International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

Comparative Study between OMRF and SMRF Structure by Pushover Analysis

Bhavesh Kuthe[1], Prof. D. L. Budhlani[2]

[1]Guru Nanak Institute of Technology, Nagpur, Maharashtra, India
Dahegaon, Nagpur-441501
bkuthe75[at]gmail.com

[2]Guru Nanak Institute of Technology, Nagpur, Maharashtra, India
Dahegaon, Nagpur-441501
dilipbudhlani[at]rediffmail.com

Abstract: ***Analysis of damages incurred in moment resisting RC framed structures subjected to past earthquake show that failure may be due to utilization of concrete not having sufficient resistance, soft storey, beam column joint failure for weak reinforcements or improper anchorage, column failure causing storey mechanism. Beam-column connection is considered to be one of the potentially weaker components when a structure is subjected to seismic loading. In this study overview of the earthquake and its devastations are mentioned, also behaviour of building during earthquake is given. Furthermore concept design, beam column joint concept and pushover analysis are mentioned. In this paper various figures are illustrated for beam column failure mechanism are also given.***

Keywords: Beam column joint, OMRF, SMRF, Pushover analysis

1. Introduction

Huge amount of damage during the past earthquakes is because of not following code provisions in design and improper execution (EERI Special Earthquake Report, 2001). This results in most common type of problems i.e., 1) slender column to make them flush with infill walls, 2) buildings with open ground storey, 3) torsion induced due to more number of infill panels on one side, 4) strong beam weak column, 5) lapping of column reinforcement above beam-column joint, 6) inadequate lapping of column reinforcement, 7) abrupt reduction in column dimensions and 8) Improper detailing (Hafeez & Ramancharla, 2009). On the other hand, earthquake resistant design significantly increases the performance of the structures. Seismic design of structures is based on elastic force; the nonlinear response of structure is incorporated in design by using appropriate response reduction factor (R). The concept of R is to de-amplify the seismic force and incorporate nonlinearity with the help of over strength, redundancy and ductility. Ductile detailing is done in structure to increase the ductility and to reduce the amount of damage, compared to non-ductile detailed structure. High ductile designed frame will attract more damage compared to structure designed for lower ductility, due to large yield excursion (Lu, Hao, & Carydis, 2001). The design seismic forces are reduced drastically by using higher values of R and incorporating higher ductility. The reduction in seismic forces leads to reduced member cross section. The capacity of structure depends on initial stiffness, strength and ductility. If ductile detailing is required to be done for a building than only ductility should be increased and other two parameters to be kept same for comparatively less damage, above mentioned behaviour cannot be achieved using provisions given in current seismic code. Response reduction factor (R) is defined differently in different countries for different types of structural systems. In Indian seismic code, IS1893 (2002), value of R for reinforced concrete structure is specified based on, ordinary moment resisting frame (OMRF) and special moment resisting frame (SMRF), and in the latest proposed draft one additional R value incorporated for reinforced concrete structure based on Intermediate moment resisting frame (IMRF). The value of R varies from 3 to 5 in IS code, depending on the type of resisting frame, but the existing literature does not provide information on what basis R values are considered.

2. Objective

This study aims to Special Moment Resisting Frame (Ductile Detailing) and Ordinary Moment Resisting Frame are considering as structural frame and Comparison are made for seismic load. Pushover analysis is carried out by ETAB 2016 software.

3. Analysis of Building for Earthquake Loads as per IS 1893(Part-1):2016

Here, dynamic analysis is carried out using response spectrum method. The response spectrum method (RSM) also known as the "modal analysis procedure" is performed in accordance with the requirements of Clause 7.8.4, IS 1893(Part 1): 2016. The method is based on superposition of modes. Hence, free vibration modes are computed using eigen value analysis. The maximum value of a quantity (say k) termed as the modal response, is obtained for each mode (say kth mode). The number of modes considered is based on a quantity termed as the mass participation factor for each mode. Sufficient number of modes (r) to capture at least 90% of the total participating mass of the building (in each of the horizontal directions), should be considered in the analysis. In the present study, 20 modes are considered and corresponding participation of the building is 92%. The modal responses from all the considered modes are then combined together using either the square root of the sum of the squares (SRSS) method or the complete quadratic combination (CQC) method. The peak response quantities (for example, member forces, displacements, storey forces, storey shears, and base reactions) are combined as per CQC or SRSS method. In the present building, the natural periods of the building considered are found to be very closely spaced. So, a formulation known as the Complete Quadratic Combination (CQC) based on the theory of random vibration and is also considered as the extension of SRSS method, is used for calculating earthquake loads for very closely spaced time periods. The base shear of building is found by response spectrum method using ETAB 2016.

4. Pushover Analysis

The well- known practical method i.e. Pushover Analysis is that analysis which is carried out under permanent vertical loads and gradually increasing lateral loads to calculate the deformation as well as damage pattern of a structure. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature weakness. This plot is known as ‘Capacity Curve’. For developing modeling parameters, acceptance criteria (performance level) and procedures of pushover analysis, there are requirement of some documents such as The ATC-40 (Applied Technology Council) and FEMA-356 (Federal Emergency Management Agency) documents.

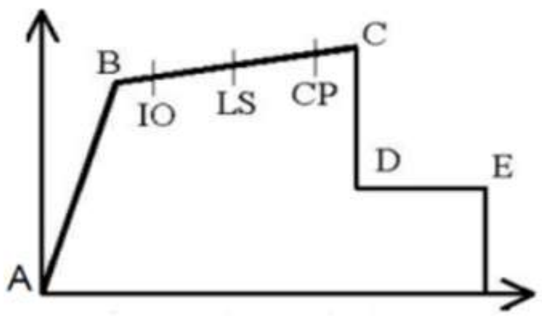

Figure 1: Force-Deformation Criterion for Hinges Used In Pushover Analysis

These documents also describe the actions followed to determine the yielding of frame member during the analysis. Two actions are used to govern the inelastic behavior of the member during the pushover analysis that is deformation-controlled (ductile action) or force-controlled (brittle action).

Acceptance Criteria (Performance Level)

The performance levels (IO, LS, and CP) of a structural element are represented in the load versus deformation curve as shown below,

B -Yield State
IO –immediate Occupancy
LS –Life Safety
CP –Collapse Prevention
C –Ultimate State

5. Problem Statement

The building is analyzed is G+6 R.C framed building of symmetrical rectangular plan configuration. Complete analysis is carried out for dead load, live load & seismic load using ETAB 2016. Response spectrum method of analysis is used. All combinations are considered as per IS 1893:2016.

Typical plan of building is shown in Figure 2

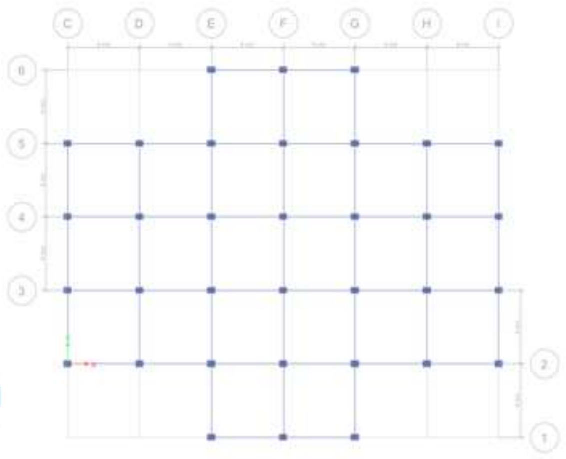

Figure 2: Plan of G+ 6 RC framed structures

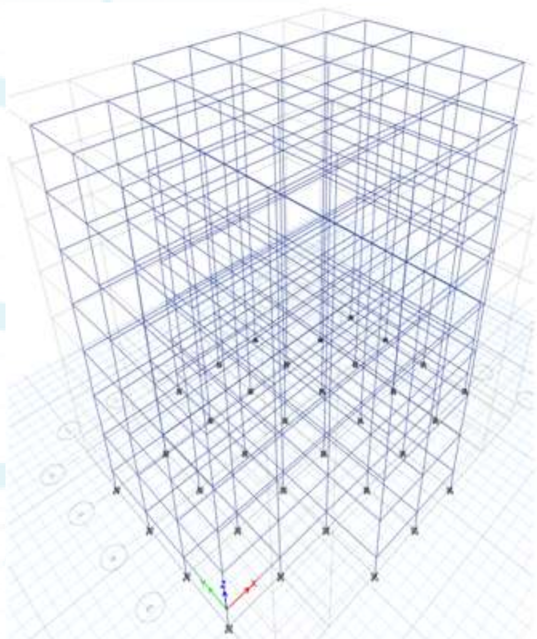

Figure 3: 3D view of G+6 RC framed structure

Building properties

Details of building: G+6
Plan Dimension: 24m x 20m, 4m span in each direction.
Outer wall thickness: 230mm
Inner wall thickness: 230mm
Floor height: 3 m
Parking floor height: 3m

Seismic Properties

Seismic zone: IV
Zone factor: 0.24
Importance factor: 1.0
Response Reduction factor (OMRF) R: 3
Response Reduction factor (SMRF) R: 5
Soil Type: medium

Material Properties

Material grades of M30 & Fe500 is used for the design.

Loading on structure

Dead load: self-weight of structure
Weight of 230mm wall: 13.8 kN/m²
Live load: For G+15: 2.5 kN/m²
Roof: 1.5 kN/m²
Seismic load: Seismic Zone IV

Table 1: Design sizes of members

	As per IS 456:2000	As per IS 13920:2016
Column size		
Plinth to First floor	500mmX300mm	500mmX350mm
Second to Third floor	400mmX300mm	400mmX350mm
Fourth to fifth floor	300mmX300mm	350mmX350mm
Sixth floor	250mmX250mm	350mmX350mm
Beam size		
Plinth to First floor	400mmX250mm	400mmX250mm
Second to Third floor	350mmX250mm	350mmX250mm
Fourth to fifth floor	300mmX250mm	300mmX250mm
Sixth floor	250mmX230mm	250mmX230mm
Slab thickness	120mm	120mm

6. Results and Discussions

It is an analysis to evaluate the seismic performance of ordinary moment resisting (OMRF) and Special moment resisting (SMRF) structures. In this dynamic loading is applied to the structure. A non linear relationship is obtained between load and displacement.

Figure 4 shows Displacement versus Base shear pushover curve for ordinary moment resisting frame in X direction and Y direction. It shows that curve reaches upto 165mm of targeted displacement in X direction while 145mm of targeted displacement in Y direction.

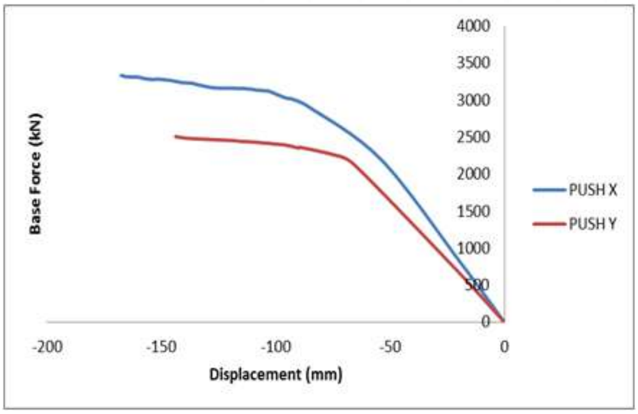

Figure 4: Pushover curve for OMRF

Figure 5 shows Displacement versus Base shear pushover curve for Special moment resisting frame in X direction and Y direction. It shows that curve reaches up to 170mm of targeted displacement in X direction while 158mm of targeted displacement in Y direction.

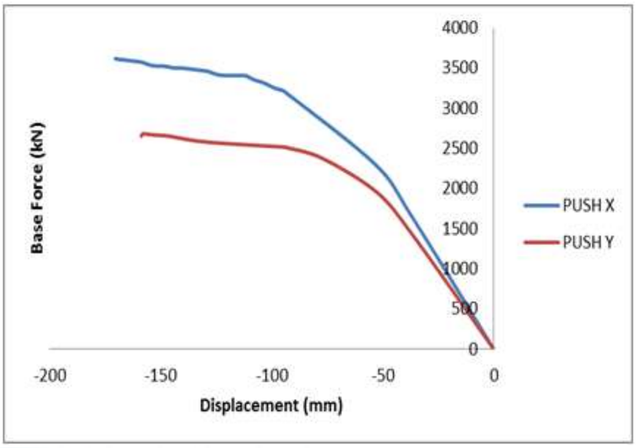

Figure 5: Pushover curve for SMRF

Table 2: Comparison of base shear

Analysis Method	IS 456		IS 13920	
	Response Spectrum Analysis	Pushover Analysis	Response Spectrum Analysis	Pushover Analysis
X-Direction	704.8554	415.393	446.1518	440.024
Y-Direction	624.8094	370.804	415.0328	410.335

Linear analysis is carried out by response spectrum method and nonlinear analysis is carried out by pushover method using ETAB 2016. Table 2 represents comparison between base shear by response spectrum method and shear at performance point by pushover method.

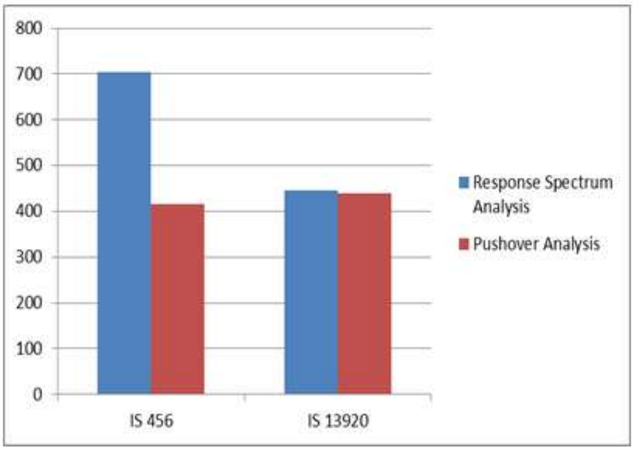

Figure 6: Comparison of shear in X direction

Figure 6 represents graphical representation between base shear by response spectrum method and shear at performance point by pushover method in X direction. It shows that base shear by response spectrum method is greater than shear at performance point for both OMRF and SMRF structures

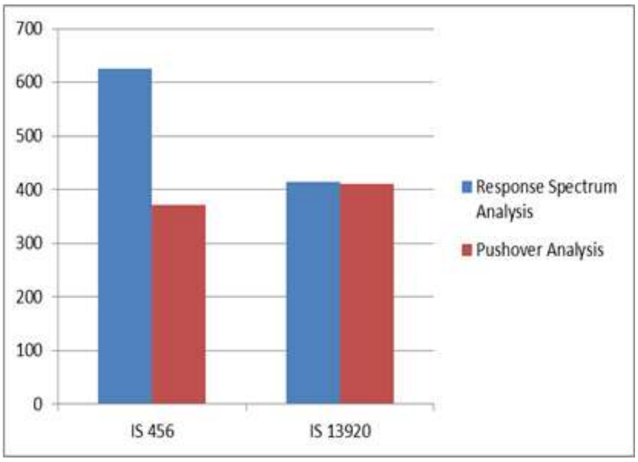

Figure 7: Comparison of shear in Y direction

Figure 7 represents graphical representation between base shear by response spectrum method and shear at performance point by pushover method in Y direction. It shows that base shear by response spectrum method is greater than shear at performance point for both OMRF and SMRF structures

7. Conclusions

- Pushover analysis shows that for SMRF structure, curve reached displacement which is higher than displacement for OMRF structure in both X and Y direction. Hence beam column joint in SMRF structure is strong.
- Pushover analysis shows that curve reached displacement which is less than targeted displacement 840mm in X and Y direction with hinge formation in collapse condition. So both structures need retrofitting.
- Also shear at performance is less than base shear by response spectrum analysis for both OMRF and SMRF structures, hence requires retrofitting.

References

[1] IS: 1893-(part-1)-2016 "Code of practice for criteria for Earthquake resistant design of structures."
[2] IS: 875(part-1)-1987 "Code of practice for Design loads (other than earthquake) for building structures-Dead loads."
[3] IS: 875(part-2)-1987 "Code of practice for Design loads (other than earthquake) for building structures-Imposed loads."
[4] IS 13920:2016- Ductile Detailing of Reinforced Concrete Structure subject to Seismic Force- Code of practice
[5] Mario Paz "Dynamics of Structures book"
[6] Aggarwal & Shrikhande" Earthquake Resistant Design book"
[7] Uma, S. R., "Seismic Behaviour of Beam Column Joints in Moment Resisting Reinforced Concrete Frame Structures," submitted to Indian Concrete Journal, October 2004
[8] Subramanian N and Prakash Rao D S "Design of Joints in RC Structures with Particular Reference to Seismic Conditions", The Indian Concrete General, February (2003).
[9] Dr. R Prabhakara, Harish R, Nambiyanna B,, "Analytical investigation of external beam column joint using ANSYS by varying the diameter of the longitudinal reinforcement in beam", Journal of engineering research and applications, Volume 5,issue 8, part -1, August 2015.

Author Profile

Bhavesh A. Kuthe is MTech - student appearing (Structural Engineering) from Gurunanak Institute of Management and Technology, Kalmeshwar road, Nagpur (RTM Nagpur University), Maharashtra State, India.

Prof. D. L. Budhlani is working as Associate Professor, Department of Civil Engineering, Guru Nanak Institute of Technology (Formerly known as Guru Nanak Institute of Engineering & Management) Dahegaon, Nagpur and Dean, Research & Development, Guru Nanak Institutions, Nagpur, Maharashtra State, India.