Seismic Behaviour of Ordinary And Special Moment Resistaing Frame

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Abstract— In this study behaviour of the structure having various structural configurations like OMRF (Ordinary Moment Resisting Frames), SMRF (Special Moment Resisting Frames). The poor performance of Ordinary Moment Resisting Frame (OMRF) in past earthquakes suggested that, the special design and detailing to require arresting a ductile behaviour in seismic zones of high earthquake (zone III, IV & V). For this purpose, a G+7 storey R.C.C. regular building are analyzed for OMRCF, SMRCF framing configurations in Seismic Zone II, III & IV according to Indian codes. For OMRF structures the guide lines of I.S. 456-2000 and the design, detailing of reinforcement are executed as per which make the structure less tough and ductile in comparison of SMRF structures. The earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure. For adequate toughness and ductility to resist the severe earthquake shocks without collapse, in the SMRF structures Beams, columns, and beam-column joints are proportioned and detailed as per I.S. code 13920(2002). Thus it has been studied and observed that SMRF structures behave well in earthquake than OMRF structures.

Keywords- *OMRF, SMRF, Response Reduction Factor, Ductility, STAAD PRO.*

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I. INTRODUCTION

In some of the earthquakes of the world which occurred in India and the earthquake engineering developments in the country started. After the 1987 Assam earthquake, earthquake resistant type of housing was developed which is still prevalent in the north-east India. In the late 1950’s the institutional development started and earthquake engineering concepts have been introduced and applied to numerous major projects in high seismic regions in the country. Large scale damage occurs during several moderate earthquakes in recent years which indicate, despite such early gains, earthquake risk in the country has been increasing alarmingly. In high seismic regions of the country most of the buildings continue to be built without appropriate earthquake resistant features.

In India more than 60% of the land area is considered which is prone to high shaking of intensity VII and above (MMI scale). Himalayan belt is considered more prone to great earthquakes of magnitude exceeding 8.0 and in a short span of about 50 years, As per previous records four such earthquakes have occurred; in 1897 Assam (M8.7), 1905 Kangra (M8.6),1934 Bihar-Nepal (M8.4),and 1950 Assam-Tibbet (M8.7). The seismic risk in the country has been increasing rapidly in the recent years. As per records we noticed five moderate earthquakes in the last eleven years(1988 Bihar-Nepal; M6.6,about 1004 dead;1991 Uttar kashi: M6.6, about 768 dead; 1993 Latur : M6.4, about 8000 dead; 1997 Jabalpur: M6.0, about 38 dead; and 1999 Chamoli: M6.5, about 100 dead). From this record we have clearly noticed the inadequate preparedness of the country to face such damaging earthquakes. Framing system depends upon two important parameters of particular type i.e. seismic risk of the zone and the budget. As per the Indian Codes the entire country divide into four seismic zones (II, III, IV & V) depending on the seismic risks. The most commonly adopted type of frame is probably OMRF in lower seismic zones. Whereas with the increase in the seismic risks, it becomes necessary to adopt SMRF system.

SMRF	OMRF
It is a moment-resisting frame specially detailed to provide ductile behaviour and to comply with the requirements given in IS 13920.	It is a moment-resisting not meeting special detailing requirement for ductile behavior.
It is used under moderate-high earthquakes	It is used for low earthquakes
Design base shear is low.	Design base shear is high.
Response reduction factor, R = 5	Response reduction factor, R = 3
Low design base shear.	High design base shear.
It is safe to design a structure with ductile detailing.	It is not safe to design a structure without ductile

	detailing.

Table no. 1 Difference of SMRF and OMRF

A. SMRF and OMRF:

Criteria for earthquake resistant design of structures is given in IS 1893 (Part 1), 2002. Part 1 gives details about general provisions and buildings. Bureau of Indian Standards (BIS) classifies RC frame buildings into two categories, Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) with response reduction factors 3 and 5 respectively. If the structure were to remain elastic during its response to the Design Basis Earthquake (DBE) shaking, then it shall be reduced to obtain the design lateral force response. Reduction Factor (R) is the factor by which the actual base shears would be generated.

B. Ductility:

The required ductility was determined at the level of full structure behavior, while the available ductility was obtained as local behavior of node (joint panel, connections or member ends). The ductility checking of columns is generally a difficult operation. For SMRF structures, to achieve a global mechanism the column sections are enlarged. This extra-strength of the column will reduce the available ductility of columns. The collapse of the building may occur due to lack of sufficient ductility. It was observed that the factors regarding seismic actions, such as velocity and cycling loading, reduce the available ductility. The deformation capacity of columns is being expressed in different ways which are curvature ductility, displacement ductility or drift.

C. Response Reduction Factor:

Now a day's it comprises the nonlinear response of a structure through a 'response reduction/modification factor' (R). A designer to use a linear elastic force-based design while accounting for nonlinear behaviour and deformation limits conducts the design as per response factors. From the results observed, it is seen that the Indian standard suggests a higher value of R, which is actually hazardous.

II. PRESENT STUDY AND SCOPE FOR FUTURE WORK

The present study is limited to Reinforced Concrete plane frames without shear wall, basement, and plinth beam. The study does not consider stiffness and strength of Infill walls. The interface effects of soil structure are not taken into account in the study. The column bases are considered and assumed to be fixed in the study. In the study the aspect ratios (i.e, ratio of height to width) of each frames considered is not to be the same. The effect of strength and stiffness of infill walls in the frames does not consider in the present study. This approach can be extended to frames modeling the infill walls.

A. Earthquake Design Philosophy:

The severity of ground shaking at any particular location depends upon during the event of an earthquake which can be categorized as *minor, moderate and major*. The aim of the structural designers / Engineer is to construct a structure that may resist even in the major earthquake shaking. It is very rare to see and it may occur only about once in 500 or 1000 years. Thus the question arises that whether should we design the buildings as Earthquake proof or Earthquake-resistant? Therefore the common practice is to make the structures earthquake-resistant. These structures may get damaged during the event of an earthquake but still would not collapse. Thus, safety of people is of prime importance & commodities are assured and it is achieved in lesser investment when compared to Earthquake-proof structures.

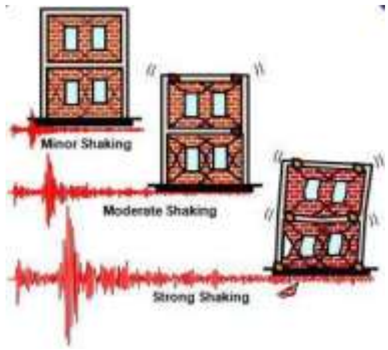


Fig 1 Effect on buildings due to ground shaking

The Earthquake Design Philosophy (EDP) can be summarized as follows:

- During the event of minor shaking, the members of the structure which do not carry any loads can sustain repairable damages and the main members of a structure that carry the vertical and horizontal forces should not get damaged is taken care of.
- During the event of moderate shaking, the non-load carrying members may get severely damaged and may even need to be replaced and the main members of a structure may sustain repairable damages.
- During the event of severe shaking, the safety of the inhabitants of the building is of prime importance, the main members may sustain severe, sometimes irreparable damages but the building should not collapse completely .

III. LITERATURE REVIEW

1. **Sheovinay Rai, Rajiv Banarjee, Tabish Izhar,** In this study the seismic behaviour of the structure having various structural configurations like Ordinary Moment Resisting Frames, Special Moment Resisting Frames using softwares like i.e. Stadd.Pro & Etabs. A comparative study of all the types of suited frame is studied and the best to be adopted for seismic loads in Indian scenario. In this study a building of G+6 storey

R.C.C. regular building are analysed for Ordinary Moment Resisting Frames, Special Moment Resisting Frames in Seismic Zone III & IV according to Indian codes. In this study linear static Analysis are carried out to evaluate their structural efficiencies in terms of average storey displacement, storey drifts, Time period. In Ordinary Moment Resisting Frames structures the design and detailing of reinforcement are executed as per the guide lines of I.S. 456-2000 which make the structure less tough and ductile in comparison of Special Moment Resisting Frames structures. In Special Moment Resisting Frames structures Beams, columns, and beam-column joints are proportioned and detailed as per I.S. code 13920(2002) which give sufficient toughness and ductility to resist the severe earthquake shock without a collapse. Thus it has been observed that Special Moment Resisting Frames structures behave well in earthquake than Ordinary Moment Resisting Frames structures.

2. **P.Ram Prasad, R. Rama Rao,** In the Moment resisting frames which is commonly used as the dominant mode of lateral resisting system for a long time in seismic regions. The poor performance of Ordinary Moment Resisting Frame in past earthquakes requires special design and detailing to have a good ductile behaviour in seismic zones of high earthquake (zone III, IV & V). When the large earthquake occurs, Special Moment Resisting Frame is specially detailed with a response reduction factor, R = 5 is expected to have greater ductility. The response reduction factor in SMRF is 5 which reduce the design base shear and in such a case building depends mostly on their ductile performance. For ensuring the ductile performance, frames must be detailed in a special manner recommended as per IS 13920. The objective of the study is to evaluate R factors of these kind of frames from their nonlinear base shear vs roof displacement curves and to check its accuracy it is compared to code recommended R value. Various concrete confinement models is carried out to study and select appropriate concrete confinement model.. The pushover curves of each Special Moment Resisting Frame and Ordinary Moment Resisting Frame are generated and converted to a bilinear format to calculate the behaviour factors. The response reduction factors shown in general both the Ordinary Moment Resisting Frame and Special Moment Resisting Frame, which failed to achieve the respective target values of response reduction factors recommended by IS 1893-2002. It was found that the shorter frames exhibit higher R factors and thus the height of the frames increases and the R factors decreases.

3. **Abhyuday Titiksh, Dr. M.K. Gupta.** The objective of this study is to study the seismic behavior of the structure in which various structural configurations like Ordinary Moment Resisting Concrete Frames, Special Moment Resisting Frames and Braced Steel Frames. A comparative study has been done on all the types of frames and the best suited frame is adopted for seismic loads in Indian condition. For this purpose, a G+4 building was designed for an Ordinary Moment Resisting Concrete Frames, Special Moment Resisting Frames and Braced Steel Frames, framing configurations in Seismic Zone V according to Indian codes. In this paper the tests were carried out to evaluate the structural efficiencies of storey drifts, Base shear, amount of reinforcement etc. Ordinary Moment resisting frames have been widely used for seismic resisting systems due to their superior deformation and energy dissipation capacities. A ordinary moment resisting 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.

4. **Jaya Prakash Kadali, M.K.M.V.Ratnam, Dr.U.RangaRaju**, Moment resisting frames were commonly used as the mode of lateral resisting system in seismic regions. In this type of frames, Beams, columns, and beam-column joints in moment frames are proportioned and detailed to resist flexural, axial, and shearing actions whose results as a building sways through multiple displacement cycles during strong earthquake ground shaking. Reinforced concrete special moment frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. The poor performance of Ordinary Moment Resisting Frame in past earthquakes suggests special design and detailing for ductile behaviour in seismic zones of high earthquake. Thus for a large earthquake, Special Moment Resisting Frame is specially detailed and is expected to have the superior ductility. Special proportioning and detailing requirements in a frame capable of resisting to the strong earthquake shaking without significant loss of stiffness or strength. Thus these moment-resisting frames are called “Special Moment Resisting Frames” such type of additional requirements, which improve the seismic resistance as compare to less stringent detailed Intermediate and Ordinary Moment Resisting Frames.

5. **Ambika-Chippa, Prerana-Nampalli,** In this study comparison of seismic analysis and design of RC moment resisting space frame is done with shear wall. In the moment resisting frame and shear wall system, two different cases were chosen for the study. In this study the moment resisting frame, Special Moment Resisting Frame and Ordinary Moment Resisting Frame were studied 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 shear wall system, structure with shear wall and without shear wall were also considered with (G+8) storey for (5x5) bay for frame with brick infill with same loading conditions. In this study Frame has been analyzed and designed using STAAD ProV8i software. IS: 456-2000, IS: 1893 (Part-1)2002 and detailing is done as according to IS: 13920-1993. From these all types of data, cost is calculated and economic structure is being found out.

6. **G.V.S.SivaPrasad, S. Adiseshu,** In this study it is use to investigate the seismic behavior of the Ordinary moment resisting frame and Special R C moment Resisting frame. For this purpose structure were modeled and

analysis was done with 5 th , 10 th , 15 th , 20 th storied using Staad.Pro software and using the different codes for analysis such as, IS 1893:2002, IS 456: 2000.In this studyit is assumed that the buildings were located in seismic zone II Visakhapatnam region. The study also involves the design of alternate shear wall in a structural frame with the different orientation, which gives better results for the Ordinary moment resisting frame and Special R C moment Resisting frame structure constructed in and around Visakhapatnam region. The buildings are modeled with floor area of 600 sqm. The whole design is carried out with the use of STAAD.PRO software. The design of Shear walls are done and the results of the maximum value of the stress contour and calculation are done manually by using the IS 456-2000 and IS 13920-1993. The framing system should meet the drift requirements.

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

7. **Dr. Valsson Varghese, Yogesh R. Borkar,** In this paper it shows the Seismic evaluation about the building performance during an earthquake. The criteria of evaluation of the building will depend basically on the materials like, strength and ductility of structural components and detailing of reinforcement. In this study Special Moment Resisting Frame and Ordinary Moment Resisting Frame are considering as the structural frame and Comparison is done for seismic load. Detailing of reinforcement and design is done in case of Ordinary Moment-Resisting Frame as per IS 456 Provision's, while in case of Special Moment-Resisting Frame detailing of reinforcement and design is done by using IS 456:2000, as well as detailing done by IS 13920:1993. Hence Ordinary Moment Resisting Frame Structure is to be designed for relatively very higher forces to that of Special Moment Resisting Frame Structures. Thus the performance of Special Moment Resisting Frame structure in Earthquake is better as compare to Ordinary Moment Resisting Frame structure.

IV. MODELING AND ANALYSIS

In this study the G+10 RCC structure is analyzed. When earthquake occurs even a small shaking is also lead to structure collapse hence the RCC structure is designed as Earthquake resisting structure as per IS 1893: 2002. In present work the two frames of G+10 RCC building is modeled and analyzed under the seismic effect. The one frame is analyzed as SMRF frame (Special Moment Resisting Frame) and another frame is analyzed as OMRF (Ordinary Moment Resisting Frame). Each model has 3.5 meter foundation depth. The basic plan area of model is 15 x 12 meter. The floor to floor height of building is 3.5 meter. Column spacing is 3 meter in X and Z - direction. The total height of structure is 39.5 meters i.e 38.5 total floor height + 1 meter plinth height. The depth of foundation is 3.5 meters. For the analysis of structure STAAD PRO V8i software is used. The structure is first modeled in software and scrutinized for any duplicate nodes or member. The beam and column parameters are provided to the structure. All the column base is assigned as fixed support. The earthquake loads on the structure is assigned as per IS 1893: 2002 guidelines. The Zone of earthquake is III. At last both the frames are analyzed and results are interpreted and compared with each other. The frames with different Response reduction factor (R) is analyzed separately and results of max. Bending moment of beams of each floors, Axial forces on column, Drift in X and Z direction and lateral force distribution on each floor is compared with another frame results.

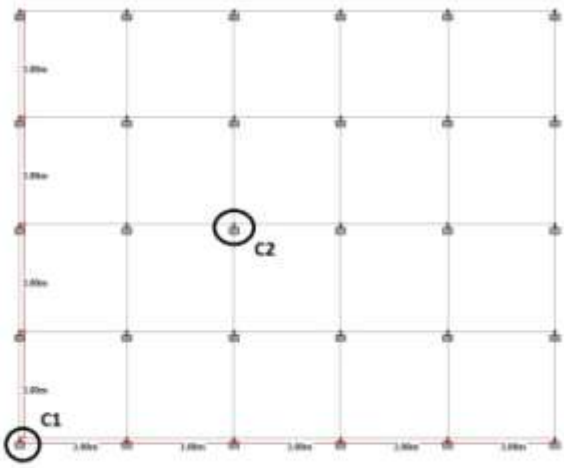


Fig 2 STAAD PRO model show column position

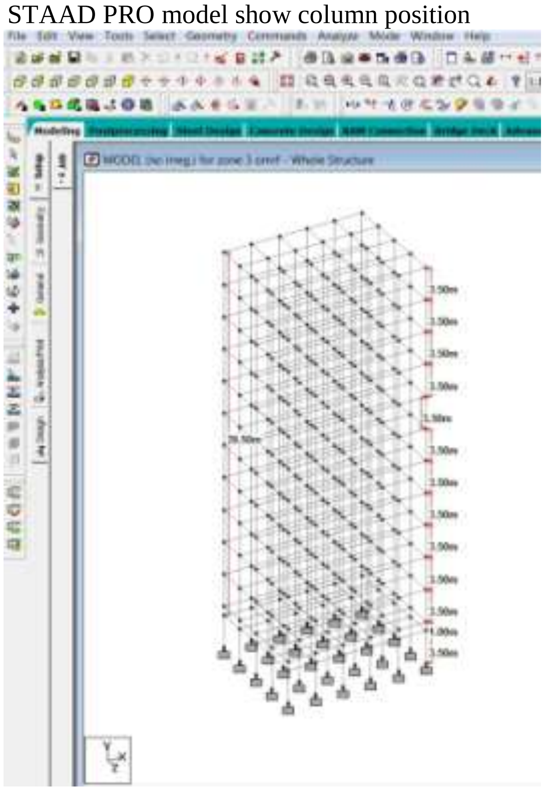


Fig 3 STAAD PRO model with fixed support

The following table contains the necessary data required for analysis of structure,

PARAMETERS	DIMENSIONS
SIZE OF BEAM	450 X 300 MM
SIZE OF COLUMN	800 X 600 MM
GEOMETRY PARAMETER	
PLINTH HT.	1M
STOREY HT.	3.5 M
SPACING OF COL.	3M
DEPTH OF FOUNDATION	3.5 M
BAY ALONG X-DIR.	5
BAY ALONG Z - DIR	4
SIZE OF BUILDING	15 X 12 M
LOADING ON STRUCTURE	
LIVE LOAD	4 KN/M^2
SLAB	125 MM
FLOOR FINISH	1.5 KN/M^2
THICKNESS OF INTERNAL WALL	115MM
THICKNESS OF EX. WALL	230 MM
PARA. WALL HT.	1M
DENSITHY OF CONCRETE	25 KN/M^2
DENSITY OF BRICK	20 KN/M^2
EARTHQUAKE PARAMETER (IS 1893:2002)	
ZONE	III
SOIL TYPE	MEDIUM SOIL
IMPORTANCE FACTOR	1.5
STRUCTURE TYPE	CONCRETE STRUCTURE
SUPPORT TYPE	FIXED TYPE
LOAD COMBINATIONS	
LOAD COMBINATION	1.5 (DL+LL) 1.2(DL+LL+ EQ) 1.2(DL+LL - EQ) 1.5(DL+_EQ) 1.5(DL - EQ) 0.9DL+ 1.5EQ 0.9DL - 1.5EQ

Table no. 2 parameters for design

IS 1893 : 2002 gives the guidelines for Earthquake Resistance design.
As per Clause 6. 4. 2, the design horizontal seismic coefficient (A_h)

$$A_h = \frac{Z}{2}\ \frac{I}{R}\ \frac{Sa}{g}$$

where,

Z = Zone factor
I = Importance Factor
R = Response Reduction factor
Sa/g = Average Response acceleration coefficient

As per IS 1893:2002 the zone of earthquake in India is divided in four zones as follows, (Clause 6. 4. 2, Table 2, Pg. 16)

ZONE	II	III	IV	V
INTENSITY	0.10	0.16	0.24	0.36

Table no. 3 Zone factor

The importance factor (I) is mention in clause 6.4.2 and values are tabulated in table no. 6 of IS 1893:2002

STRUCTURE	IMPORTANCE FACTOR
IMPORTANT SERVICE AND COMMUNITY BUILDING SUCH AS SCHOOL, HOSPITALS ETC.	1.5
ALL OTHER BUILDINGS	1

Table no. 4 Importance factor

The Response Reduction Factor (R) as Per IS1893:2002 Clause 6. 4. 2, Table No.7 of IS 1893:2002

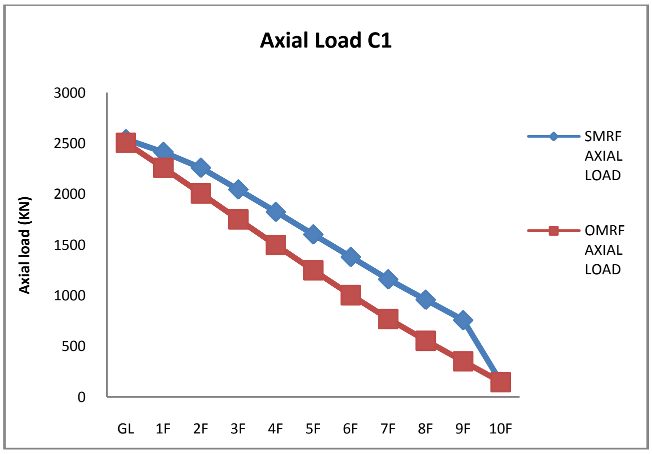
SYSTEM	R
SMRF	3
OMRF	5

Table no. 5 Response reduction factor

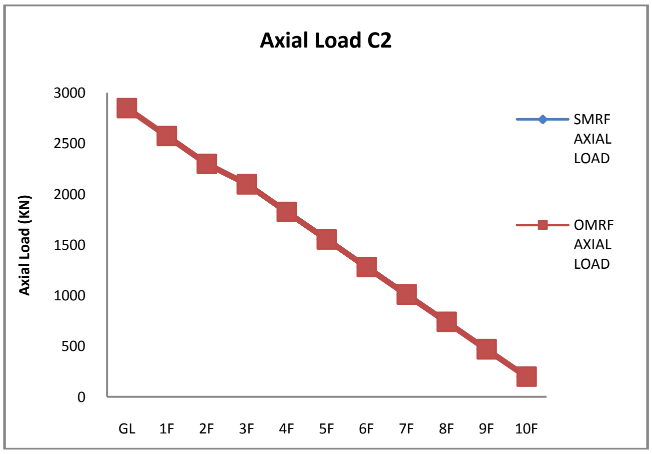
The design base shear according to clause 7.5.3

$$Vb = A_h W$$

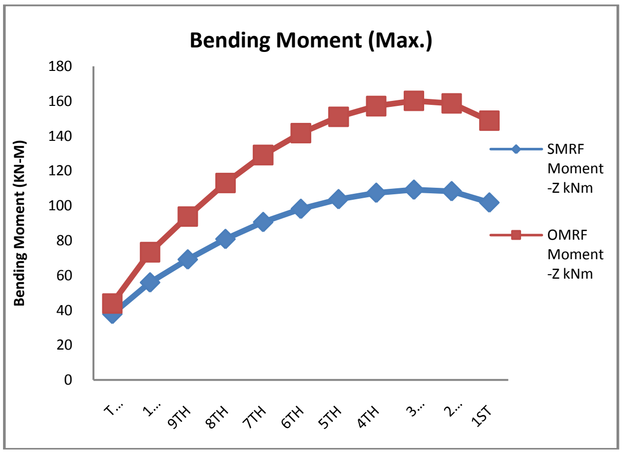
where, w= seismic weight of building
Ah = Design horizontal spectrum value as per clause 6.4.2



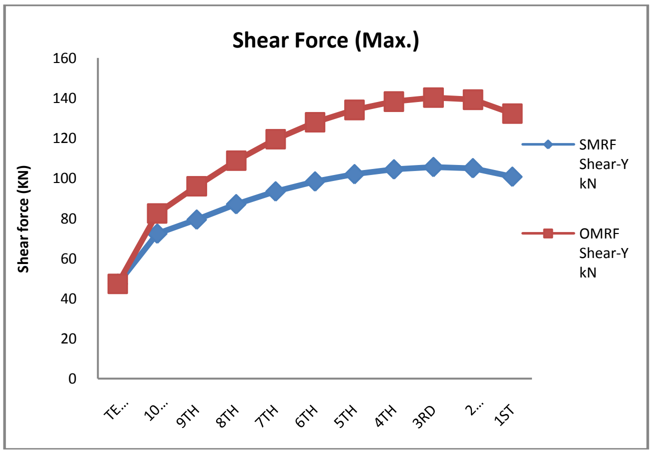
Graph 1 Axial load for column C1



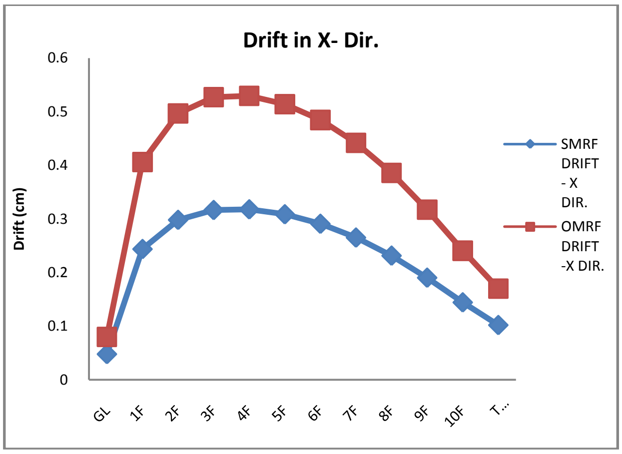
Graph 2 Axial load for column C2



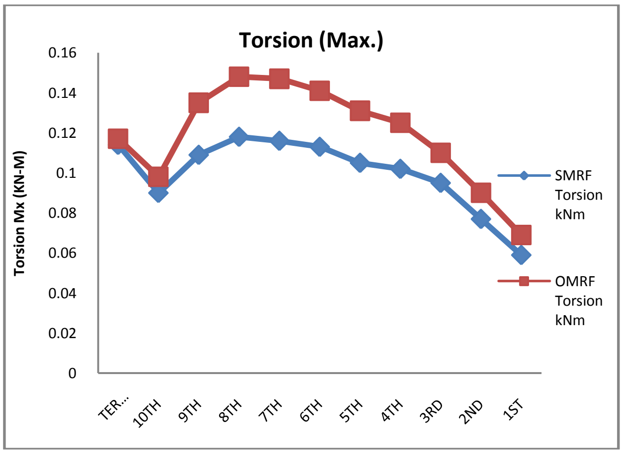
Graph 5 Max. Bending moment on each floor beam



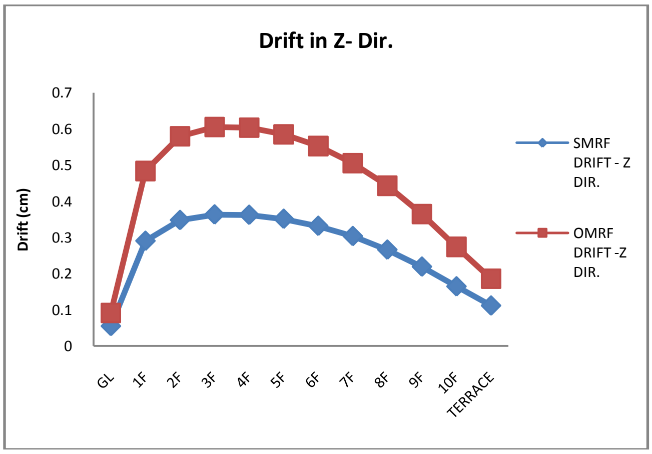
Graph 3 Max. shear force on each floor beam



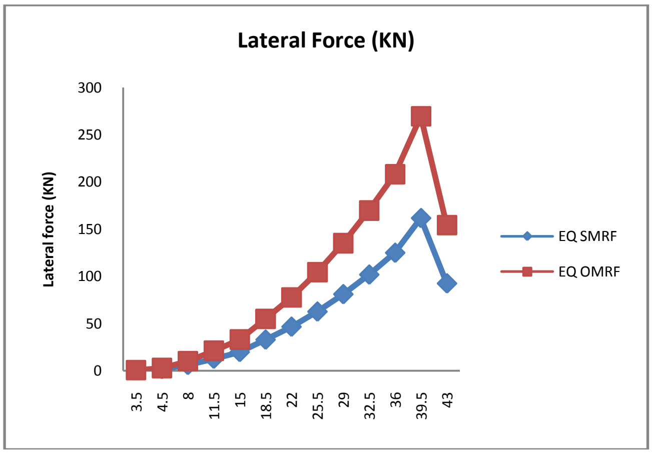
Graph 6 Drift in X-direction



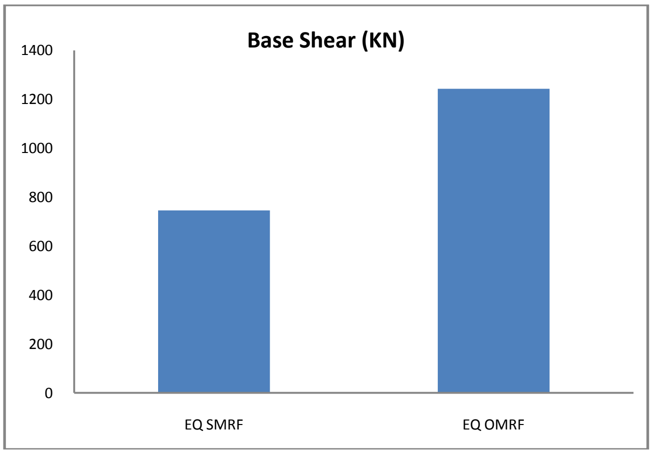
Graph 4 Max. Torsion on each floor beam



Graph 7 Drift in Z-direction



Graph 8 Lateral force on each floor



Graph 9 Comparison of base shear

V. Conclusion

After the analysis of structure and comparing with each other following conclusions are as,

1) The axial load on column C1 i.e column situated at corner carries less load when (structure is considered for OMRF) when compared with SMRF. The axial load carried by column C2 is equal in both the system.
2) The max. Shear force on the floor beam in the SMRF system is 20% - 25% less than the OMRF system.
3) The torsion in SMRF system is 15% - 20% less when compared with OMRF system.
4) The Bending moment carries by each floor in SMRF system is 25% - 30% less than OMRF system.
5) The drift in X and Z direction of SMRF system is 40% less than drift cause due to OMRF system.
6) The lateral force distributed on each floor is linear and the SMRF system shows less attraction of lateral force.
7) The base shear of SMRF system is less 40% than OMRF system.
8) It can be conclude that the SMRF system of ductile design is best for the analysis and design of earthquake resisting structure.

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