User Defined Plastic Hinge Modelling for Non- Linear Seismic Response on Reinforced Concrete Building

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Abstract It is seen that from the previous major earthquakes in India, the most damage was seen in many medium and high-rise buildings, which affected people's life safety. Therefore, investigation and evaluation of the seismic resistance of the structure. It is an important job. This study focuses on nonlinear modeling of the seismic response of reinforced concrete buildings using hinge components. In the rest of the product, time constant and time transformation relationships are created using Eurocode-8 recommendations. On this basis, methods have been developed to study the moment and curvature values of certain beams and columns in the relevant software. G+9 building will be constructed as per IS 456:2000 and its seismic performance will be evaluated in SAP2000 software. The seismic nonlinear response of a proposed building was evaluated with user-defined hinges and the results were compared with modeling using the automatic hinge method. The building considered in the analysis is IV. It is a mid-rise symmetrical building with a middle ground type in the earthquake zone. Displacements between floors, element forces and hinge type performance elements are criteria that were not observed in the study. The seismic response of buildings with additional masonry infill and shear walls was also investigated using the nonlinear modeling technique described above. The study concluded that the difference between the results of automatic hinges and user-defined hinges varies between 5% and 8%. The analysis shows that the user-defined hinge model exhibits better nonlinear response than the automatic hinge model.

Keyword: Auto Hinge and user-defined hinge approach, inter-story drift, base shear, ductility ratio, performance point.

I. INTRODUCTION

Nonlinear static analysis, a modern standard in structural engineering that offers accurate reaction predictions, is used to assess the seismic performance of structures. As previously indicated, nonlinear analysis may be utilized to gauge a building's seismic performance using more flexible models. The research gives enough details regarding the system's seismic characteristics and seismic laws. Recent earthquakes have revealed that uneven mass distribution, stiffness, and strength are the causes of significant structural damage and that such structures experience torsional movements. The earthquake-produced forces operate from the center of mass, whereas the response forces generated by the lateral load-resisting components act from the center of stiffness. Eccentricity is the distinction between the centre of mass and the centre of hardness. This eccentricity leads to the torsional moment. The proportion of maximum slip to mean slip at each level is known as torsional irregularity. It is a parameter that assesses how torsional structure affects performance. Because the torsional and lateral responses are linked, the deformation requirement increases, making irregular buildings more susceptible to seismic damage.

As a result, a building's seismic analysis is required in order to minimize or avoid structural damage. Inelastic (or irreversible) reverse loading, stiffness, and strength degradation are all examples of this type of damage. Analysing the behaviour of materials in various systems through modelling is a crucial first step in assessing a building's performance. Nonlinear analyses are required to characterise the underlying seismic structure since the majority of structures that are occasionally subjected to seismic stress are engineered to be inelastic. Economics employs the nonlinear static approach (NSP) or analysis (as described in FEMA-356 and ATC-40) since it is straightforward. When carried out properly, overall support analysis is certain to offer useful data not available through static analysis or dynamic analysis techniques. Additionally, IS 13920-compliant ductile components should be employed, and the material specifics of the hinges should be evaluated, to minimise material damage. Moment–curvature analysis of structural components like beams and columns is required for user-defined hinge characteristics. Building deformation is considered to occur exclusively due to moment under application of lateral seismic loads in the issue stated. As a result, user-defined hinges require moment-curvature and load-deformation curves, whereas code-defined hinges will employ FEMA-356 characteristics

II. PROBLEM STATEMENT

The G+10 storey model was considered to describe the average reinforced concrete building for the study. Pushover analysis of concrete slabs is done with user-defined and preset hinge methods. To prevent undesirable torsional effects caused by lateral forces, the building is symmetrical in both perpendicular directions and the columns are anchored to the foundation. The building is believed to be in India's fourth earthquake zone. The characteristic features of the products are given below.

Table 1 details of the model

1.	Number of stories	: G+10 Storey building
2.	Spacing Between Columns	: 5 m in both X and Y Direction
3.	Plan Area	: 400 m^2
4.	Column Sizes	: 0.500m X 0.550m
5.	Beam Sizes	: 0.300m X 0.450 m
6.	Total Height of building	: 32.5 m
7.	Height of typical Storey	: 3.1 m
8.	Slab Thickness	: 0.150 m
9.	Grade of Concrete	: M25, M30, M40
10.	Grade of Steel	: Fe415, Fe500
11.	Live Load On the floor	: 3 KN/m^2
12.	Live Load On Roof	: 1.5 KN/m^2
13.	Floor Finish	: 1 KN/m^2
14.	Roof Treatment	: 1.5 KN/m^2
		Seismic Data
15.	Type of frame	: RC Moment Resisting Frame
16.	Seismic Zone	: IV
17.	Soil Type	: II
18.	Importance Factor	: 1
19.	Response Reduction Factor	: 5

III. METHODOLOGY

A study of the seismic response of framed structures under seismic (lateral) loads is proposed as a research project. It also looks at the impact of plastic hinges, such as default hinges (code-specified hinges FEMA 356) and user-specified hinges. In addition, nonlinear modelling of RC framed structures in appropriate software and comparison of structural parameters for various types of hinge characteristics are being investigated. The approach is presented in a step-by-step format below.

- Step 1: To study the performance of buildings under seismic activity, different Research articles and required Standard Codes.
- Step 2: utilizing appropriate tools, create a model of a midrise reinforced building.
- Step 3: To Define various loads and load Patterns
- Step 4: Seismic Analysis of Building
- Step 5: Develop a moment-curvature relationship for the column and beam section under flexure.
- Step 6: Investigate properties of axial, shear, and flexural plastic hinges for the respective degree of freedom (DoF) in beam, column, joint, shear wall, and brick masonry infill.
- Step 7: Assign Non-linearity to building elements.

Table 3.1. Different Hinge types and properties

Sr. No.	Building Element	Type of Hinge	
1.	Beam	Flexural hinge (M3)	Shear Hinge
2.	Column	Flexural hinge (PM2M3)	Shear Hinge
3.	Beam-Column Joint	Shear Hinge	
4.	Brick Infill	Axial Hinge	
5.	Shear Wall	Flexural hinge (PM2M3)	

- Step 8: Nonlinear analysis of RC building using code-defined techniques of modeling.
- Step 9: Nonlinear analysis of RC building using user-defined techniques of modeling.
- Step 10: Comparison of Results.

IV. MODEL DESCRIPTION

The comparison of the use of automatic hinges and the user hinge method was made for the first two cases, that is, the exposed model and the exposed frame + curtain wall. For both, i.e. bare structure + wall and bare structure + infill wall + curtain wall, only the user-defined hinge method is used to make the building frame non-linear because there is no way to place the automatic hinges differently. For example, inspection of brick fill

Table 2: Analysis models

Sr.No.	Model Details	Pushover Analysis using	
1.	Bare Frame Model	User Defined Hinge	Default Hinge

		approach	Approach
2.	Bare Frame Model + Shear Wall	User Defined Hinge approach	Default Hinge Approach
3.	Bare Frame Model + Infill wall	User Defined Hinge approach	
4.	Model+ Infill wall+ Shear Wall	User Defined Hinge approach	

1) Bare Frame Model

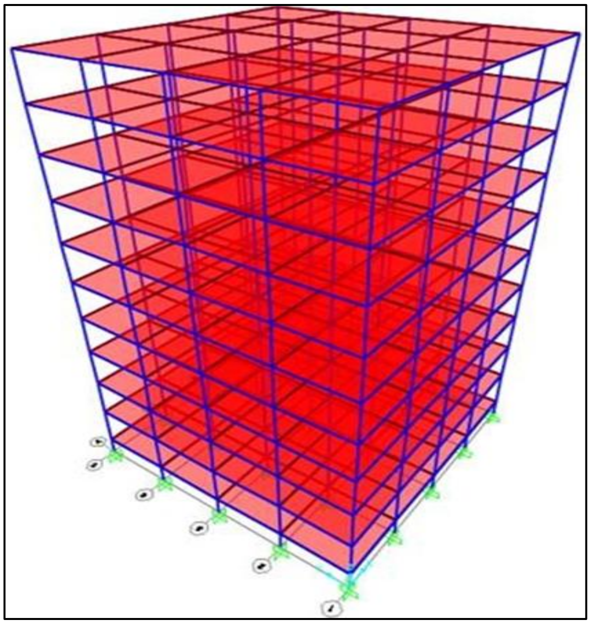

Fig 1 Bare Frame Model

2) Bare Frame Model + Shear Wall

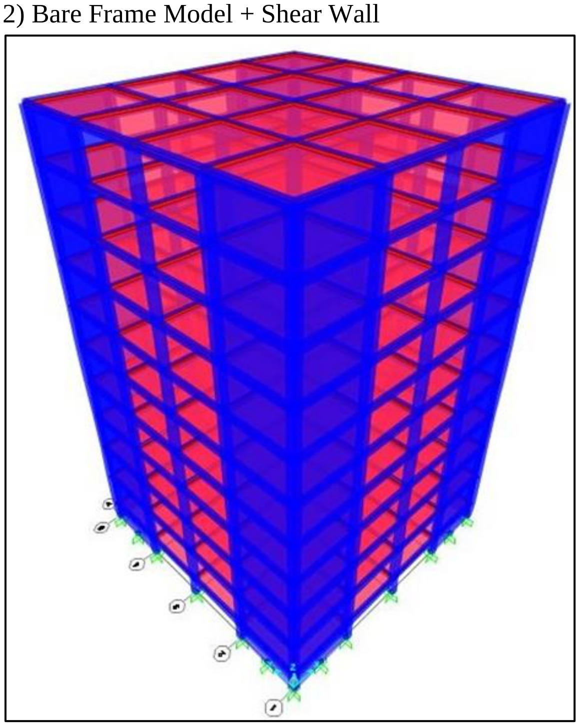

Fig 2 Bare Frame Model + Shear Wall

3) Bare Frame + Brick Infill

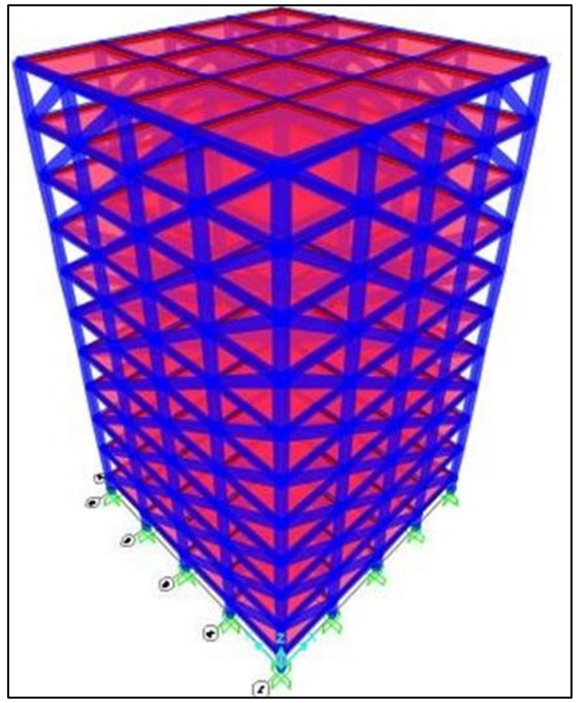

Fig 3 Bare Frame + Brick Infill

4) Bare Frame Model + Shear Wall + Infill Wall

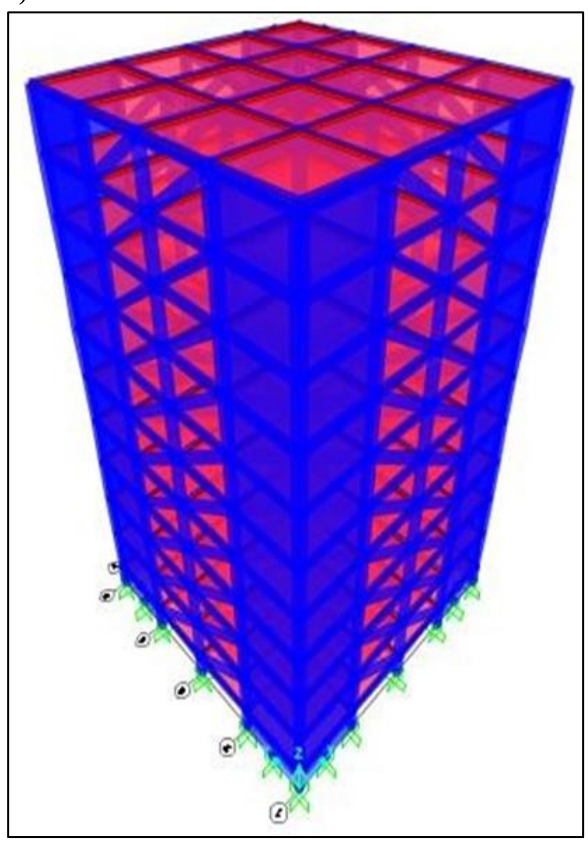

Fig 4 Bare Frame Model + Shear Wall + Infill Wall

V. RESULT AND DISCUSSION

1) Bare Frame Model

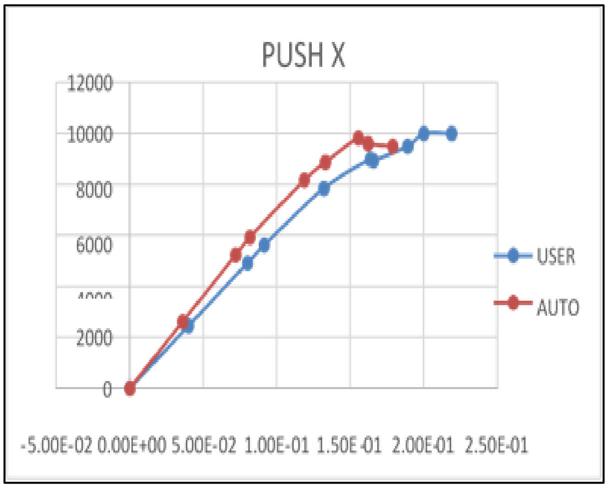

Fig 5 Pushover curve in X direction for bare frame model

2) Bare Frame Model + Shear Wall

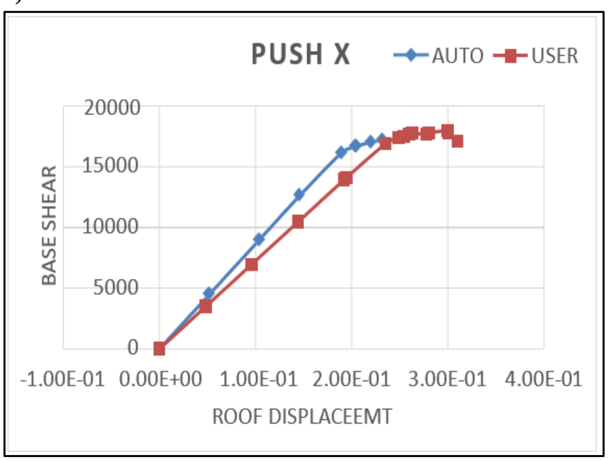

Fig 6 Pushover curve in X direction for bare frame model

3) Bare Frame + Brick Infill

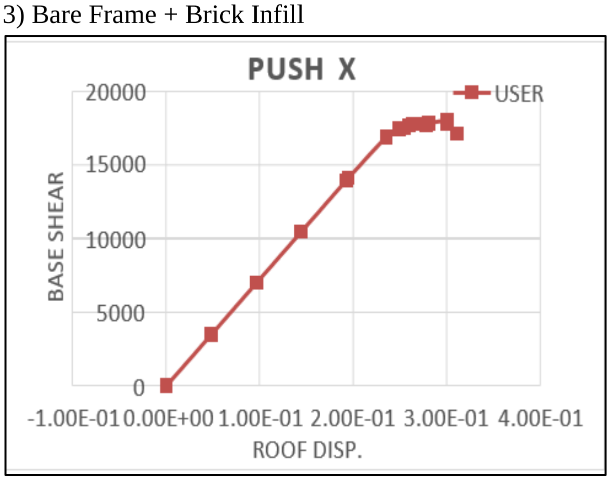

Fig 7 Pushover curve in X direction for bare frame + Shear Wall model

4) Bare Frame Model + Shear Wall + Infill Wall

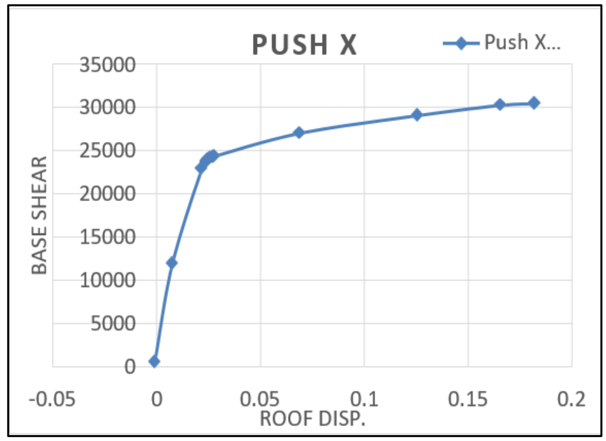

Fig 8 Pushover curve in X direction for bare frame+ Shear Wall + Infill Wall model

Table 3 Axial Load distribution

Column	Bare Frame	Bare frame + Brick Infill	Bare frame + shear wall	Bare frame Brick+Shear Wall
C1	1617.36	2148.72	901.53	1019.80
C2	2255.05	2611.88	1008.91	933.280
C3	2305.51	2697.07	2100.83	1990.27
C4	2255.05	2630.66	1008.91	1156.38
C5	1617.36	2131.66	901.53	918.03
C6	2255.05	2611.88	1008.91	933.28
C7	2938.98	3145.73	2739.95	2455.37
C8	3026.87	3243.21	2955.11	2844.89
C9	2958.98	3168.11	2739.95	2550.80
C10	2255.05	2610.12	1008.91	914.59
C11	2305.51	2697.07	2100.83	1990.27
C12	3026.87	3243.21	2955.11	2884.89
C13	3098.45	3344.17	3077.39	3077.01
C14	3026.87	3266.53	2955.11	2903.52
C15	2305.51	2700.97	2100.83	2087.07
C16	2255.98	2630.66	1008.91	1156.38
C17	2958.98	3168.11	2739.95	2550.80
C18	3026.87	3266.53	2955.11	2903.52
C19	2958.98	3189.50	2739.95	2637.05
C20	2255.05	2626.45	1008.91	1137.20
C21	1617.36	2131.66	901.53	918.03
C22	2255.05	2610.12	1008.91	914.59
C23	2305.51	2700.97	2100.83	2087.07
C24	2255.05	2626.45	1008.91	1137.20
C25	1617.36	2107.81	901.53	814.90

VI. CONCLUSION

1. The effective design strategy is to provide a structural design that will determine the seismic resistance of the building.

2. For different plastic hinge lengths, the base shear strength of preset hinges and custom hinges can vary by up to 10%. Therefore the base cutting capacity does not depend on whether the hinge preset or the hinge material is used.
3. The plastic hinge length (Lp) has a significant impact on the movement capacity of the frame. When automatic models and user-defined models are evaluated, it is seen that there is a difference of up to 35% in discharge capacity due to Lp.
4. The response spectrum method shows that internal and external changes in the structure are within the limits of each model.
5. From the safety ratio and central force result of PP, it can be seen that the building structure is safe, its value is greater than 1 (Sr > 1) and has reached the construction industry.
6. Buildings with user-defined hinge patterns have been shown to have greater ductility and lower tensile strength at service points. Therefore, it is important to consider this model for proper security assessment.
7. Comparison of hinge patterns showed that similar patterns were found on plastic hinges for models with preset hinges and custom hinges.
8. The structure with brick infill and curtain wall addition showed a decrease in moment and an increase in base shear compared to the bare structure. Comparison of all models shows that the addition of infill and shear walls shows a reduction in displacements depending on the configuration and materials used

REFRENCE

[1] Applied Technology Council (1996), “Seismic Evaluation and Retrofit of Concrete Buildings”, Vol.1., California
[2] Alvarez J. C., and Brena S. F. (2017), “Modeling Parameters for the Nonlinear Seismic Analysis of Reinforced Concrete Columns Retrofitted using FRP or Steel Jacketing." ACI Structural Journal 115.1.
[3] Ayala D., & Ansal A. (2012), "Non-linear push over the assessment of heritage buildings in Istanbul to define seismic risk". Bulletin of Earthquake Engineering, 10(1), 285-306.
[4] Baragani R., and Dyavanal S. (2014), "Performance-based seismic evaluation of G+ 6 RC buildings considering soil-structure interaction." International Journal of Engineering Trends and Technology 14.3: 119-127.
[5] Cinitha A., Umesha P.K., Iyer R. N. (2012), “Non-Linear analysis to assess Seismic Performance and Vulnerability of Code- Confirming RC Buildings”, World Conference on Applied and Theoretical Mechanics Issue 1, Volume 7.
[6] CSI SAP2000 V-8. (2002) Integrated finite element analysis and design of structures basic analysis reference manual.
[7] Deierlein G. G., Reinhorn A. M., and Willford M. R. (2010), "Nonlinear structural analysis for seismic design." NEHRP seismic design technical brief 4: 1-36.
[8] Douglas K. T., Davidson B. J., and Fenwick R. C. (1996), "Modelling Reinforced Concrete Plastic Hinges." Proceedings of the eleventh world conference on earthquake engineering
[9] Fajfar P., Damjan M., and Iztok P. (2005), "Torsional effects in the pushover-based seismic analysis of buildings." Journal of Earthquake Engineering 9.06 (2005): 831-854.
[10] FEMA (273-1997), “NEHRP Guidelines for The Seismic Rehabilitation of Buildings”, ASCE for the Federal Emergency Management Agency, Washington D. C.
[11] FEMA (356-2000), “Prestandards and Commentary for The Seismic Rehabilitation of Buildings”, ASCE for the Federal Emergency Management Agency, Washington D. C.
[12] Kadid, A., and A. Boumrkik (2008), "Pushover analysis of reinforced concrete frame structures." Asian Journal of Civil Engineering (Building and Housing) Volume 9: 47- 59.
[13] Kaushik, Hemant B., Durgesh C. Rai, and Sudhir K. Jain. (2007) "Uniaxial compressive stress–strain model for clay brick masonry." Current Science: 497-501.
[14] Ahmett I. and Ozmen H. B.2006), "Effects of Plastic Hinge Properties in Nonlinear Analysis of Reinforced Concrete Buildings." Engineering structures 28.11 (2006): 1494- 1502.
[15] Lew, H. S., and Kunnath S. K. (2001), "Evaluation of Nonlinear Static Procedures for Seismic Design of Buildings." 33rd joint meeting of the UJNR panel on wind and seismic effects.
[16] Martino R., Spacone E., and Kingsley G. (2000), "Nonlinear Pushover Analysis of RC Structures." Advanced technology in structural engineering.

[17] Mwafy, A. M., and Elnashai A. S. (2001) "Static pushover versus dynamic collapse analysis of RC buildings." Engineering structures 23.5: 407-424.

[18] Naik P. and Annigeri S. (2017), "Performance evaluation of 9-storey RC building located in North Goa." Procedia engineering 173: 1841-1846.

[19] Pecce M., Amadio C., Rossi F., Rinaldin G. (2012), "Non-Linear Behaviour of Steel- Concrete Composite Moment Resisting Frames." 15th World Conference on Earthquake Engineering, IAEE.

[20] Rahai A. R. and Nafari S. Fallah. (2013), "A comparison between lumped and distributed plasticity approaches in the pushover analysis results of a pc frame bridge." International Journal of Civil Engineering 114: 217-225.

[21] Rana, R., Jin, L., & Zekioglu, A. (2004,). "Pushover analysis of a 19-story concrete shear wall building." 13th World Conference on Earthquake Engineering. No. 133.

[22] Shekhappa, D., and Dyavanal S. S. (2015), "Nonlinear Static Analysis of G+ 6 RC Building with Infill walls and User defined hinges." International Research Journal of Engineering and Technology (IRJET) 2.9: 2060-2065.

[23] Siddiqui M., and Krishna N. M. (2015), "Non-Linear Static Analysis of Multi Storeyed Building–A Modified Approach." International Journal of Structural and Civil Engineering Research Vol 4.

[24] Smith B.S. and Carter C. (1969), "A method of analysis for infilled frames." Proceedings of the institution of civil engineers 44.1 (1969): 31-48.

[25] Sofyan Y. A. (2013), Seismic Evaluation of Reinforced Concrete Frames Using Pushover Analysis. AL-Rafdain Engineering Journal (AREJ) 21.3(2013): 28-45.