Comparative Seismic Analysis of RC Special Moment Resisting Frames with Regular and Irregular Configurations

Amit Kumar Yadav*, Prof. Anubhav Rai
Dr. Sofia Martínez

Department of Civil Engineering, University of Barcelona, Spain

ABSTRACT

A comparative study of all the types of frames will shed light on the best suited frame to be adopted for seismic loads in Indian scenario. Seismic evaluation will provide a general idea about the building performance during an earthquake. In this report Special Moment Resisting Frame is considered as structural frame and comparison are made in various seismic zones. The objective of this study is to investigate the seismic behaviour of reinforced cement concrete structure having SMRF (Special moment Resisting frame) in nature. For this purpose regular and irregular structures were modelled and analysis was done using STAAD.Pro software and using the codes for analysis, IS 1893:2002, IS 456: 2000. The study assumed that the buildings were located in all seismic zones

KEYWORDS: Seismic Behaviour, SMRF, model, analysis, staad.pro.

INTRODUCTION

The selection of a particular type of framing system depends upon two important parameters i.e. Seismic risk of the zone and the budget. The lateral forces acting on any structure are distributed according to the flexural rigidity of individual components. Indian Codes divide the entire country into four seismic zones (II, III, IV & V) depending on the seismic risks. OMRF is probably the most commonly adopted type of frame in lower seismic zones. However with increase in the seismic risks, it becomes insufficient and SMRF frames need to be adopted. A rigid frame in structural engineering is the load resisting skeleton constructed with straight or curved members interconnected by mostly rigid connections which resist movements induced at the joints of members. Its members can take bending moment, shear, and axial loads. They are of two types: Rigid-framed Structures & Braced-frames Structures The two common assumptions as to the behaviour of a building frame are that its beams are free to rotate at their connections and that its members are so connected that the angles they make with each other do not change under load. Moment-resisting frames are rectilinear assemblages of beams and columns, with the beams rigidly connected to shear, amount of reinforcement etc. Moment frames have been widely used for seismic resisting systems due to their superior deformation and energy dissipation capacities. A moment frame consists of beams and columns, which are rigidly connected. The components of a moment frame should resist both gravity and lateral load. Lateral forces are distributed according to the flexural rigidity of each component.

The main aims of the present study are as follows:

- To model structures for analyzing multi-storeyed frames having SMRF configurations.
- To carry out the analysis of the selected buildings in all seismic zone.
- To analyse regular and irregular structure and find out effective one.
- To make a comparative study with the help of results like bending moment, shear force, displacement etc.

LITERATURE REVIEW

Najif Ismail (2008): explain all structural systems are not treated equal when response to earthquake-induced forces is of concern. Aspects of structural configuration, symmetry, mass distribution, and vertical regularity must be considered. The importance of strength, stiffness, and ductility in relation to acceptable response must also be appreciated. While considering the lateral force resisting systems we come up with so many options to have structural systems like Bearing wall systems, Moment Resisting frames, Lateral Bracing systems, designing the moment resisting concrete frame structures we have option to use IMRF, OMRF or SMRF. The basic step in conceptual design is to find the best suitable framing system and then lateral load resisting mechanism, while designing structures in the field mostly engineers face problem about the decision of Response Modification Factor R which is a measure of ductility and over strength of the structures. It is used to find the base shear which is distributed on different stories. SMRF and IMRF being emphasized in the research and a detailed computer simulation of the different RCC structures in zone 2 B with different R values i.e., 5.5 and 8.5 given in UBC-1997 are used. Total 04 Structures with different heights of stories, Plans and No. of stories are modelled in software which uses the advanced finite element method to analyse the structure. The conclusions are drawn from the research for the approximation of the most suitable R values and to check the reliability of the values given in UBC.

Kiran Parmar et. al. (2013) deals with the comparison between three dual lateral load resisting systems in the multistory buildings. Dual system which used in the multistory building to resist lateral loads (wind/earthquake) are used in this study are 1. Moment resisting frame with shear wall (MRSW) 2. Moment resisting frame with bracing (MRBR) 3. Flat slab with shear wall (FSSW). The comparison shows the efficiency of dual system for lateral load resistance at variable heights of buildings. E-tab software is used for make this study done. The present study deals with analysis of these systems and their suitability against deformation at different heights.

Ambika-Chippa et. al. (2014) compare seismic analysis and design of RC moment resisting space frame with shear wall (Dual System). In moment resisting frame and dual system, two different cases were selected for the study. In moment resisting frame Special Moment Resisting Frame and Ordinary Moment Resisting Frame were considered with Variations of heights, i.e. (G+4), (G+6),(G+8), (G+10) , and bays viz. (2x2),(3x3),(4x4),(5x5),(6x6) for bare frame and frame with brick infill, and in dual system, structure with shear wall and without shear wall were considered with (G+8) storey for (5x5) bay for frame with brick infill with same loading conditions. Frame has been analyzed and designed using STAAD ProV8i software referring IS: 456-2000, IS: 1893 (Part-1)2002 and detailing is made according to IS: 13920-1993. From these data, cost is calculated and economic structure is being found out.

G.V.S. Siva Prasad et. al. (2013) investigated the seismic behavior of the structure i.e... OMRF (Ordinary moment resisting frame) & SMRF (Special R C moment Resisting frame). For this purpose 5th, 10th, 15th , 20th storied structure were modeled and analysis was done using STAAD.Pro software and using the codes for analysis, IS 1893:2002, IS 456: 2000. The study assumed that the buildings were located in seismic zone II (Visakhapatnam region).The study involves the design of alternate shear wall in a structural frame and its orientation, which gives better results for the OMRF & SMRF structure constructed in and around Visakhapatnam region. The buildings are modeled with floor area of 600 sqm (20m x30m) with 5 bays along 20 m span each 4 m. and 5 bays along the 30 m span each 6 m. The design is carried out using STAAD.PRO software. Shear walls are designed by taking the results of the maximum value of the stress contour and calculation are done manually by using IS 456-2000 and IS 13920-1993. The displacements of the current level relative to the other level above or below are considered. The preferred framing system should meet drift requirements.

1. Up to 20 floored building subjected to seismic load for Visakhapatnam without shear wall
2. Up to 20 floored building subjected to seismic load for Visakhapatnam with shear wall

METHODOLOGY

Methodology And Selection Of Problems

This work deals with comparative study of behaviour of high rise building frames considering different geometrical configurations and response reduction factor under earthquake forces. A comparison of results in terms of moments, shear force, displacements, and storey displacement has been made. Following steps are applied in this study:-

Step-1 Selection of building geometry, bays and storey (3 geometries)
Step-2 Selection of response reduction factor (SMRF) models
Step-3 Selection of 4 zones (II,III, IV and V) seismic zones

Table 3.1 Seismic zones for all cases

Case	Model	Earthquake zones as per IS 1893 (part-1) : 2002
	RCC Structure	II to V

Step-4 Considering of load thirteen combination

Table 3.2: Load case details

Load case no.	Load case details
1.	E.Q. IN X_DIR.
2.	E.Q. IN Z_DIR.

3.	DEAD LOAD
4.	LIVE LOAD
5.	1.5 (DL + LL)
6.	1.5 (DL + EQ_X)
7.	1.5 (DL - EQ_X)
8.	1.5 (DL + EQ_Z)
9.	1.5 (DL - EQ_Z)
10.	1.2 (DL + LL + EQ_X)
11.	1.2 (DL + LL - EQ_X)
12.	1.2 (DL + LL + EQ_Z)
13.	1.2 (DL + LL - EQ_Z)

Step-5 Modelling of building frames using STAAD.Pro software.
Step-6 In analyses different SMRF models, seismic zones and 13 load combinations are considered.
Step-7 Comparative study of results in terms of beam forces, displacement and storey displacement

Analysis Of Building Frames
Modelling and Analysis of building frames is carried out as per following details

Modelling of building frames
Following geometries of building frames are considered for analysis-

RESPONSE REDUCTION	TYPE OF STRUCTURE	ZONE
SMRF	BARE FRAME (REGULAR STRUCTURE)	4
SMRF	PLAZA (IRREGULAR STRUCTURE)	4
SMRF	STEPPED (IRREGULAR STRUCTURE)	4
TOTAL CASES		**12**

STAAD.Pro is used in modelling of building frames. STAAD.Pro is Structural Analysis and Design Program is a general purpose program for performing the analysis and design of a wide variety of structures. The essential 3 activities which are to be carried out to achieve this goal are -
a. Model generation
b. Calculations to obtain the analytical results
c. Result verification- These are all facilitated by tools contained in the program's graphical environment.

STRUCTURAL MODELS
Structural models for different cases are shown in Figures

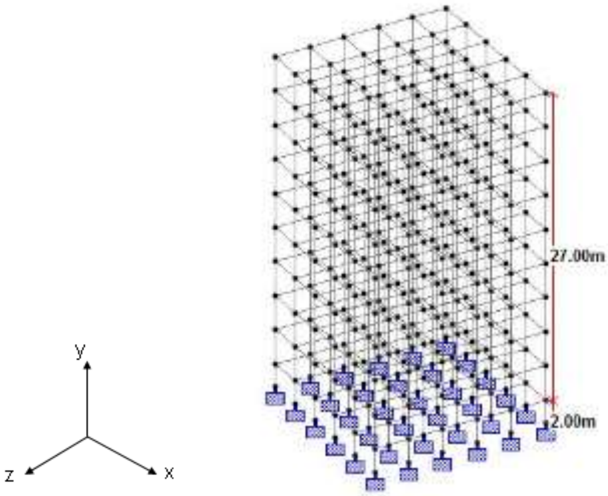

Fig.3.1:Isometric view of regular structure

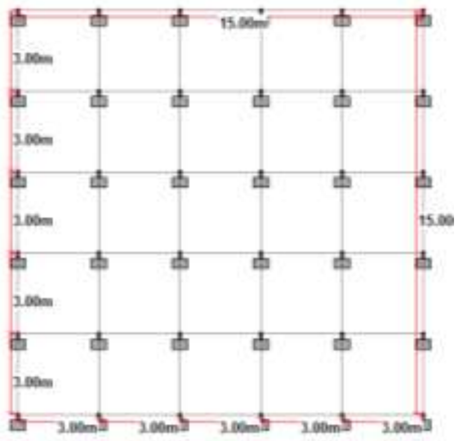

Fig. 3.2:Base Plan for all structures

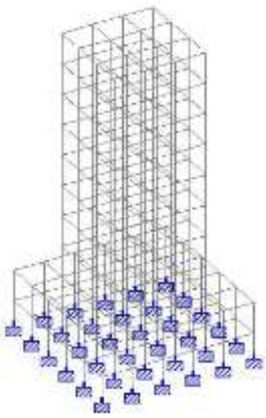

Fig.3.3:Isometric view of irregular plaza building

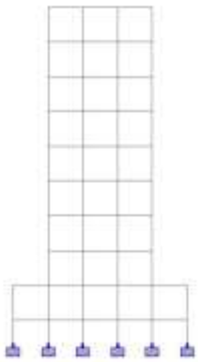

Fig.3.4:Front view of irregular plaza

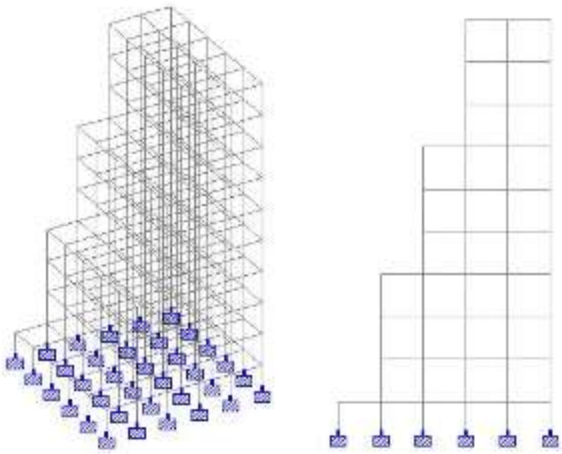

Fig.5:Isometric and Front views of irregular stepped building

The column size is of 0.35 m x 0.45 m, and the beam size is 0.23 m x 0.45 m.

MATERIAL AND GEOMETRICAL PROPERTIES

Following properties of material have been considered in the modelling -
Unit weight of RCC: 25 kN/m^3
Unit weight of Masonry: 20 kN/m^3 (Assumed)
Modulus of elasticity, of concrete: $5000\sqrt{fck}$
Poisson's ratio: 0.17

The depth of foundation is 2 m and the height of floor is 3 m.

LOADING CONDITIONS

Following loading conditions are used-

(i) **Dead Loads**: according to IS code 875 (part 1) 1987

(a) Self weight of slab

(b) Slab = 0.15 m x 25 kN/m^3 = 3.75 kN/m^2 (slab thickness 0.15 m assumed)

Finishing load = 1 kN/m^2

Total slab load = 3.75 + 1 = 4.75 kN/m^2

(c) Masonry external wall Load = 0.20 m x 2.55 m x 20 kN/m^3 = 10.2 kN/m

(d) Masonry internal wall Load = 0.10 m x 2.55 m x 20 kN/m^3 = 5.1 kN/m

(e) Parapet wall load = 0.10 m x 1 m x 20 kN/m^3 = 2 kN/m

(ii) **Live Loads**: according to IS code 875 (part-2) 1987

Live Load = 3 kN/m^2

Live Load on earthquake calculation = 0.75 kN/m^2

(iii) **Seismic Loads**: Seismic calculation according to IS code 1893 (2002)

1. Seismic zone-II,III,IV,V (Table - 2)
2. Importance Factor: 1.5 (Table - 6)
3. Response Reduction Factor:
   SMRF: 5 (Table - 7)
4. Damping: 5% (Table - 3)
5. Soil Type: Medium Soil (Assumed)
6. Period in X direction (PX):$\frac{0.09xh}{\sqrt{dx}}$seconds Clause 7.6.2
7. Period in Z direction (PZ):$\frac{0.09xh}{\sqrt{dz}}$seconds Clause 7.6.2

Where h = building height in meter

dx= dimension of building along X direction in meter

dz= dimension of building along Z direction in meter

LOADING DIAGRAM

Typical diagram for different types of loading conditions are shown in Fig. 3.7 to Fig. 3.10

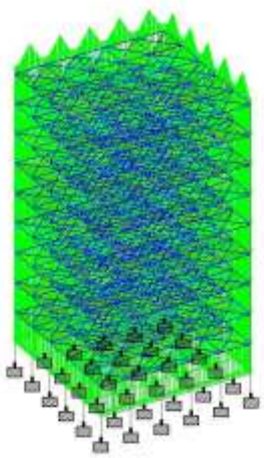

Fig. 3.7: Dead load diagram

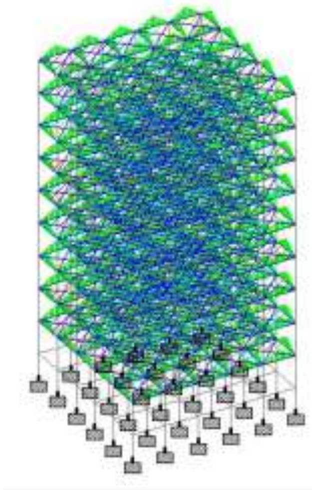

Fig. 3.8: Live load diagram

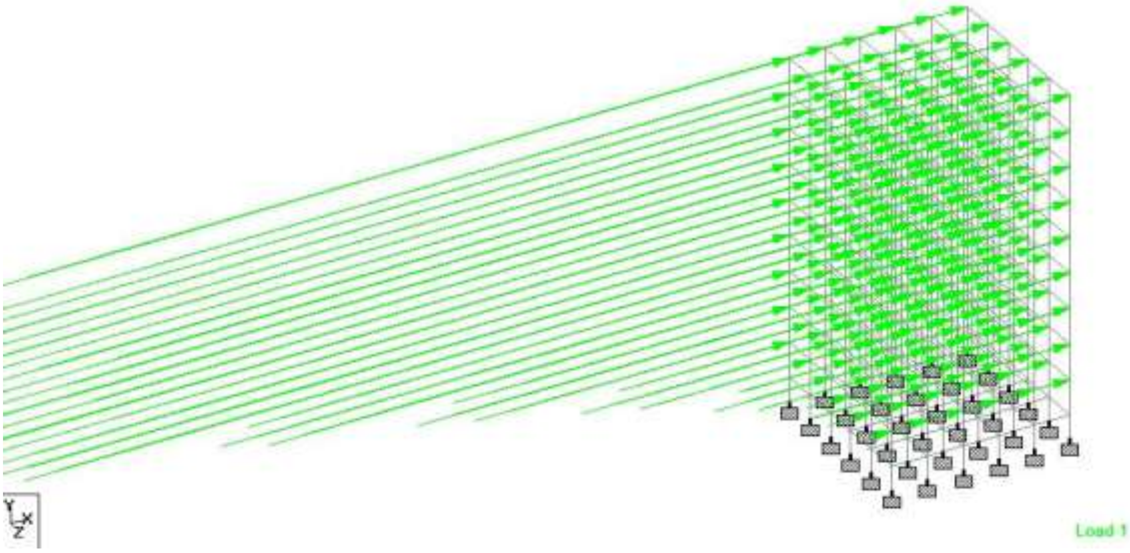

Fig. 3.9: Seismic load in X direction

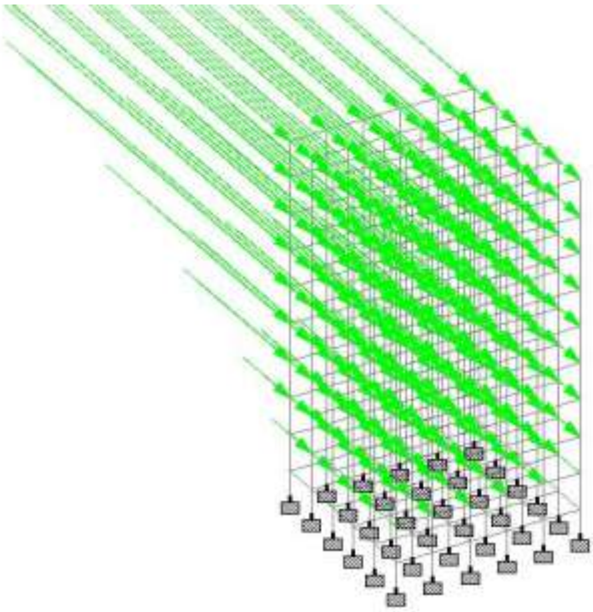

Fig. 3.10: Seismic load in Z direction

RESULT ANALYSIS

Bending moment

Maximum bending moment (kNm) in zone II is shown in Table 4.1 and Fig. 4.1

Table 4.1: Maximum bending moment (kNm) in zone II

MAXIMUM BENDING MOMENT (kNm) IN ZONE II			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	101.692	116.136	121.919

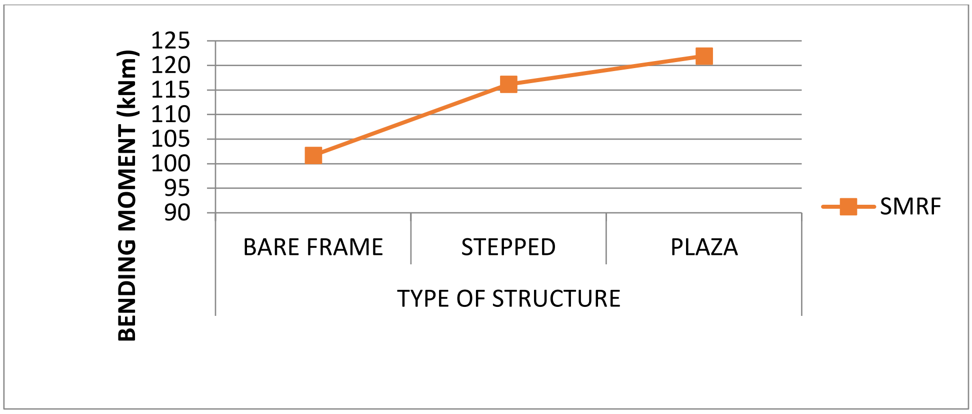

Fig. 4.1: Maximum bending moment (kNm) in zone II

It is observed that maximum bending moment is seen in OMRF and minimum in SMRF

Maximum bending moment (kNm) in zone III is shown in Table 4.2 and Fig. 4.2

Table 4.2: Maximum bending moment (kNm) in zone III

MAXIMUM BENDING MOMENT (kNm) IN ZONE III			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	150.978	167.462	182.736

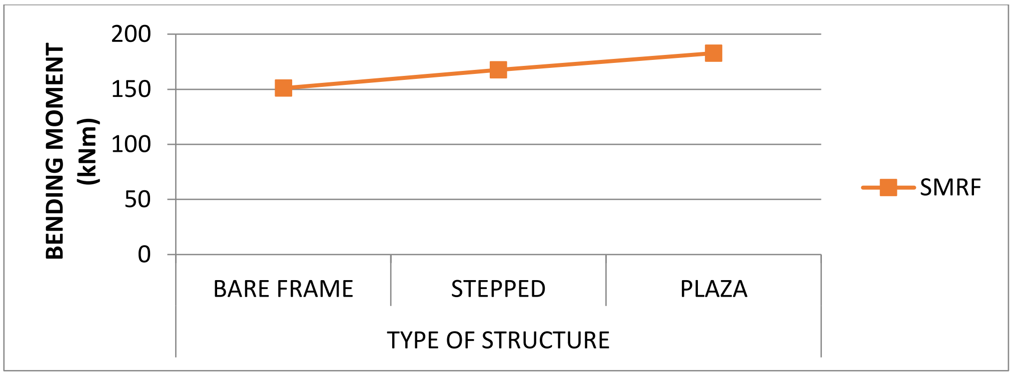

Fig. 4.2: Maximum bending moment (kNm) in zone III

It is observed that maximum bending moment is seen in OMRF and minimum in SMRF
Maximum bending moment (kNm) in zone IV is shown in Table 4.3 and Fig. 4.3

Table 4.3: Maximum bending moment (kNm) in zone IV

MAXIMUM BENDING MOMENT (kNm) IN ZONE IV			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	217.25	235.897	263.824

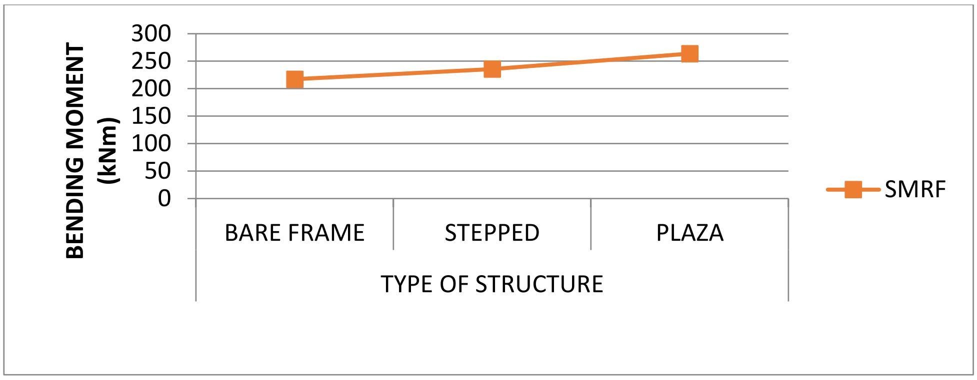

Fig. 4.3: Maximum bending moment (kNm) in zone IV

It is observed that maximum bending moment is seen in OMRF and minimum in SMRF
Maximum bending moment (kNm) in zone V is shown in Table 4.4 and Fig. 4.4

Table 4.4: Maximum bending moment (kNm) in zone V

MAXIMUM BENDING MOMENT (kNm) IN ZONE V			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	317.428	338.55	385.457

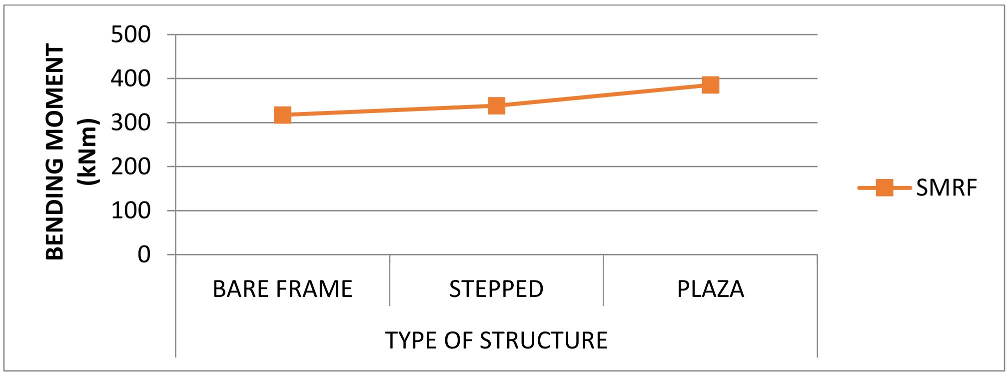

Fig. 4.4: Maximum bending moment (kNm) in zone V

It is observed that maximum bending moment is seen in OMRF and minimum in SMRF
Maximum shear force (kN) in zone II is shown in Table 4.5 and Fig. 4.5

Table 4.5: Maximum shear force (kN) in zone II

MAXIMUM SHEAR FORCE (kN) IN ZONE II			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	88.351	95.749	100.176

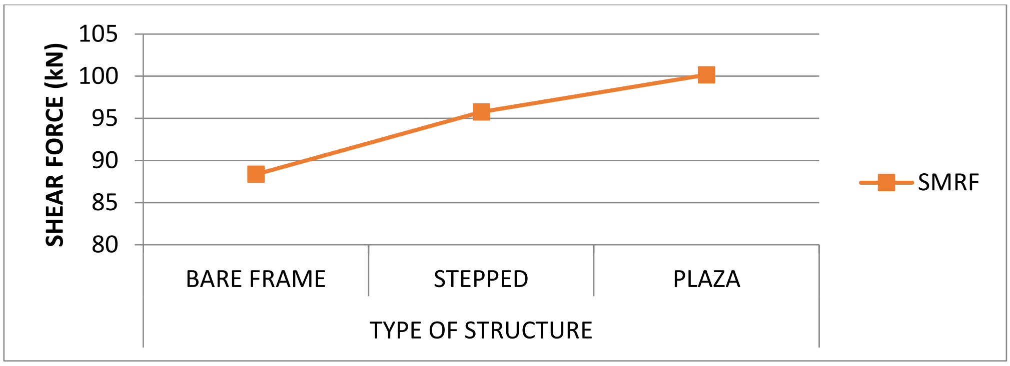

Table 4.5: Maximum shear force (kN) in zone II

It is observed that maximum shear force is seen in OMRF and minimum in SMRF
Maximum shear force (kN) in zone III is shown in Table 4.6 and Fig. 4.6

Table 4.6: Maximum shear force (kN) in zone III

MAXIMUM SHEAR FORCE (kN) IN ZONE III			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	118.444	126.604	136.927

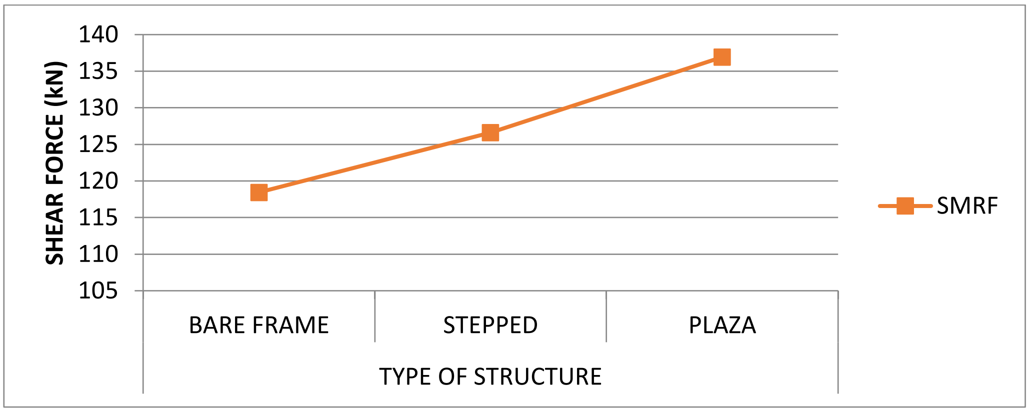

Fig. 4.6: Maximum shear force (kN) in zone III

It is observed that maximum shear force is seen in OMRF and minimum in SMRF
Maximum shear force (kN) in zone IV is shown in Table 4.7 and Fig. 4.7

Table 4.7: Maximum shear force (kN) in zone IV

MAXIMUM SHEAR FORCE (kN) IN ZONE IV			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	158.88	168.431	185.928

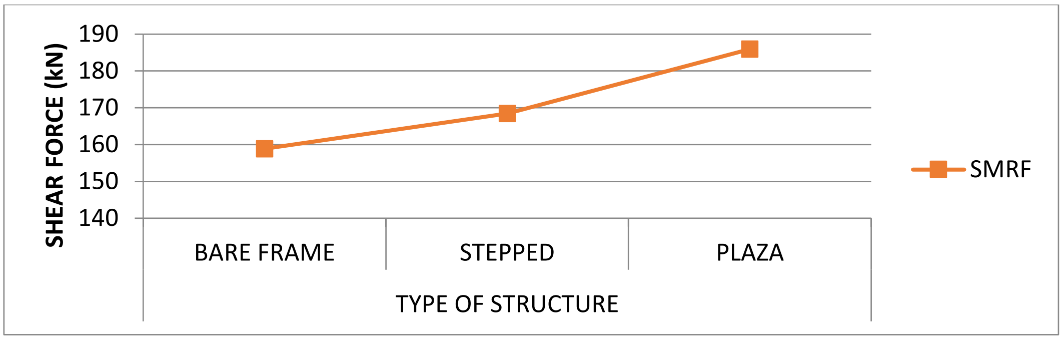

Fig. 4.7: Table 4.7: Maximum shear force (kN) in zone IV

It is observed that maximum shear force is seen in OMRF and minimum in SMRF
Maximum shear force (kN) in zone V is shown in Table 4.8 and Fig. 4.8

Table 4.8: Maximum shear force (kN) in zone V

MAXIMUM SHEAR FORCE (kN) IN ZONE V			
RF	TYPE OF STRUCTURE		
	BARE FRAME	STEPPED	PLAZA
SMRF	219.534	231.171	259.429

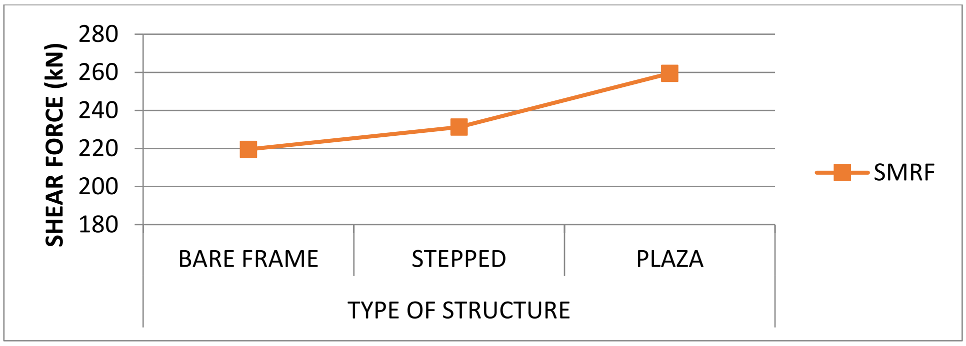

Fig. 4.8: Maximum shear force (kN) in zone V

It is observed that maximum shear force is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone II at X direction is shown in Table 4.9 and Fig. 4.9

Table 4.9: Maximum displacement (mm) in zone II at X direction

MAXIMUM DISPLACEMENT (mm) IN ZONE II			
RF	TYPE OF STRUCTURE IN X DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	51.821	52.346	58.542

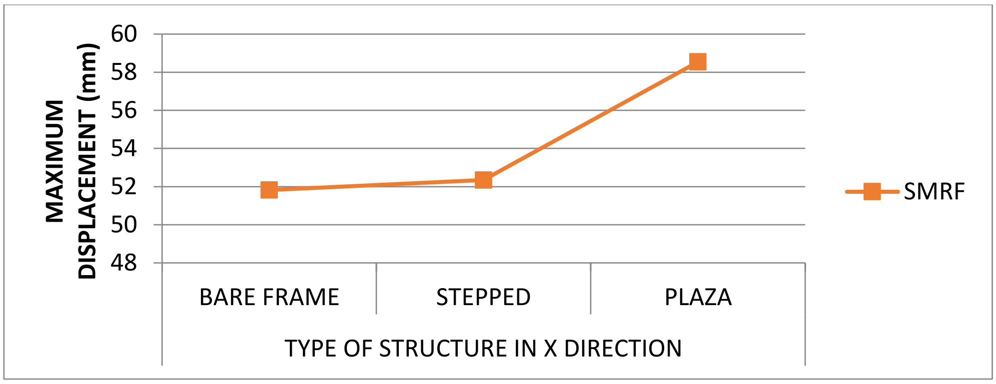

Fig. 4.9: Maximum displacement (mm) in zone II at X direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone II at Z direction is shown in Table 4.10 and Fig. 4.10

Table 4.10: Maximum displacement (mm) in zone II at Z direction

MAXIMUM DISPLACEMENT (mm) IN ZONE II			
RF	TYPE OF STRUCTURE IN Z DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	51.521	54.015	58.542

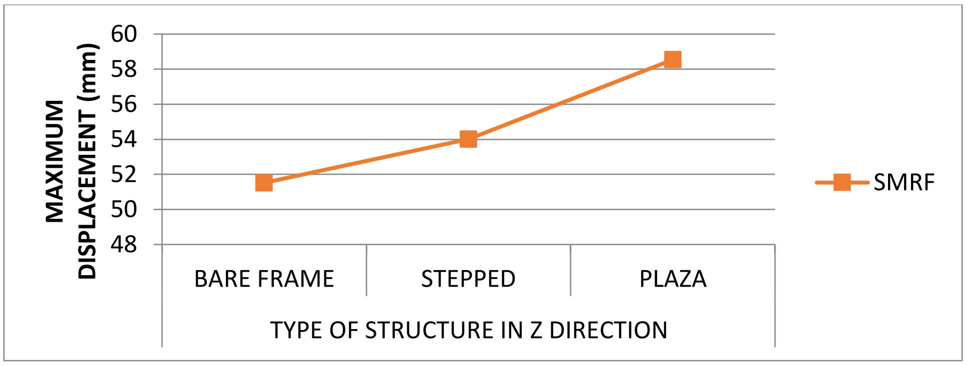

Fig. 4.10: Maximum displacement (mm) in zone II at Z direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone III at X direction is shown in Table 4.11 and Fig. 4.11

Table 4.11: Maximum displacement (mm) in zone III at X direction

MAXIMUM DISPLACEMENT (mm) IN ZONE III			
RF	TYPE OF STRUCTURE IN X DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	82.888	82.222	93.653

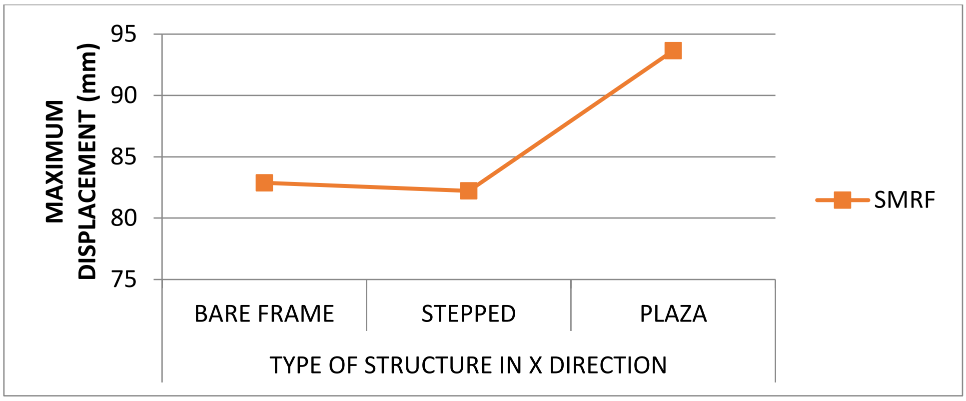

Fig. 4.11: Maximum displacement (mm) in zone III at X direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone III at Z direction is shown in Table 4.12 and Fig. 4.12

Table 4.12: Maximum displacement (mm) in zone III at Z direction

MAXIMUM DISPLACEMENT (mm) IN ZONE III			
RF	TYPE OF STRUCTURE IN Z DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	82.888	86.397	93.653

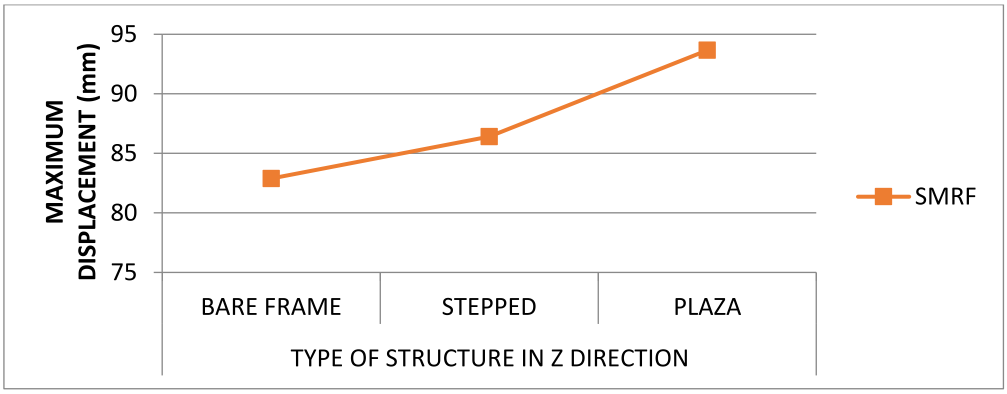

Fig. 4.12: Maximum displacement (mm) in zone III at Z direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone IV at X direction is shown in Table 4.13 and Fig. 4.13

Table 4.13: Maximum displacement (mm) in zone IV at X direction

MAXIMUM DISPLACEMENT (mm) IN ZONE IV			
RF	TYPE OF STRUCTURE IN X DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	124.31	122.058	140.468

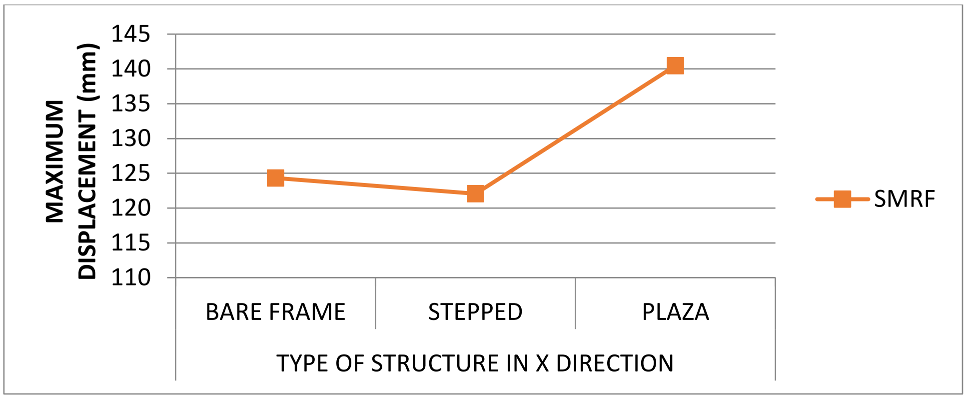

Fig. 4.13: Maximum displacement (mm) in zone IV at X direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone IV at Z direction is shown in Table 4.14 and Fig. 4.14

Table 4.14: Maximum displacement (mm) in zone IV at Z direction

MAXIMUM DISPLACEMENT (mm) IN ZONE IV			
RF	TYPE OF STRUCTURE IN Z DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	124.31	129.574	140.468

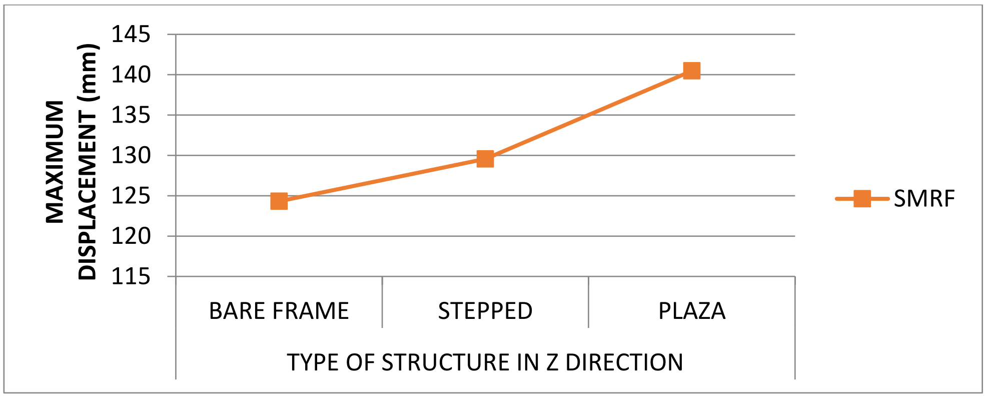

Fig. 4.14: Maximum displacement (mm) in zone IV at Z direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone V at X direction is shown in Table 4.15 and Fig. 4.15

Table 4.15: Maximum displacement (mm) in zone V at X direction

MAXIMUM DISPLACEMENT (mm) IN ZONE V			
RF	TYPE OF STRUCTURE IN X DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	186.444	181.81	210.691

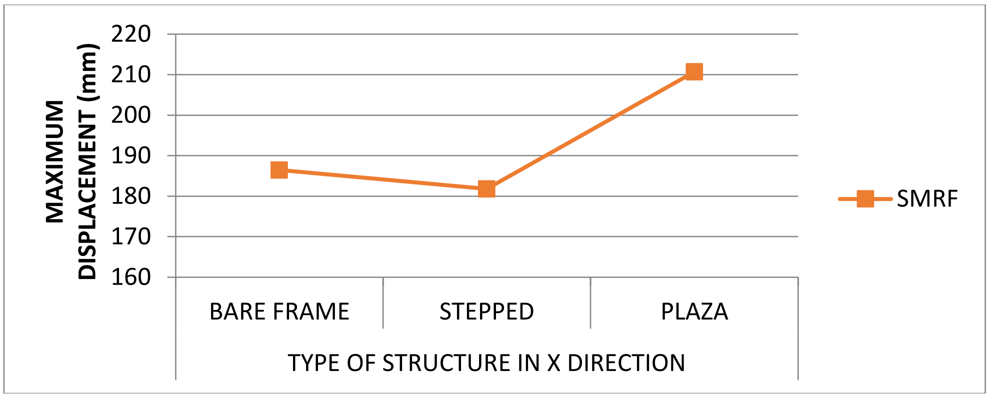

Fig. 4.15: Maximum displacement (mm) in zone V at X direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF
Maximum displacement (mm) in zone V at Z direction is shown in Table 4.16 and Fig. 4.16

Table 4.16: Maximum displacement (mm) in zone V at Z direction

MAXIMUM DISPLACEMENT (mm) IN ZONE V			
RF	TYPE OF STRUCTURE IN Z DIRECTION		
	BARE FRAME	STEPPED	PLAZA
SMRF	186.44	194.339	210.691

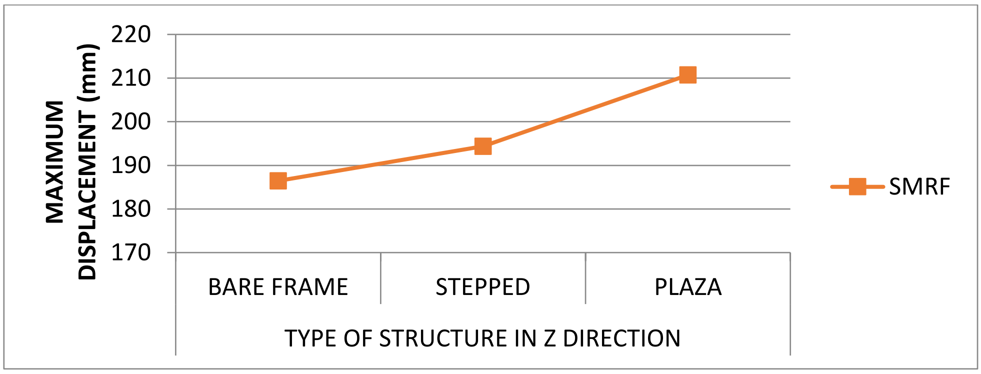

Fig. 4.16: Maximum displacement (mm) in zone V at Z direction

It is observed that maximum displacement is seen in OMRF and minimum in SMRF

CONCLUSION

CONCLUSION

Here in this work SMRF (special moment resisting frame) is analysed with all seismic zone considering various regular and irregular structures. The conclusion of the work is as follows

BENDING MOMENT

- The maximum bending moment is observed in irregular plaza building and minimum in regular bare frame building
- The rate of increase in bending moment is increases as the seismic zone intensity increases
- While observing nature of graph is same in all seismic zone it is clear that bare frame is best, stepped is second best and plaza building is critical

SHEAR FORCE

- The maximum shear force is observed in irregular plaza building and minimum in regular bare frame building
- The rate of increase in shear force is increases as the seismic zone intensity increases

- While observing nature of graph is same in all seismic zone it is clear that bare frame is best, stepped is second best and plaza building is critical

MAXIMUM DISPLACEMENT

- The maximum displacement is observed in irregular plaza building and minimum in regular bare frame building
- The rate of increase in displacement is increases as the seismic zone intensity increases
- Maximum displacement is almost same in both direction (X and Z direction)
- While observing nature of graph is same in all seismic zone it is clear that bare frame is best, stepped is second best and plaza building is critical

So from above graph and table it is observed that regular frame is better than irregular frame because it reduces various parameter like bending moment, shear force, and displacement. Above results also clears that SMRF is a moment resisting frame which is specially detailed to provide ductile behaviour in the structure and due to which size of section and area of reinforcement can be reduce. This analysis is very useful from high rise structures because SMRF gives a more safety to designer to design the structure and it is cost efficient to the builders.

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