Seismic Performance Assessment of Multi-storeyed RC Special Moment Resisting Frames By Pushover Analysis

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Abstract - *In this paper study about the seismic analysis of special and ordinary moment resisting frame by the pushover analysis with the help of the SAP2000 software which is product of the Computer and Structure &Inc. The code used for seismic analysis IS CODE 1893 part1:2016. The method used in this analysis is Nonlinear static Analysis in which static analysis represent the Response Spectrum method. The main aims of this paper to study about the plastic hinges which produce after the collapse of the structure and also comparative study about the ordinary and special moment resisting frame that which one is perform better in the push over analysis. The hinges apply at the all beam and column to study about the plastic hinges in the structure. The main purpose to choose special moment resisting frame is that frame which resist the strong ground motion during the earthquake. The ordinary moment resisting frame is that frame which resists the low ground motion as compared to the special moment resisting frame. After analysis we can say that which frame produce little plastic hinges as compared to the other frame. The designing criteria of the Special Moment Resisting Frame and Ordinary Moment Resisting Frame are given in the Indian Standard Code 1893 part1:2016.*

Key Words: SAP2000, Response Spectrum Analysis, SMRF, OMRF, Pushover Analysis, Plastic Hinges.

1. INTRODUCTION

According to Indian standards Code 1893 part1:2016, moment resisting frames are classified as Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) with response reduction factors 3 and 5 respectively. Moment-resisting frames are commonly used in urban areas worldwide as the dominant mode of building construction. However, documented poor performance of ordinary moment frames in past earthquakes warned the international community that this structural system required special design and detailing in order to warrant a ductile behavior when subjected to the action of strong earthquake. Current design provisions assigned the highest R factor to SMRF. The elastic forces are reduced by a response reduction factor to calculate the seismic design base shear. . Present study is an attempt to evaluate the response reduction factors of SMRF and OMRF frames and to check the adequacy of R factors used by IS code containing objectives as,

(i) To find Earthquake response of frames designed as SMRF and OMRF according to IS 1893 (2016) using Pushover analysis.
(ii) To determine the Performance level of SMRF and OMRF frames using Pushover analysis.

2. Modelling

In the modeling we write the details about the model which was analyzed in SAP2000. Such as the material parameter, Section parameter, load parameter, and seismic parameter.

2.1.Material Parameter

Table-2.1: Material Parameter

Material Name	Value
Concrete	M25
Rebar	HYSD415, Mild250

2.2.Section and Seismic Parameter

Table-2.2: Section and Seismic Parameter

Beam	500mmX40mm
Column	600mmX400mm
Slab	150mm
Seismic Zone factor	0.36
SMRF	5.0
OMRF	3.0
Importance Factor	1.0
Soil Type	2nd (Medium soil)

2.3.Load Parameter

Table-2.3: Load Parameter

Dead	Auto Defined
Live	3KN/m^2
Finishing Load	1 KN/m^2
Roof	2 KN/m^2
Wall Load	15KN/m
Parapet Wall Load	7.5KN/m
EX	1893 part1:2016 (X-Direction)
EY	1893 part1:2016 (Y-Direction)

2.4.Different View of Model

The model for the SMRF and OMRF is same only value of the response reduction factor is 5 and 3 respectively

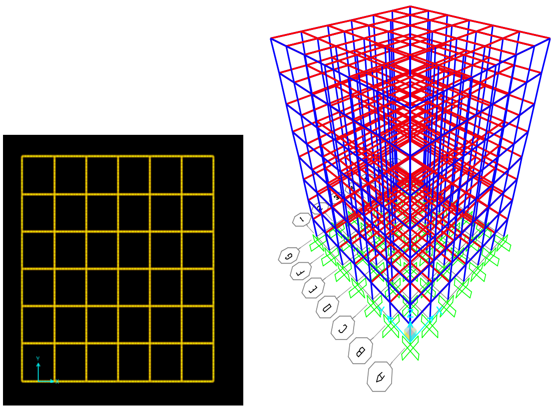

Fig-2.4: Plan and 3D View

3. Methodology

3.1.Response Spectrum Method

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure. Response-spectrum analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping. It is practical to envelope response spectra such that a smooth curve represents the peak response for each realization of structural period.

Response-spectrum analysis is useful for design decision-making because it relates structural type-selection to dynamic performance. Structures of shorter period experience greater acceleration, whereas those of longer period experience greater displacement. Structural performance objectives should be taken into account during preliminary design and response-spectrum analysis.

3.2. Pushover Analysis

Pushover analysis is a static, nonlinear procedure to analyze the seismic performance of a building where the computer model of the structure is laterally pushed until a specified displacement is attained or a collapse mechanism has occurred as shown in Fig-3.2.The loading is increased in increments with a specific predefined pattern such as uniform or inverted triangular pattern. The gravity load is kept as a constant during the analysis. The structure is pushed until sufficient hinges are formed such that a curve of base shear versus corresponding roof displacement can be developed and this curve known as pushover curve. A typical Pushover curve is shown in Fig-3.2.The maximum base shear the structure can resist and its corresponding lateral drift can be found out from the Pushover curve.

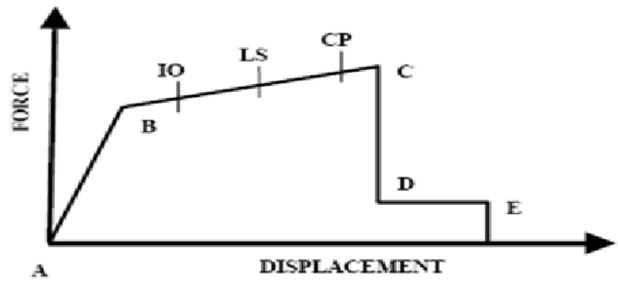

Fig-3.2: Pushover Curve

A = Original State (OL) of the structure.
B = Yielding. No deformation occur up to point B.
C = represent ultimate capacity/limit for pushover analysis.
D = Represent residual strength limit in the structure. After this limit structure initialized collapsing.
E = Represent total failure of structure. After this point hinges break down

4. Result and Discussion

After analysis the model of SMRF and OMRF following results are given below:-

4.1. Modal Period and Frequency

The modal period and frequency of the both Special Moment Resisting Frame (SMRF) and Ordinary Moment Resisting Frame (OMRF) is same

Mode	Period (sec)	Frequency (cyc/sec)
Mode1	0.644814	1.550835394
Mode2	0.533867	1.873124305
Mode3	0.53248	1.878003432
Mode4	0.212995	4.694935292
Mode5	0.175383	5.701802045
Mode6	0.17328	5.771002298
Mode7	0.12474	8.016700066
Mode8	0.102318	9.773496604
Mode9	0.098745	10.12707928
Mode10	0.088379	11.31494737
Mode11	0.071359	14.01359763
Mode12	0.068665	14.5634917

4.2. Axial force and Bending Moment at Hinges of Special Moment Resisting Frame (SMRF) due to Pushover Analysis in X-direction (Model1)

Hinges	Axial Force (P) (KN)	Moment in Local Axis Y Direction (M2) KN-m	Moment in Local Axis Z Direction (M3) KN-ms
1016H1	-47..1119	-5.283	5.8838
1016H3	-30.9167	6.6193	-8.3109
1017H1	-60.3464	-6.6567	1.0029
1017H3	-44.1511	8.2088	-1.2131
1018H1	-57.2674	-6.3205	4.625
1018H3	-41.0722	7.7999	-5.7436
1019H1	-60.7137	-6.7144	$2.484X10^{-15}$
1019H3	-44.5185	8.28	$1.698X10^{-13}$
1020H1	-60.3464	-6.6567	-1.009
1020H3	-44.1511	8.2088	1.2131
1021H1	-57.2674	-6.3205	-4.625
1021H3	-41.0722	7.7999	5.7436

4.3.Axial Force and Bending Moment At hinges of the Ordinary Moment Resisting Frame (OMRF) due to Pushover Analysis in X-direction (Model2)

Hinges	Axial Force (P) (KN)	Moment in Local Axis Y Direction (M2) KN-m	Moment in Local Axis Z Direction (M3) KN-ms
1016H1	-61.0178	-8.034	7.9012
1016H3	-43.190	10.0015	-11.0795
1017H1	-77.8944	-9.8703	8.2306
1017H3	-53.8034	13.7013	-5.0048
1018H1	-59.7309	-11.9804	7.9801
1018H3	-53.6901	9.8107	-9.1364
1019H1	-68.6408	-10.3400	1.5690
1019H3	-51.4098	13.7311	0.9452
1020H1	-73.7106	-9.4508	-5.3100
1020H3	-55.0659	13.1056	4.9736
1021H1	-68.7603	-9.4588	1.3470
1021H3	-54.9003	9.8960	8.3701

The graph of the axial forces at the selected hinges of the SMRF and OMRF is given below

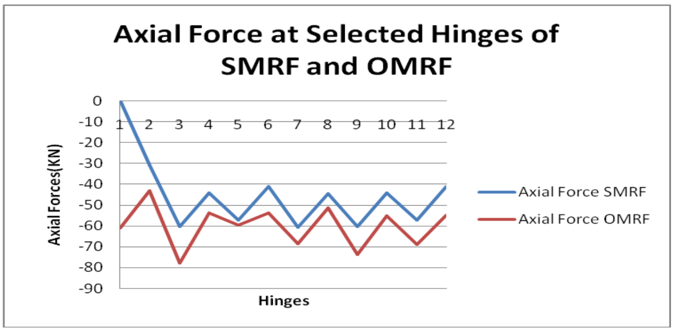

Chart-4.3: Axial Force at Selected Hinges of the SMRF and OMRF

4.4.Displacement At Joint In Special Moment Resisting Frame at step-1

The joint displacement due to apply pushover analysis in the X-direction in the special Moment Resisting Frame (SMRF) at step-1 is given below:-

Table-4.4: Displacement in SMRF

Joint No	U1(m)	U2 (m)	U3 (m)
1	-0.000001093	-9.207E-07	-0.000189
2	-0.000001022	-6.851E-07	-0.000235
3	-0.000001013	-3.471E-07	-0.000246
4	-0.000001011	0.000005256	-0.000247
5	-0.000001013	0.000025	-0.000246
6	-0.000001022	0.000048	-0.000235
7	-0.000001093	0.000063	-0.000189
8	-8.286E-07	-8.161E-07	-0.00023
9	-8.143E-07	-6.454E-07	-0.000289
10	-8.069E-07	-3.326E-07	-0.000303

4.5.Displacement At Joint In Ordinary Moment Resisting Frame at step-1

The joint displacement due to apply pushover analysis in the X-direction in the Ordinary Moment Resisting Frame (OMRF) at step-1 is given below:-

Table-4.5: Displacement in OMRF

Joint No	U1(m)	U2 (m)	U3 (m)
1	-0.004342	-0.000011	-0.000554
2	-0.004355	-0.000008147	-0.000616
3	-0.00436	-0.00000422	-0.000629
4	-0.004362	-2.422E-14	-0.000631
5	-0.00436	0.00000422	-0.000629
6	-0.004355	0.000008147	-0.000616
7	-0.004342	0.000011	-0.000554
8	-0.004352	-0.000004004	-0.000267
9	-0.00436	-0.000002984	-0.000328
10	-0.004366	-0.000001757	-0.000342

The graph of displacement joint due to Pushover in X-direction at step-1 for SMRF and OMRF is given below:-

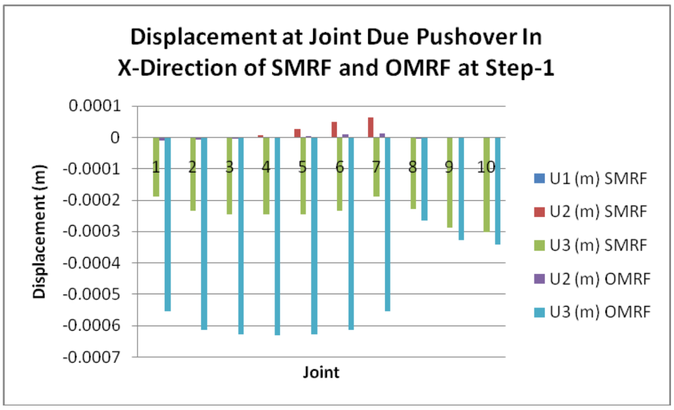

Chart-4.4: Comparative of Displacement between SMRF and OMRF

The displacement in the OMRF due U1 is maximum as compared to the other dsplacement which given above.

4.6.Plastic hinges Due to Pushover analysis in X direction in Special Moment Resisting Frame (SMRF)

Due to apply pushover analysis in special moment resisting frame in the X-direction at the step-2, there is no plastic hinges are formed but at the fixed support the number of yielding is 7 formed in the building which represent the building cannot collapse due to applies all load pattern. The figure is given below which represent the yielding at the fixed support:-

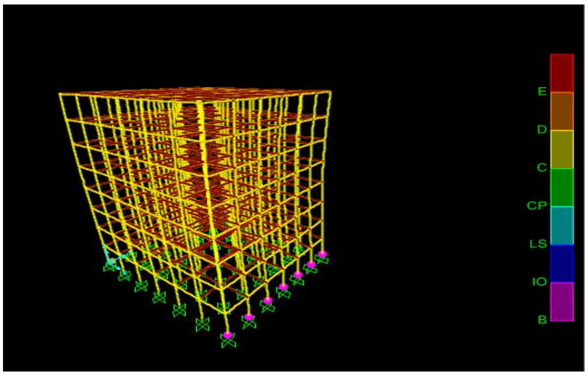

Fig-4.6: Yielding the Fixed Support In SMRF in X-direction at step-1

The pink color looking at the fixed support representing that that support is in the yielding condition.

4.7.Plastic hinges Due to Pushover analysis in Y direction in Special Moment Resisting Frame (SMRF)

Due to apply pushover analysis in special moment resisting frame in the Y-direction at the step-2, there is no plastic hinges are formed but at the fixed support the number of yielding is 28 formed in the building which represent yielding in pushover analysis in X-direction more than the apply pushover analysis in the X-direction which represent the building cannot collapse due to applies all load pattern. The figure is given below which represent the yielding at the fixed support:-

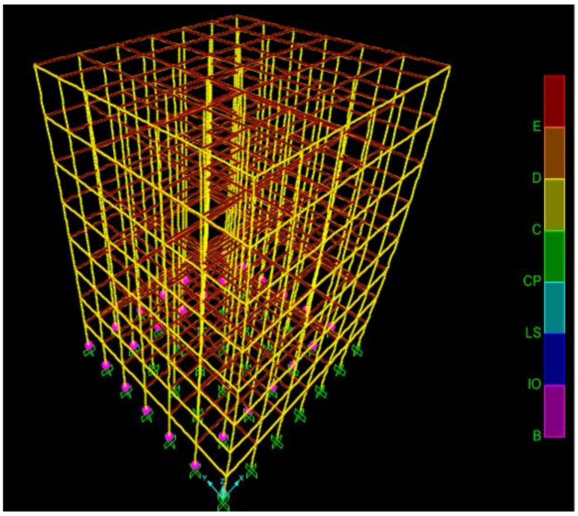

Fig-4.7: Yielding the Fixed Support In SMRF in X-direction at step-2

The pink color looking at the fixed support representing that that support is in the yielding condition.

5. Conclusions

After analyzing the above two model which are Special Moment Resisting Frame and Ordinary Moment Resisting Frame by the pushover analysis with respect to the response spectrum method then following conclusions are obtained which is given below:-

- In the model of Special Moment Resisting Frame and Ordinary Moment Resisting Frame the value of the modal time period and frequency is almost same.
- In this model, there is no plastic hinges formed but yielding point is formed in the both Special Moment Resisting Frame and Ordinary Moment Resisting Frame. The point of the yielding in the Special Moment Resisting Frame is low as compared to the Ordinary Moment Resisting Frame.
- The value of the joint displacement increasing from lower step number to higher step number in the both Special Moment Resisting Frame and Ordinary Moment Resisting Frame. This is representing that in the building the chances of the plastic hinges increase at the higher step number.
- In the Ordinary Moment Resisting Frame we found that in the local direction of the x-axis, the value of the displacement i.e. (U1) maximum as compared to the all joint displacement.
- In the both Special Moment Resisting Frame and Ordinary Moment Resisting Frame, there is only yielding point found which is mostly below the top second floor of the building.

References

[1] A. Shuraim, A. Charif, (2007) Performance of pushover procedure in evaluating the seismic adequacy of reinforced concrete frames. King Saud University

[2] Athanassiadou CJ. (2008), Seismic performance of R/C plane frames irregular inelevation. Engineering Structures 2008;30:1250

[3] Das, S. (2000),"Seismic design of vertically irregular reinforced concrete structures", Ph.D Thesis, North Carolina State University", Raleigh. NC.

[4] Davis, P. R., (2009) Earthquake Resistant Design of Open Ground Storey RC Framed Buildings. Ph.D. Thesis, Indian Institute of Technology Madras, Chennai.

[5] Dr. Valsson Varghese, Yogesh Ramakant Borkar(2013) 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 (IJERA) ISSN: 2248-9622

[6] Duan, H., & Hueste, M. B. D. (2012). Seismic performance of a reinforced concrete frame building in China. Engineering Structures, 41, 77–89.

[7] Dutta, S. C., (2001)," Effect of Strength Deterioration on Inelastic Seismic Torsional Behavior of Asymmetric RC Buildings," Building and Environment,36(0), 1109-1118.

[8] G.V.S.Sivaprasad1, S. Adiseshu2(2013) 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, volume: 02 Issue: 09; p.239-250
[9] Hasan, R., Xu, L., & Grierson, D. E. (2002)," Push-over analysis for performance based seismic design", 80(July), 2483–2493.

[10] Murty, C. V. R.(2002),"Performance of reinforced concrete frame buildings during 2001 Bhuj earthquake", Proceedings of the 7th US National Conference on Earthquake Engineering. Boston. USA. Paper No. 745.

[11] Poluraju, P. (2011). Pushover analysis of reinforced concrete frame structure using SAP 2000, 04(06), 684-690.

[12] Pradip, Sarkar., (Dec. 2008),"Seismic Evaluation of Reinforced concrete stepped building frames", A thesis for the award of the degree of doctor of philosophy, IIT Madras, Chennai. National Institute of Technology, Rourkela.

[13] Priestley, M. J. N. & Park, R.(1987),"Strength and Ductility of Concrete Bridge columns Under Seismic Loading", ACI Structural Journal, Technical paper, 61-76, January-February.

[14] Sadjadi, R., Kianoush, M. R., & Talebi, S. (2007). Seismic performance of reinforced concrete moment resisting frames. Engineering Structures, 29(9), 2365–2380.

[15] Sermin Oguz.(2005),"A thesis on "Evaluation Of Pushover Analysis Procedures For Frame Structures", April,2005.

BIOGRAPHIES

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