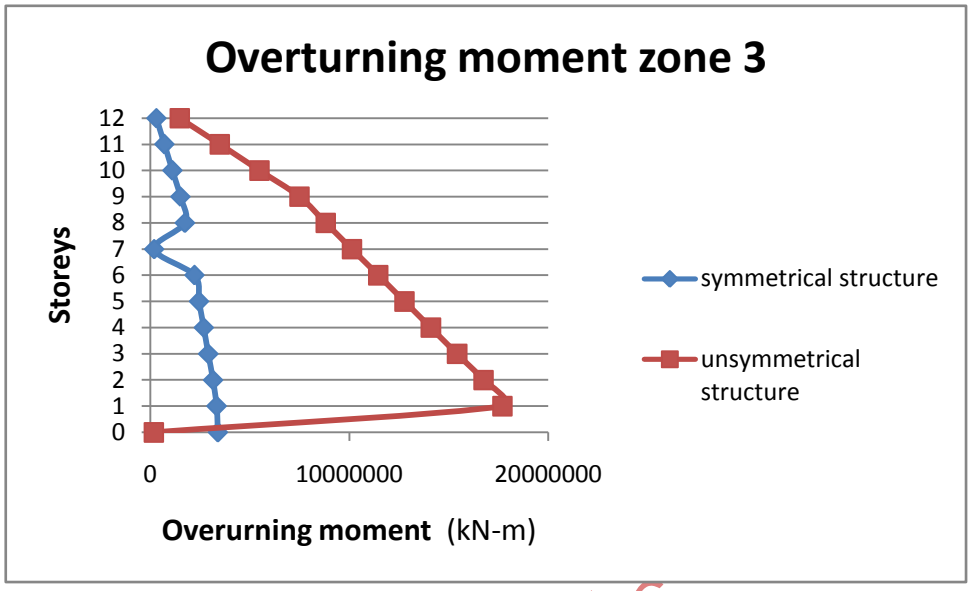

Fig.(18)

The variation of overturning moment throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (19). The maximum storey drift is found to be higher in storey 1 of the structure, in unsymmetrical structure with seismic zone 4.

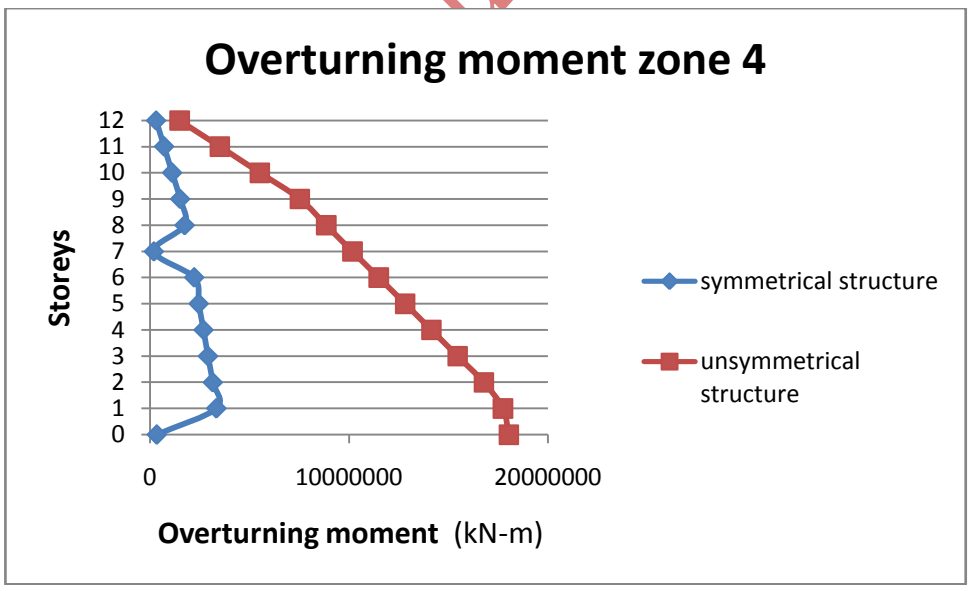

Fig.(19)

The variation of storey stiffness throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (20). The maximum storey drift is found to be higher in storey 9 of the structure, in symmetrical structure with seismic zone 3.

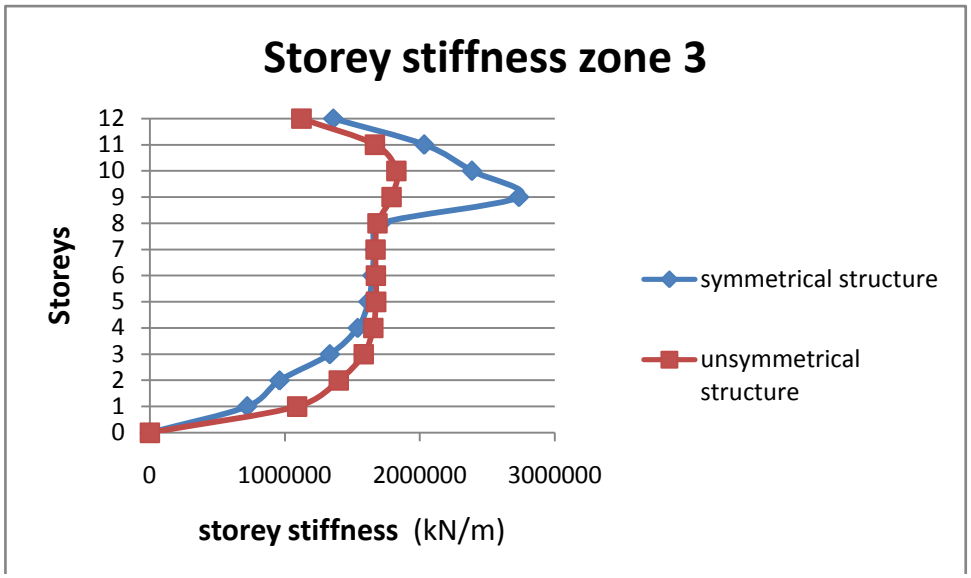

Fig.(20)

The variation of storey stiffness throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (21). The maximum storey drift is found to be higher in storey 9 of the structure, in symmetrical structure with seismic zone 4.

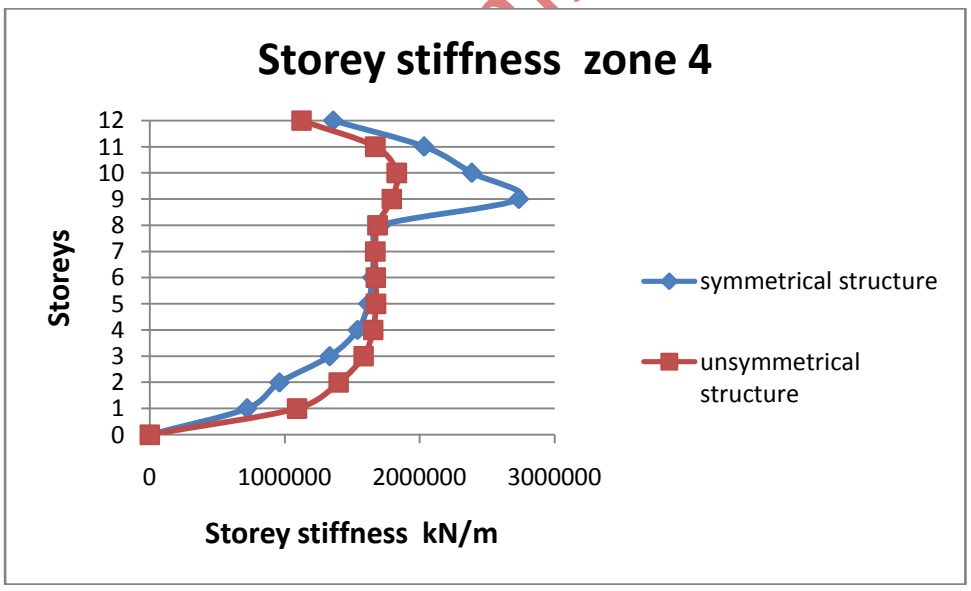

Fig.(21)

The variation of storey shear throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (22). The maximum storey drift is found to be higher in storey 1 of the structure, in unsymmetrical structure with seismic zone 3.

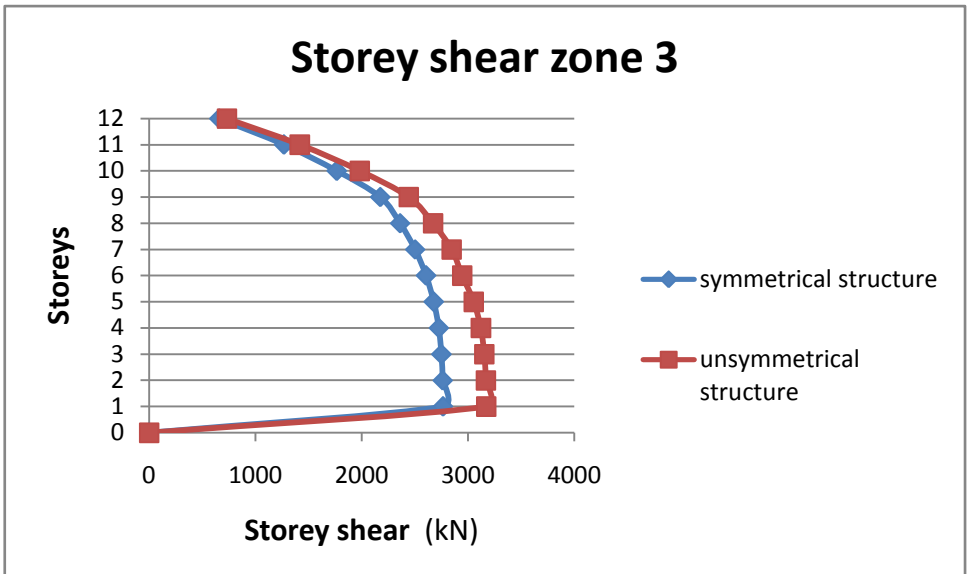

Fig.(22)

The variation of storey shear throughout the height of symmetrical structure & unsymmetrical structure with respect to no. of storeys in the structure is shown in fig (23). The maximum storey drift is found to be higher in storey 1 of the structure, in unsymmetrical structure with seismic zone 4.

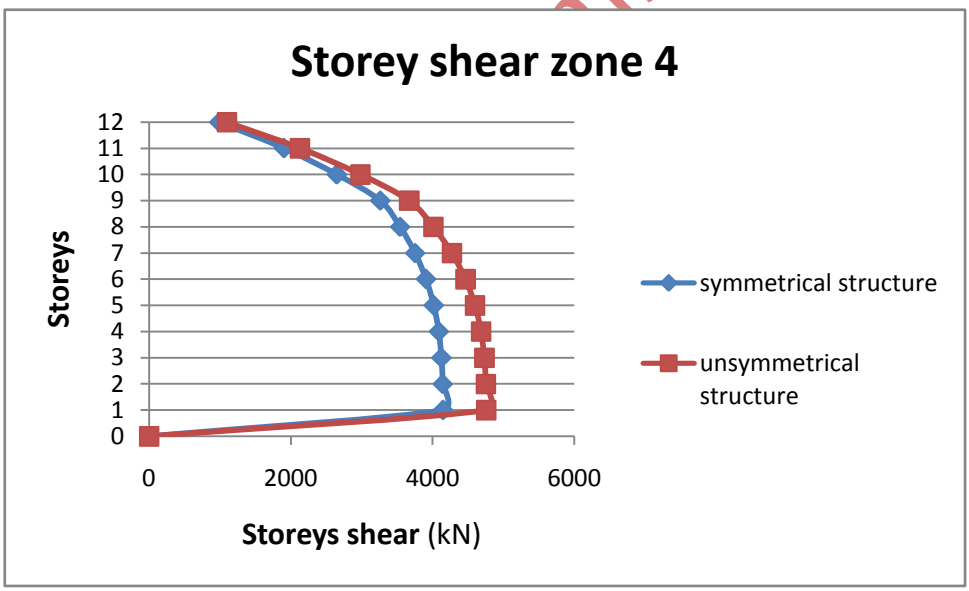

Fig.(23)

VI. METHODOLOGY

This research work includes various stages for analysis and design of unsymmetrical frame with cantilever section **.**

Stage-1 Planning of structure.

- SYMMETRICAL STRUCTURE WITH CANTILEVER.
- UNSYMMETRICAL STRUCTURE WITH CANTILEVER.

Stage-2 Modelling of structure frame.

- Identification of material & geometric properties in all structures.
- Assessment of the loads & load combinations on frames similarly in all structures.

Stage-3 Analysis of all structure frames.

VII. VALIDATION THROUGH SOFTWARE

The importance of software are as follows:

- Software is necessary for comparison of manual calculation and calculation done by software which helps in being confident about the work done.
- This also helps for further work on software with confidence. Otherwise, it will be difficult to trust the validity and correctness of the results and outputs given by the software.
- This section deals with the software for understanding the behavior of unsymmetrical structure with cantilever section subjected to seismic loading in zones (III, IV)

VIII. OBSERVATIONS OF RESULT

The result has been represented,

- Seismic behavior of symmetrical structure & unsymmetrical structure with cantilever section based on material and geometry.
- The effect of torsion for symmetric and unsymmetric multi-storied R.C.C. building in a high seismic zone.
- The response parameters such as storey drift, storey shear, displacement, of Symmetrical and conventional building.
- The torsional moment & overturning moment of Symmetrical and unsymmetrical structure with cantilever section.
- Parameters such as bending moments and shear forces in symmetrical structures & unsymmetrical structures with cantilever sections.
- The response of the symmetrical structure & unsymmetrical structure with cantilever sections subjected to gravity loads and seismic loading using computer-aided software.

IX. CONCLUSION

From the literature review, it can be concluded that the seismic analysis of unsymmetrical structure with cantilever depends upon factors which are load distribution, joint displacements, eccentricity between the centre of stiffness and the centre of mass etc. The seismic behaviour of unsymmetrical structures with cantilever sections may cause interruption of force flow and stress concentration. This induces twistin in the structure, which causes an increase in shear force, lateral displacement, and eventually failure. Hence it is necessary to identify an appropriate technique suitable for the analysis of large span cantilevers in unsymmetrical structure. The seismic response of large span cantilevers in an unsymmetrical structure under different loading conditions is required to study under various failure criteria. The failure of such a structure is hazardous therefore safety of a structure is important.

- Structural parameters such as storey drift, lateral displacement, stiffness are higher into an unsymmetrical structure.
- Base shear of unsymmetrical structure is more as compared to a symmetrical structure.
- The torsional moment in unsymmetrical structure is more than symmetrical structure.
- The Symmetric model provides more Gross Leasable Area (GLA) as compared to the Unsymmetrical model. Hence, Area Utilization will be more.
- The Load Distribution in the Symmetric model is more uniform as compared to the Unsymmetrical model.

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