Seismic Comparison of OMRF and SMRF Structural Systems on High Rise Building

Aswathi P.M[#1], Faisal Najeeb N.M[#2], Fasna T[#3], Mahmood[#4], Muhammad Fayiz L[#5], Sivakumar B*[6]

[#]*B.Tech Students, Department of Civil Engineering, Eranad Knowledge City Technical Campus, University of Calicut, Manjeri, Malappuram, Kerala, India.*

[*]*Professor& Head, Department of Civil Engineering, Eranad Knowledge City Technical Campus, University of Calicut, Manjeri, Malappuram, Kerala, India.*

Abstract — *Seismic analysis will ascertain the conduct of RCC structures during seism. The seismic evaluation greatly hinge on materials, ductility of structural members, strength, stiffness and reinforcement detailing. Criteria for Earthquake Resistant Design of Structures (IS 1893:2002) have provisions to follow different framing systems. In this study ordinary moment resisting frames (OMRF) and special moment resisting frames (SMRF) are used as framing systems. A G+5 mini civil station building at Calicut is selected for the study. For the purpose of equivalence the G+5 building is modified to a G+10 building with all floors typical. The two buildings are rendered with SMRF and OMRF framing systems and analysed in four different seismic zones. The modeling of the structure is done in Extended Three Dimensional Analysis of Building System (ETABS) software. Thus sixteen models with SMRF and OMRF framing system in all seismic zones are generated and comparisons are made on analytical results such as maximum shear force, maximum bending moment and maximum story drift. This project will help in determining best framing system in high rise building in defying the earthquake encroachment.*

Keywords — *Ordinary moment resisting frames (OMRF), Special moment resisting frames (SMRF), earthquake resisting structures, ETABS.*

I. INTRODUCTION

Structures that are intended to resist the impact of earthquakes are illustrious as earthquake resistant structures. The designs of these structures are made more pliable with the espousal of best framing system in buildings [1]. Through this the annihilating upshot of earthquake can be trimmed down to a greater extent [2] Earthquake design code of India has urge to espouse different framing system according to the seismic intensity in a particular region. The code has provisions over OMRF and SMRF framing systems [3]. The best framing system whirl economical, dependable, safe and better seismic performance. Indian seismic code divide the entire country in to five seismic zones (I, II, III, IV, V) depending upon the seismic risks [4]. OMRF is commonly adopted type of framing system in mild seismic zones. As the seismic peril increase OMRF become deficient to defy the gain of lateral force and is supersede by SMRF[5]. OMRF is comprised of less stringently proportioned and detailed members and joints, while SMRF consist of additional requisite to ameliorate inelastic response characteristics[6].

This study focus on the seismic comparison of various moment resisting frames in high rise buildings based on elevation and response reduction factor. A G+5 mini civil station building is selected for the study. All the stories are typical with a floor area of $577m^2$. For the purpose of comparison the G+5 building is modified with extra five stories with distinctive floor areas reckoning future expansion. The two buildings are provided with SMRF and OMRF framing systems and analysed in four different seismic zones. The analysis of the buildings is carried out using ETABS software. The analysis results are then compared to find out the best framing system. The mix used for all RCC works is M20 for slabs and beams and M30 for columns. The grade of steel used is Fe 500. The foundation given is pile foundation. The length of the building is 45.8m. Width is 13.2m. Typical floor height is 3m. The total height of the G+10 building is 31.5m. The total height of G+5 building is 20.5m.

II. METHODOLOGY

The methodology followed in this study is;

1) Study of ETABS software.
2) Plan preparation in AutoCAD software.
3) Modeling of selected buildings in ETABS.
4) Analyzing the building with OMRF and SMRF configurations in all seismic zones with envelope option.
5) Comparative study of results in terms of maximum shear force, maximum bending moment and maximum story drift.

III. SELECTION OF SEISMIC ZONES

The G+10 and G+5 building is supposed to exist in four different seismic zones and subjected to analysis in ETABS with different framing systems. Seismic zone for all cases is shown in following table 1.

Table 1. Seismic zones for all cases

Case	Model	Earthquake zones as per IS 1893(part-1):2002
	G+10	II to V
	G+5	II to V

IV. EQUIVALENT STATIC METHOD AS PER IS 1893:2002

Following procedure is generally used for the equivalent static analysis:

(1) Base shear of the building,

$V_B = A_h W$

$$A_h = \frac{ZI}{2R} \times \frac{Sa}{g}$$

(2) Lateral distribution of design base shear,

$$Q_i = V_b \times \frac{W_i \times h_i^2}{\sum_{i=1}^{n} W_i \times h_i^2}$$

V. TIME PERIOD

The values of fundamental natural period of vibration (T) in seconds, all buildings, including moment resisting frame buildings with brick infill panels are estimated using the formula:

$$T = 0.09 \frac{h}{\sqrt{d}}$$

Table 2. Time period of G+10 building in four seismic zones

zone	Z	I	R	$\frac{Sa}{g}$ In x direction	$\frac{Sa}{g}$ In y direction	T (in seconds) In x direction	T (in seconds) In y direction	Ah In x direction	Ah In y direction
V SMRF	.36	1.5	5	1.76	2.5	0.774	0.419	0.095	0.135
V OMRF	.36	1.5	3	1.76	2.5	0.774	0.419	0.158	0.225
IV SMRF	.24	1.5	5	1.76	2.5	0.774	0.419	0.063	0.09
IV OMRF	.24	1.5	3	1.76	2.5	0.774	0.419	0.106	0.15
III SMRF	.16	1.5	5	1.76	2.5	0.774	0.419	0.042	0.06
III SMRF	.16	1.5	3	1.76	2.5	0.774	0.419	0.070	0.0704
II OMRF	.1	1.5	5	1.76	2.5	0.774	0.419	0.0264	0.0375
II OMRF	.1	1.5	3	1.76	2.5	0.774	0.419	0.044	0.0625

Table 3. Time period of G+5 building in four seismic zones

zone	Z	I	R	$\frac{Sa}{g}$ In x directio	$\frac{Sa}{g}$ In y direction	T (in seconds) In x direction	T (in seconds) In y direction	Ah In x direction	Ah In y direction

				n					
V SMRF	.36	1.5	5	2.5	2.5	0.504	0.273	0.i35	0.135
V OMRF	.36	1.5	3	2.5	2.5	0.504	0.273	0.225	0.225
IV SMRF	.24	1.5	5	2.5	2.5	0.504	0.273	0.09	0.09
IV OMRF	.24	1.5	3	2.5	2.5	0.504	0.273	0.15	0.15
III SMRF	.16	1.5	5	2.5	2.5	0.504	0.273	0.06	0.06
III SMRF	.16	1.5	3	2.5	2.5	0.504	0.273	0.0704	0.0704
II OMRF	.1	1.5	5	2.5	2.5	0.504	0.273	0.0375	0.0375
II OMRF	.1	1.5	3	2.5	2.5	0.504	0.273	0.0625	0.0625

VI. SPECIFICATIONS

Specifications used in the modeling are given in table 4.

Table 4. Specifications

Specification	G+10	G+5
Grade of concrete for slabs	20N/mm^2	20N/mm^2
Grade of concrete for columns, beams and staircase	30N/mm^2	30N/mm^2
Density of concrete	25N/mm^2	25N/mm^2
Yield strength of reinforcing steel	500 N/mm^2	500 N/mm^2
Number of storey	10	5
Typical storey height	3m	3m

VII. LOAD AND LOAD COMBINATIONS

A. Load combinations

- 1.5(DL+LL)
- 1.2(DL+LL+WLX)
- 1.2(DL+LL+WL-X)
- 1.2(DL+LL+WLY)
- 1.2(DL+LL+WL-Y)

- 1.5(DL+WLX)
- 1.5(DL+WL-X)
- 1.5(DL+WLY)
- 1.5(DL+WL-Y)
- 0.9DL+1.5WLX
- 0.9DL+1.5WL-X
- 0.9DL+1.5WLY
- 0.9DL+1.5WL-Y
- 1.2(DL+LL+EQX)
- 1.2(DL+LL+EQ-X)
- 1.2(DL+LL+EQY)
- 1.2(DL+LL+EQ-Y)
- 1.5(DL+EQX)
- 1.5(DL+EQ-X)
- 1.5(DL+EQY)
- 1.5(DL+EQ-Y)
- 0.9DL+1.5EQX
- 0.9DL+1.5EQ-X
- 0.9DL+1.5EQY
- 0.9DL+1.5EQ-Y
- DL+0.5LL
- 1.5DL+0.75L

B. Live load

Live load is calculated as per IS 875(part 2):1987

Table 5. Live Load

Rooms without separate storage	4 KN/m^2
Bath and toilets	2 KN/m^2
Corridors, passages, lobbies and stairs including fire escape	4 KN/m^2

C. Dead load

As per IS code 875 (part 1)1987:
Floor load = 25 x 0.15=3.75 KN/m^2
(Slab thickness assumed as 0.15m)
Finishing load=1 KN/m^2
Total floor load= 3.75+1= 4.75 KN/m^2
External wall load= 0.23 x3 x 21=15KN/m
Partition wall load=0.1 x3 x21=6.3KN/m
Parapet wall load=0.23 x1 x21=5KN/m

D. Wind load

As per IS 875 (part 3) 1987:
Basic wind speed: 39m/s (Calicut)
Basic wind pressure, P_z= 0.6 V_z^2
Design wind speed, V_z= V_b x k_1x k_2x k_3= 39.78m/s
Design wind pressure, P_z= 0.6 V_z^2 =949.469N/m^2

E. Seismic load

As per IS 1893:2002:
Importance factor =1.5
Response reduction factor:
For OMRF=3
For SMRF=5

F. Seismic weight

The seismic weight of each floor is its full dead load plus appropriate amount of imposed loads. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey. The seismic weight value for the building is obtained directly from the software.

VIII. MODELLING OF BUILDING FRAMES

Modeling of the G+10 and G+5 buildings are done in ETABS software. Sixteen models are made in ETABS and analysed in four seismic zones.

Table 6. Total Cases

Type of building	Framing system	Zone
G+10	OMRF	4
	SMRF	4
G+5	OMRF	4
	SMRF	4
Total cases		16

IX. STRUCTURAL MODELS

Key plan of the mini civil station building is prepared in Auto CAD software and it is given in figure 1.

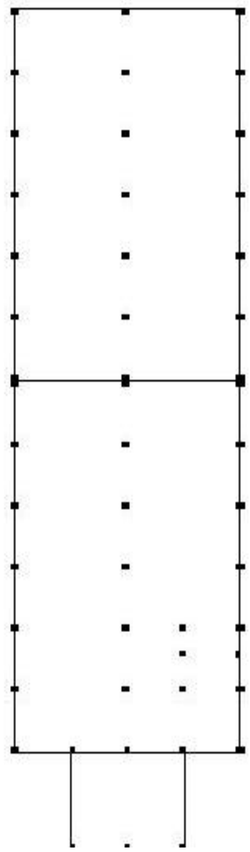

Fig 1: Key plan

In analysis stage the buildings are analysed with given specifications. Seismic analysis is performed in 16 models adopting suitable zone factor, response reduction factor and importance factor. The analysis results such as maximum shear force, maximum bending moment and maximum displacement are compared to find out the best framing system. Interactive design is performed in designing the building. The shear force and bending moment diagram for the G+10 and G+5 building is given in figure 2 and figure 3.

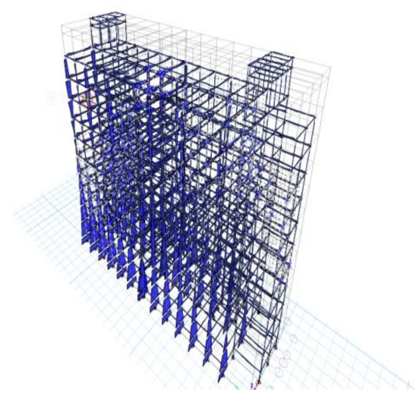

Fig 2: Shear Force and Bending Moment Diagram

for G+10 Building

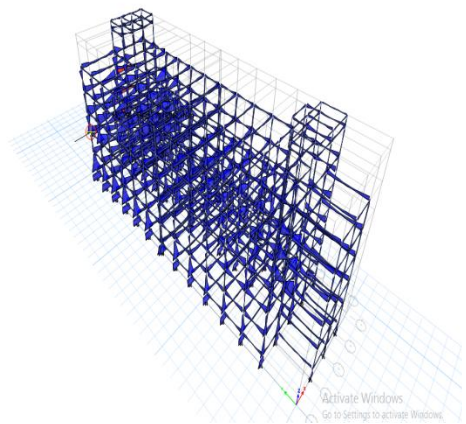

Fig 3: Shear Force and Bending Moment Diagram for G+5 Building

X. MATERIAL AND GEOMETRICAL PROPERTIES

Grade of concrete for slabs: 20N/mm^2
Grade of concrete for beams, columns, staircase: 30N/mm^2
Unit weight of RCC: 25N/mm^2
Unit weight of masonry: 21N/mm^2
Yield strength of reinforcing steel: 500N/mm^2
Modulus of elasticity of concrete: 5000√fck

XI. ANALYSIS AND RESULTS

Maximum bending moment in zone 2 for G+10 and G+5 building is given in following table 7 and figure 4.

Table 7. Maximum Bending Moment (kNm) in Zone 2

Maximum bending moment (kNm) in zone 2		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	984.3236	143.7101
SMRF	946.2927	94.2421

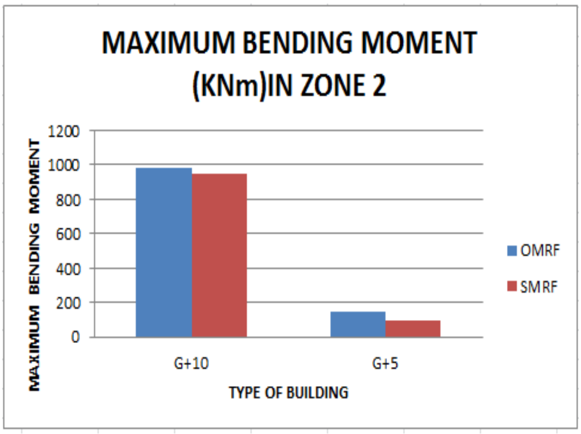

Fig 4: Maximum Bending Moment (KNm) in Zone 2

It is observed that maximum bending moment is in OMRF and minimum in SMRF. How much the height of building increase or decrease the OMRF imparts higher moment than SMRF.

Maximum bending moment in zone 3 for G+10 and G+5 building is given in following table 8 and figure 5.

Table 8. Maximum Bending Moment (KNm) in Zone 3

Maximum bending moment (kNm) in Zone 3		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	1688.8691	214.9891
SMRF	982.7883	138.7633

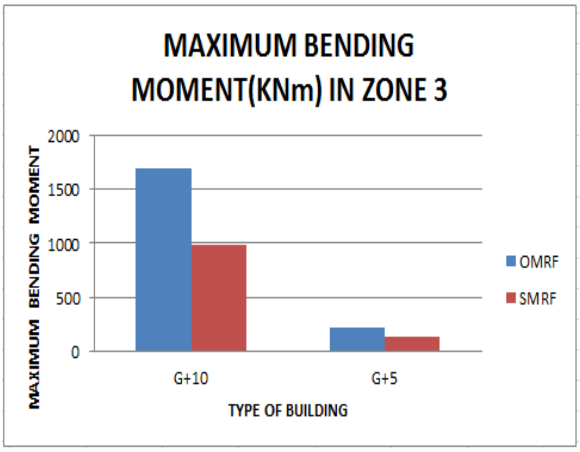

Fig 5: Maximum Bending Moment (KNm) in Zone 3

It is observed that maximum bending moment is in OMRF and minimum in SMRF. Or in other words, whatever be the height of the building, the OMRF imparts higher resistance to moment than SMRF.

Maximum bending moment in zone 4 for G+10 and G+5 building is given in following table 9 and figure 6.

Table 9. Maximum Bending Moment (KNm) in Zone 4

Maximum bending moment (kNm) in Zone 4		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	1740.4285	342.0957
SMRF	1040.8105	194.5250

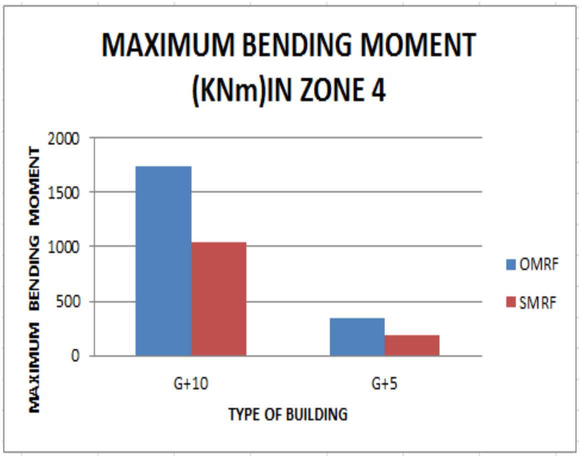

Fig 6: Maximum Bending Moment (KNm) in Zone 4

It is observed that however the height of building increase or decrease the OMRF imparts higher moment than SMRF.

Maximum bending moment in zone 5 for G+10 and G+5building is given in following table 10 and figure 7.

Table 10. Maximum Bending Moment (KNm) in zone 5

Maximum bending moment (kNm) in Zone 5		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	2496.9976	488.1284
SMRF	1473.7229	254.1384

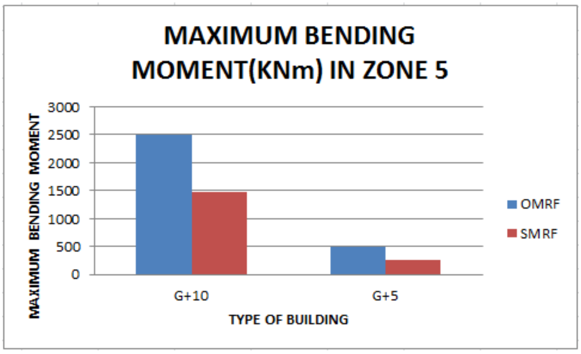

Fig 7: Maximum Bending Moment (KNm) in Zone 5

Intensity of earthquake is maximum in zone 5. Graph gives the value of bending moment of G+10 and G+5 building in zone 5, SMRF reduces the intensity of earthquake in both building.

Maximum shear force in zone 2 for G+10 and G+5 building is given in following table 11and figure 8.

It is observed that maximum shear force is exerted in OMRF than SMRF. Zone 2 is less susceptible to seismic forces. Hence in zones having less seismic intensity OMRF are generally preferred.

Table 11. Maximum shear force (kN) in zone 2

Maximum shear force (kN) in Zone 2		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	153.9955	45.7329
SMRF	145.0857	29.2882

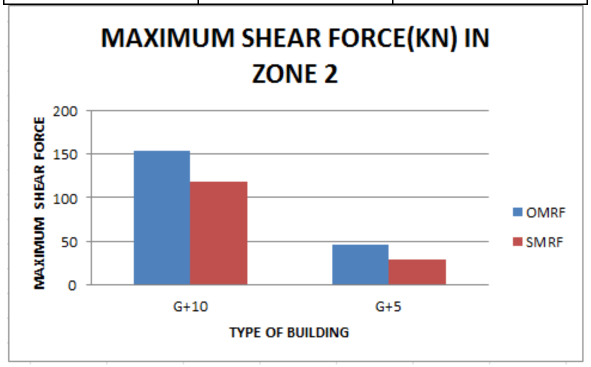

Fig 8: Maximum shear force (kN) in zone 2

Maximum shear force in zone 3 for G+10 and G+5 building is given in following table 12 and figure 8.

Table 12. Maximum shear force (kN) in zone 3

Maximum shear force (kN) in Zone 3		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	459.0657	71.9071
SMRF	222.0194	43.9880

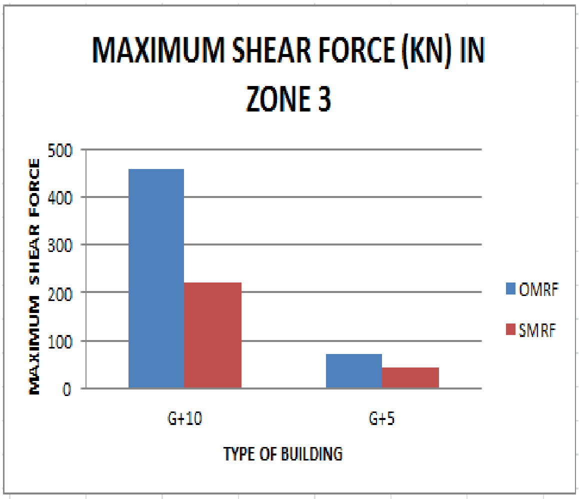

Fig 9: Maximum Shear Force (kN) in Zone 3

The seismic intensity increases from zone 2 to zone 3.However the OMRF produces more shear force.

Maximum shear force in zone 4 for G+10 and G+5 building is given in following table 13 and figure 10.

Table 13. Maximum Shear Force (kN) in Zone 4

Maximum shear force (kN) in Zone 4		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	539.4098	111.4765
SMRF	240.5340	46.9284

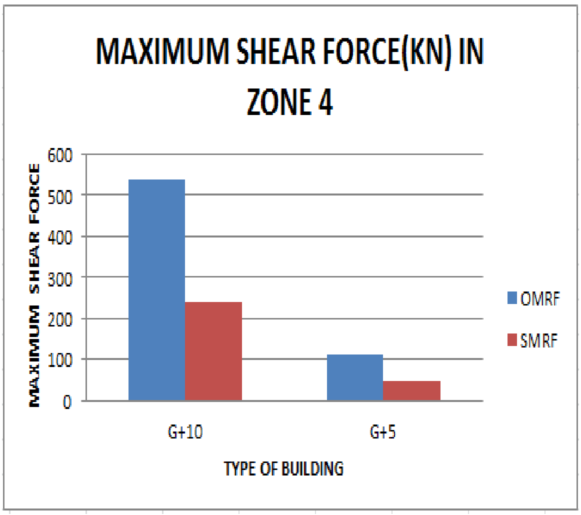

Fig 10: Maximum Shear Force (kN) in Zone 4

Independent of height of building OMRF produces more shear force than SMRF.

Maximum shear force in zone 5 for G+10 and G+5 building is given in following table 14 and figure 11.

Table 14. Maximum Shear Force (kN) in Zone 5

Maximum shear force (kN) in Zone 5		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	635.8536	166.5213
SMRF	394.3159	108.4167

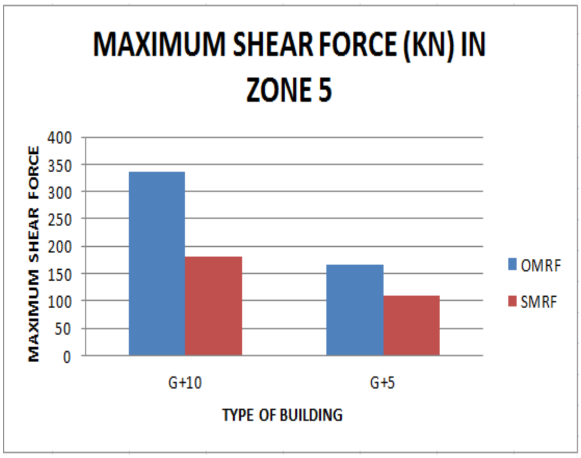

Fig 11: Maximum Shear Force **(kN)** in zone 5

The Seismic intensity is maximum in zone 5.Graph explains that SMRF impart less values for shear force offering better performance during earthquake.

Maximum story drift in zone 2 for G+10 and G+5 building is given in following table 15 and figure 12.

Table 15. Maximum story drift (mm) in Zone 2

Maximum story drift (mm) in Zone 2		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	63.15	69.03
SMRF	56.18	43.81

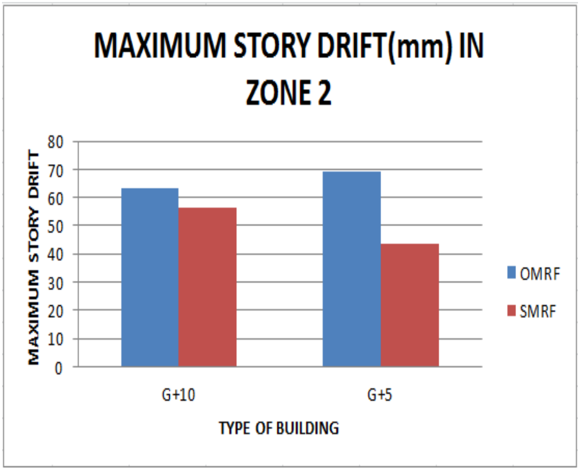

Fig 12: Maximum Story Drift (mm) in Zone 2

More story drift is observed for OMRF than SMRF.

Maximum story drift in zone 3 for G+10 and G+5 building is given in following table 16 and figure 13.

Table 16. Maximum story drift (mm) in Zone 3

Maximum story drift (mm) in Zone 3		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	108.03	88.17
SMRF	72.343	68.01

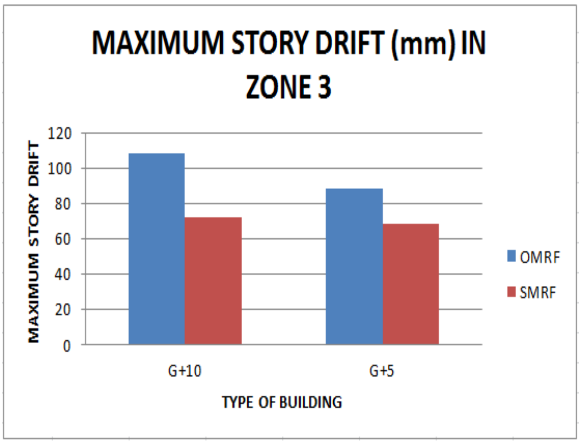

Fig 13: Maximum Story Drift (mm) in Zone 3

As seismic intensity increases story drift also increases. The graph picturize the poor performance of OMRF during earthquake.

Maximum story drift in zone 4 for G+10 and G+5 building is given in following table 17 and figure 14.

Table 17. Maximum story drift (mm) in Zone 4

Maximum story drift (mm) in Zone 4		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	163.05	112.31
SMRF	95.50	86.35

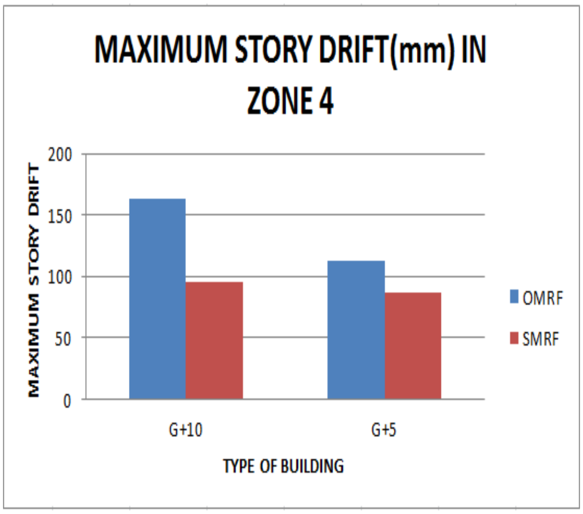

Fig 14: Maximum Story Drift (mm) in Zone 4

The graph explains that maximum story drift experienced in OMRF.OMRF has poor performance during seismic forces.

Maximum story drift in zone 5 for G+10 and G+5 building is given in following table 18 and figure 15.

Table 18. Maximum story drift (mm) in Zone 5

Maximum story drift (mm) in Zone 5		
Framing system	**Type of structure**	
	G+10	**G+5**
OMRF	251.42	186.21
SMRF	141.92	109.35

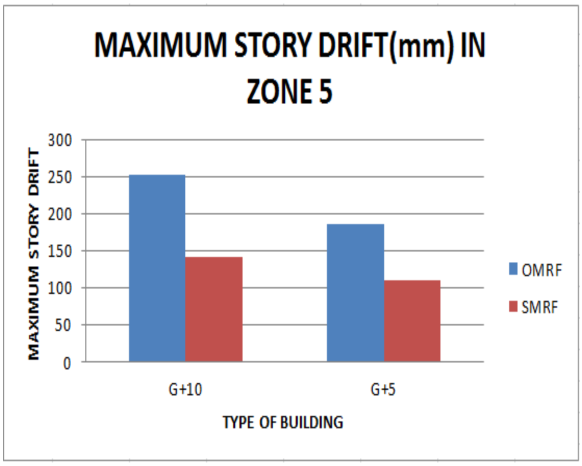

Fig 15: Maximum Story Drift (mm) in Zone 5

Seismic intensity is more observed in zone 5. In zone 5 SMRF offer better performance than OMRF in resisting seismic forces**.**

XII. CONCLUSION

In this study OMRF and SMRF framing systems in G+10 and G+5 building were analysed in all four seismic zones.

The important conclusions of this study are:

A. *Bending moment*

Bending moment increases as zone changes from zone 2 to zone 5.Value of bending moment increases as height of building increases. Thus more value of bending moment is observed in G+10 building than G+5 building with OMRF framing system. Thus SMRF framing system offer better performance than OMRF framing system. Increase in moment increases area of steel required hence OMRF is uneconomical. SMRF is economical.

B. *Shear force*

Shear force increases as zone changes from zone 2 to zone 5.Also value of shear force increases as height of building increases. Hence SMRF is more efficient than OMRF in resisting shear forces. Decreased shear force means reduction of shear reinforcement .Hence SMRF is more economical than OMRF.

C. *Story drift*

Maximum story drift is observed in OMRF and minimum in SMRF. Story drifts increases in zone 5 as seismic intensity increases. SMRF minimum story drift. Decrease in story drift indicates reduction of size of section.

So from above graphs and tables it can be concluded that SMRF framing system reduces bending moment, shear force and story displacement. Also the results explain that SMRF is a moment resisting frame specially detailed to provide ductile behaviour. The size of section is reduced considerably and area of steel reinforcement is also reduced. SMRF framing system helps the structural engineer to design the structure that is safe and cost effective.

This study is limited in seismic comparison of OMRF and SMRF structural systems for regular buildings on the platform such as maximum bending moment, maximum shear force and maximum story drift.

REFERENCES

[1] C. Ambika and N. Prerana. "Analysis and Design of R.C. Moment Resisting Frames with and without Shear Wall for Different Seismic Parameters." *International Journal of Innovative Science, Engineering & Technology*, 1(6),(2014).

[2] S. V. Itti, A. Pathade and R. B. Karadi. "A comparative study on seismic provisions made in Indian and international codes for RC buildings."*International Research Journal of Engineering and Technology*, 2(1),(2006).

[3] G. V. S. Prasad and S. Adiseshu. "A Comparative Study of OMRF & SMRF Structural System for Tall & High Rise Buildings Subjected to Seismic Load." *International Journal of Research in Engineering and Technology*, 2319-1163,(2013).

[4] Criteria for Earthquake Resistant Design of Structures (IS 1893:2002)

[5] V. Varghese and Y. R. Borkar. "Comparative Study of S.M.R.F. Building over O.M.R.F. Building With Seismic And Wind Effect." *International Journal of Engineering Research and Applications*, 3(3), 1501-1503,(2013).

[6] A. K. Yadav and A. Rai."A Seismic Comparison of OMRF & SMRF Structural System for Regular and Irregular Buildings."*International Journal for Research in Applied Science & Engineering Technology*, 5(3),(2017).