International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Performance based Seismic Evaluation of RCC Framed Building using Shear Deformation Model

Krishna Kumar

[1]MTech Scholar in 4th semester at Ganga Institute of Technology and Management, (GITAM), Kablana, Jhajjar, Haryana, India

Abstract: ***Performance based seismic design using pushover analysis tools is performed on a three storey residential apartment building, which is RCC framed with un-reinforced brick in fills. This building is located in seismic zone III designed with IS 1893:2002 and IS 456:2000.Plan dimensions of building was 20.50 x 13.30 m and building height above plinth level was 13.1 m. Performance based design was performed to verify intent of Life safety performance objectives to avoid total catastrophic damage and to restrict the structural damages caused under design earthquake.***

Keywords: Performance based seismic evaluation, pushover analysis, shear hinges.

1. Introduction

Design of civil engineering structures is typically based on prescriptive methods of building codes. Normally, loads on these structures are low and result in elastic structural behavior. However under a strong seismic event, a structure may actually be subjected to forces beyond its elastic limit. Although building codes can provide reliable indication of actual performance of individual structural elements, it is out of their scope to describe the expected performance of a designed structure as a whole, under large forces. With the availability of digital computers, performance based seismic evaluation (PBSE), where inelastic structural analysis is combined with seismic hazard assessment to calculate expected seismic performance of a structure, has become increasingly feasible. For this purpose Static push over analysis in SAP 2000 software is used to evaluate the real strength of the structure and it promises to be useful and effective tool of performance based seismic design.

In earthquake resistance structure emphasis given on providing adequate ductility to structure so that flexural failure antedates the shear failure. Hence shear failure must be avoided because it is a brittle mode of failure. However past earthquake reveal the majority of reinforced concrete structures failed due to shear. Moreover many old buildings in India do not conform to have adequate ductility provisions. Due to these reasons, prediction of shear hinges in performance based seismic design is inevitable to incorporate shear deformation model in the analysis.

1.1 Objective

The primary objective of present work is to develop nonlinear force deformation model for reinforced concrete section for shear and demonstrate modeling shear hinge in seismic evaluation of building. Two Buildings models one with shear hinges and other without shear hinges are analyzed using nonlinear static (pushover analysis).

2. Description of Structure

2.1 Material Properties

The material grades used for Building frame model are presented in table below-

Material	Grade
Concrete	M20
Reinforcing steel	Fe415

2.2 Building Geometry

The Building is almost symmetric in both directions. The concrete slab is 150 mm thick at every floor level. The wall thickness is 230 mm for the exterior and 120 mm for interior walls. Sizes of beams are 230x400 mm and columns sizes are 230x230 & 230x450.

Building type	RCC frame with un reinforced brick in fill
Year of construction	2001
Number of stories	Ground+3 stories
Plan dimensions	20.50 mx13.30m
Building height	13.1 m above plinth level

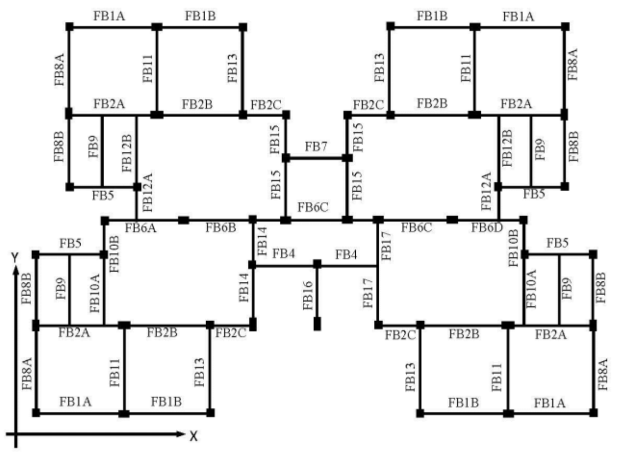


Figure 1

General Floor Plan of Building

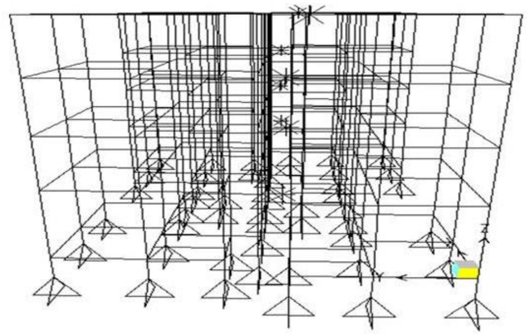


Figure 2
Elevation of Building- Side view

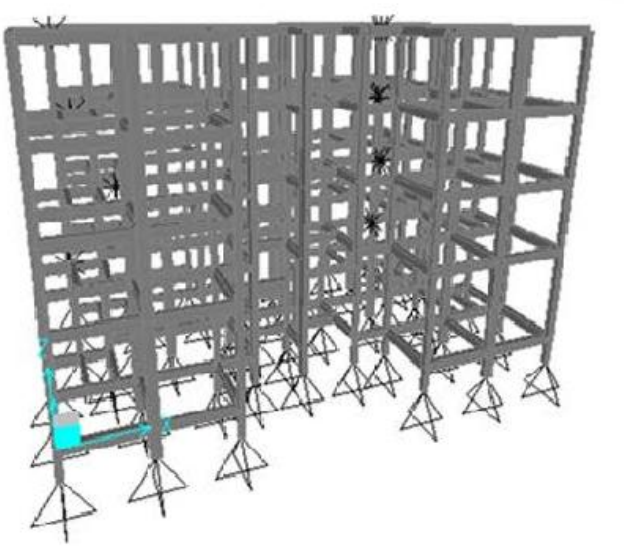


Figure 3
3D computer Model of the Building

3. Literature survey

3.1 Nonlinear Pushover Analysis

A nonlinear pushover analysis of the selected building is carried out as per FEMA 356 code (Pre standard and commentary for the seismic rehabilitation of Buildings) for evaluating the structural seismic response. In this analysis gravity loads and a representative lateral load pattern are applied to frame structure. The lateral loads were applied monotonically in a step-by-step manner. The applied lateral loads in X- direction representing the forces that would be experienced by the structures when subjected to ground shaking. The applied lateral forces were the product of mass and the first mode shape amplitude at each story level under consideration. P–Delta effects were also considered in account. At each stage, structural elements experience a stiffness change as shown in Fig. 4, where IO, LS and CP stand for immediate occupancy, life safety and collapse prevention respectively.

First total gravity load (Dead load and 25% live load) is applied in a load controlled pushover analysis followed by lateral load pushover analyses using displacement control. An invariant parabolic load pattern similar to IS 1893:2002 equivalent static analyses is considered for all the pushover analyses carried out here.

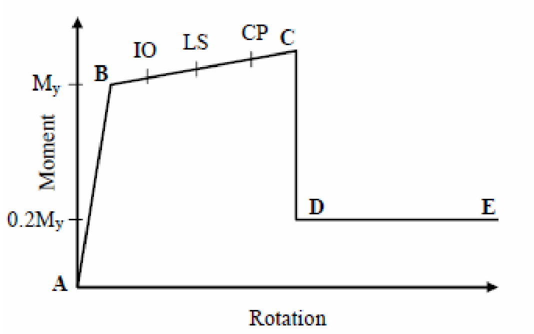


Figure 4

3.2 Capacity curve

In pushover analysis, the behavior of the structure is depends upon the capacity curve that represents the relationship between the base shear force and the roof displacement. It is observed that roof displacement was used for the capacity curve because it is considered to exhibit maximum drift. Two models of the selected building one with shear hinges and other without shear hinges are analyzed in the present study
1. Considering Flexural Hinges only.
2. considering both flexural and shear Hinges.

3.3 Modeling of flexural hinges

In the implementation of pushover analysis, the model must account for the nonlinear behavior of the structural elements. In the present study, a point-plasticity approach is considered for modeling nonlinearity, wherein the plastic hinge is assumed to be concentrated at a specific point in the frame member under consideration. Beam and column elements in this study were modeled with flexure (M3for beams and P-M2-M3 for columns) hinges at possible plastic regions under lateral load (i.e., both ends of the beams and columns).Properties of flexure hinges must simulate the actual response of reinforced concrete components subjected to lateral load. In the present study the plastic hinge properties are calculated by SAP 2000.

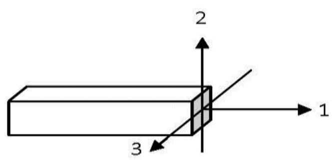


Figure 5: The coordinate system used to define the flexural and shear hinges

3.4 Modeling of Shear Hinges

When there is no prior failure in shear, flexural plastic hinges will develop along with the predicted values of ultimate moment capacity. Design codes prescribe specifications (e.g. ductile detailing requirement of IS 13920: 1993) for adequate shear reinforcement, corresponding to the ultimate moment capacity level. Therefore, it is obvious for a code designed building to fail in flexure and not in shear. There are a lot of buildings existing those are not detailed with IS 13920: 1993. Also, poor construction practice may lead to shear failure in framed building in the event of severe earthquakes.

Shear failure mostly occur in beams and columns owing to inadequate shear design. In non-linear analysis, this can be modeled by providing ‘shear hinges’. These hinges located at the same points as the flexural hinges near the beam column joints. If the shear hinge mechanism occurred before the formation of flexural hinge, the moment demand gets automatically restricted because of this flexural hinge may not develop.
Shear hinges for beams and columns can be modeled by generating shear force-deformation curves. It is assumed that shear force-deformation curves is symmetric for positive and negative shear

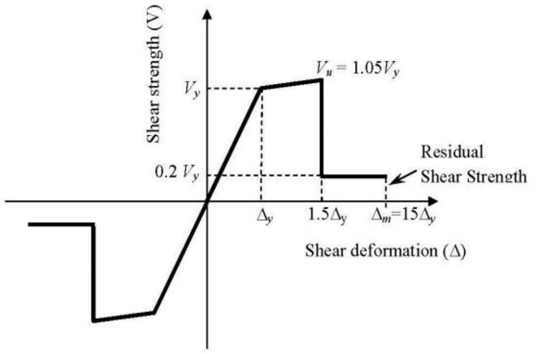
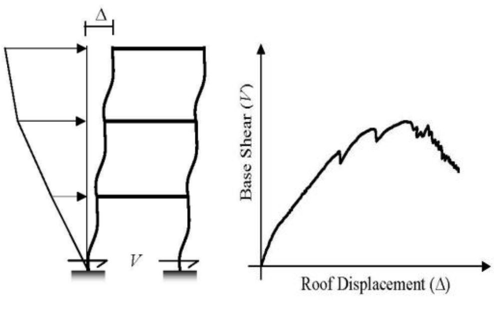


Figure 6: Shear force-deformation curve

4. Methodology

Pushover analysis is a static nonlinear procedure in which the magnitude of the lateral load is increased monotonically maintaining a predefined distribution pattern along the height of the building. The Building is displaced till the ‘control node’ reaches ‘target displacement’ or building collapses. The sequence of cracking, plastic hinging and failure of the structural components throughout the procedure is observed. The relation between base shear and control node displacement is plotted for all the pushover analysis (Fig. 7). Generation of base shear to control node displacement curve is single most important part of pushover analysis. This curve is conventionally called as pushover curve or capacity curve. The capacity curve is the basis of ‘target displacement’ estimation.



a) Building model b) Pushover curve

Figure 7

5. Results and Discussions

5.1 Capacity Curves for Push X and for Push Y

The two resulting capacity curves for Push X and for Push Y analysis are plotted in Fig 8.0 and Fig 9.0, respectively. Two building models, one with and one without shear are considered. They are initially linear but start to deviate from linearity as the beams and the columns undergo inelastic deformation. When the buildings are pushed well into the inelastic range, the curves become linear again but with a smaller slope. The two curves could be approximated by a bilinear relationship.

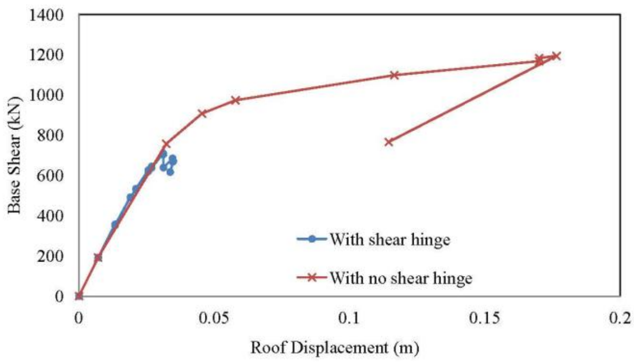


Fig. 6.2. Capacity curve for Push X analysis

Figure 8:

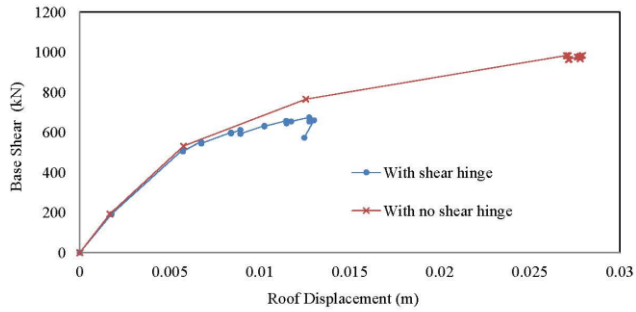


Fig. 6.3. Capacity curve for Push Y analysis

Figure 9:

Figure 8 and Figure 9 presents the relation between the base shear and roof displacement of the building as obtained from pushover analysis. Study of Fig.8 and Fig 9 together clearly show how that when shear failure mode is not considered in the analysis, it overestimates the base shear and roof displacement capacity of the building. As per Table 1 pushover analysis overestimates base shear capacity of the building by approximately 70% in X-direction and 45% in Y-direction when shear hinges ignored. The maximum roof displacement capacity is overestimated by 460% in X-direction and 120% in Y-direction.

Table 1

	Push-X		Push-Y	
	No shear	With shear	No shear	With shear
Yield disp (mm)	32.2	31.1	5.8	5.7
Ultimate disp (mm)	176.5	34.8	27.0	17.7
Plastic Disp (mm)	144.3	3.7	21.2	7.0
Ductility ratio	5.5	1.1	4.7	2.2

5.2 Ductility Ratio for Push X and for Push Y

Table 2 presents the numerical values for estimated yield, ultimate and plastic displacement of the building in global sense. This table also shows the ductility ratio (ratio between ultimate and yield displacement) estimated for different analysis case. These data are derived from the capacity curves of the building. It is found from the table that shear failure makes a structure less ductile. In X-direction, ductility ratio reduces from 5.5 to 1.1 when shear hinges are incorporated in the model. Similarly, ductility ratio reduces from 4.7 to 2.2 in Y-direction.

Table 2

	Push-X		Push-Y	
	No shear	With shear	No shear	With shear
Yield disp (mm)	32.2	31.1	5.8	5.7
Ulltimate disp(mm)	176.5	34.8	27.0	17.7
Plastic Disp (mm)	144.3	3.7	21.2	7.0
Ductility ratio	5.5	1.1	4.7	2.2

6. Conclusion

This chapter presents the results obtained from performance based seismic analysis of the selected building models. Analysis were carried out for two building models, one without shear hinges and other with shear hinges, and for two orthogonal lateral directions (X- and Y-) of each model. The results presented here shows that the analysis can grossly overestimate the base shear and maximum roof displacement capacity of a building if the model ignores shear hinges. Also, estimated ductility ratio is found to be very high for the selected building model that does not consider shear hinge. These results demonstrate that shear deformation behavior of structure must be considered to predict probability and location of shear hinges in the structure model. So that Brittle failure of on ductile structural elements can be avoided under large earthquake forces.

7. Future Scope

(i) The nonlinear shear hinge properties of rectangular RC sections developed here can be validated through experimental study
(ii) The present study considers only rectangular sections with rectangular links as web reinforcement. This study can be further extended to spiral web reinforcement in circular section.

References

[1] A. Kadid and A. Boumrkik, "Pushover analysis of Reinforced concrete frame structures", Asian journal of civil engineering (building and housing) Vol. 9, No.1, pp.75-83, 2008.
[2] A.Ghaffar, A.Javed, H.Rehman, K.Ahmed and M hyas, "Development of shear capacity equations for rectangular reinforced beams", Park J Eng. & appl.Sci.Vol.6, pp.
[3] Applied Technology Council (ATC-40), "Seismic evaluation and retrofit of concrete buildings", Vol.1& 2, California, 1996.
[4] Bazant Z P and Kazemi M T, "Size effect on diagonal shear failure of beams without stirrups", ACI Structural Journal, 88(3), pp.268–276, 1991.
[5] BS 8110-1, Structural use of concrete, Part 1: Code of Practice for Design and Construction, British Standards Institution, London, 1997.
[6] C.G.Karayannis, C.E.Chalioris and P.D.Mavroeidis, "Shear capacity of RC rectangular beam with continuous spiral transverse reinforcement", proceedings of Twelfth International Conference on Computational Methods and Experimental Measurements, Malta, pp.379-386, 2005

Author Profile

Krishna Kumar is M. Tech 4th semester Scholar in Ganga Institute of Technlogy and Management (GITAM), Kablana, Jhajjar, Haryana, India