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Pushover Analysis of R.C. Frame Building with Shear Wall: A Review

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The structure in high seismic areas may be prone to the severe damage. The structural safety for earthquake loading is most important factor along with building serviceability and prospective for economic loss during major earthquakes. Performance - based design is controlling the structural damage based on precise estimation of proper response parameter. By performance based seismic analysis one can evaluates how building is likely to perform. It is an iterative process with selection of performance objective and subsequently development of preliminary design, an assessment whether or not the design meets the performance objective. This review article is based on Non-linear Static Analysis (Pushover Analysis) of RC frame buildings with shear wall and its parameters such as Lateral Displacement, Storey Shear, Storey Drift, Base shear and demand Capacity (Performance Point) are been evaluated using E-TABS and SAP software. The comparative study has been done for story drift, base shear, spectral acceleration, spectral displacement, story displacement

Keywords: Earthquake; Pushover analysis; Storey Drift; Storey Shear; Spectral Acceleration.

1. Introduction

As the population increases and due to limited area of land the construction of structures goes vertically. About 60% of the land in our country is susceptible to damaging levels of seismic hazard. No one can avoid future earthquakes, but safe building construction practices can certainly reduce the extent of damage and loss. It leads to construction of tall buildings like residential, commercial and the trend is moving towards tall and slender structures. The objective of seismic design is to provide building structures with sufficient strength and deformation capacity to sustain seismic demands imposed due to ground motion with adequate margin of safety. Design of structures extreme loading, a criterion is adopted in such a way that a major earthquake, with a relatively low probability of occurrence is expected to cause significant damages which may not be repairable but not associated with loss of life Performance based seismic design is gaining popularity from last decades. To evaluate the performance of framed Structures for future expected earthquakes, one of the most commonly used lateral load resisting system is shear wall and usually used in tall building to avoid collapse of buildings. Shear wall may become imperative from the point of view of economy and control of lateral deflections. By providing shear wall system the structure become safe and durable and also more stable the function of shear wall is to increase rigidity for wind and seismic load resistance. When shear wall are situated in advantageous positions in the building they can form an efficient lateral force resisting systems.

1.1. Pushover Analysis

- **Description to Pushover Analysis**

Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the popular analysis procedure for style and unstable performance analysis is comparatively straightforward procedure. Applied Technical Council (ATC) and Federal Emergency Management Agency (FEMA) are the two agencies which formulated and suggested the Non-linear Static Analysis or Pushover Analysis under seismic rehabilitation programs and guidelines. This included documents FEMA-356, FEMA-273 and ATC-40. Many countries are having separate document over this method. But Indian codes square measure still silent over this technique. Even the IS 1893(part I): 2007 draft doesn't have a discussion about performance based seismic design. Pushover analysis could be a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the capacity curve or force-displacement relationship, for a structure or structural elements. The analysis involves applying horizontal hundreds, in a prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or element of structure to reach the collapse condition. Pushover analysis can provide a significant insight into the weak links in seismic performance of structures.

- **Types of Pushover Analysis**

Presently, there are two types of non-linear static analysis procedures available, one termed as the Capacity Spectrum Method (CSM) documented in ATC-40 and other the Displacement Coefficient Method (DCM), documented FEMA-356. Both methods are depend on lateral load-deformation variation obtained by non-linear static analysis under the gravity loading and idealized lateral loading due to the seismic actions. This analysis is called Pushover Analysis.

a) Displacement Coefficient Method

The concept of Displacement Coefficient Method is based a non-linear static analysis procedure which provides a numerical process for estimating the displacement demand on the structure, by using a bilinear representation of the capacity curves and a series of modification factors to calculate a target displacements. The point on the capacity curves at the target displacement is the equivalent of the performance point in the capacity spectrum method.

b) Capacity Spectrum Method

The concept of Capacity Spectrum Method is based on a non-linear static analysis procedure which provides a graphical representation of the expected seismic performance for the structure by intersecting the structure's capacity spectrum with the response spectrum (demand spectrum) of the earthquake. The intersection point is called as the performance point, and the displacement coordinate d_p of performance point is the estimated displacement demand on structure for the specified level of seismic hazard.

1.2 Introduction to FEMA-273

The primary purpose of FEMA-273 [4] document is to provide technically sound and nationally acceptable guidelines for seismic rehabilitation of buildings. The Guidelines for the Seismic Rehabilitation of Buildings are intended to serve as ready tool for design professionals for carrying out the design and analysis of buildings, a reference document for building regulatory officials, and a foundation for the future development and implementations of building code provisions and standards.

1.3 Introduction to ATC-40

Seismic analysis and Retrofitting of Concrete Buildings normally said as ATC-40 [32] was developed by the Applied Technology Council (ATC) with funding from the Calif. Safety Commission. Although the procedures counselled during this document square measure for concrete buildings, they are applicable to most building types.

1.4 Plastic Hinges

Locations of inelastic action of the structural member are called as plastic hinges. For nonlinear static, and nonlinear direct-integration time-history analyses, users may simulate post-yield behaviour by assigning concentrated plastic hinges to frame and tendon objects. Elastic behaviour happens over member length, and then deformation beyond the elastic limit occurs entirely within hinges, which are modelled in discrete locations. Inelastic behaviour is obtained through integration of the plastic strain and plastic curvature at intervals a user-defined hinge length. To capture plasticity distributed along member length, a series of hinges can be modelled. Multiple hinges can also coincide at an equivalent location. Force and Displacement relation of a hinge is as shown in Fig. 1.

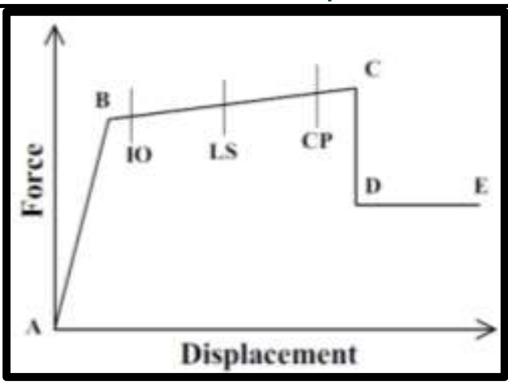

figure 1. Performance Level of Pushover Analysis

Plasticity associated with force-displacement behaviour or moment-rotation. Hinges can be assigned (uncoupled) to any of the six DOF. Strength loss modelling is discouraged, to mitigate load redistribution and to ensure numerical convergence.

2. LITERATURE REVIEW

(M.D. Kevadkar, P.B. Kodag 2013) In this study R.C.C. building is modeled and analyzed in three parts: Model without bracing and shear wall, Model with different shear wall system and Model with Different bracing system.[1]
The computer aided analysis is done by using E-TABS software to find out the effective lateral load system during earthquake in high seismic areas. The performance of the building is evaluated in terms of Storey Drifts, Lateral Displacement, Storey Shear, Base shear and Demand Capacity (Performance point).

- **Modeling:** The lateral loads applied on the buildings are based on Indian standards. The study is performed for seismic zone III as per IS 456 (Dead load, Live Load), IS 1893:2002 (Earthquake load), IS875: 1987(Wind Load). G+12 storied building is analyzed for seismic and gravity forces.

- **Analysis and Results:** Linear Analysis in which all the models are analyzed for parameters such as Storey drift, Lateral displacement, Storey shear.

- **Plastic Hinge Mechanism***:* Models with shear wall shows better performance compared to bare frame model. The yielding of model with shear wall happens at events C-D at step-2 and D-E at step 5-10. Better performance is observed in model with steel bracings. The yielding of the model with steel bracing happens at event B-IO and IO-LS and LS-CP the amount of damage in this structure has been limited.

- **Conclusions:** G+ 12 bare frame model, shear wall model and Steel bracing model is analyzed and compared. The following conclusions are proposed based on present study. The concept of using steel bracing is one of the advantageous concepts that are used to strengthen structure. Steel bracing reduces flexure and shear demands on beams and columns, and transfer the lateral load by axial load mechanism. The lateral displacement of the building gets reduced by 40 to 60 percent by the use of shear wall and steel bracing system. Storey drift of the Shear wall and steel braced model are within the limit as stated on IS-1893 (Part-1):2002.

(**Nitin Choudhary and Mahendra Wadia 2014)** carried pushover analysis on two multi-storeyed RC frame building, in which plan of first building was taken symmetrical and it consist of 2 bay of 5m in X direction and 2 bay of 4m in Y direction and second building having L shaped unsymmetrical plan. The shear wall is provided to resist the lateral loads. This study highlight the effect of shear wall on R.C frame building while providing shear wall along the longer and shorter side of the building. The comparative study has been done for storey drift, base shear, spectral acceleration, spectral displacement, storey displacement.[2]

1) Description of Building: Four storied reinforced concrete frame building situated in Zone IV, is taken for the purpose of study. [1]The plan area of building is 10 x 8 m with 3.5 m as typical storey height. It consists of 2 bays of 5 m each in X-direction and 2 bays of 4 m each in Y-direction. Hence, the building is symmetrical about both axes. The total height of the building is 14 m. The building is considered as a Special Moment resisting frame.

For the analysis purpose, two buildings are considered, of which one is symmetrical about both the axis and the other is an unsymmetrical building. Shear wall is provided on both the buildings.

2) Analysis and Results: Base force and Roof displacement for both symmetrical and unsymmetrical buildings are analyzed and compared.

a) For symmetrical building, base shear decreases by 7.55 percent when shear wall is provided in one bay of structure. There is a predominant decrease (63.30 percent) in roof displacement when shear wall is provided in building.

b) For unsymmetrical building, there is a decline of 4.3percent in the base force capacity, when shear wall is provided on the larger side of the building frame, whereas when it is provided on the smaller side there is a decrease of 7.9 percent. There is a predominant decrease of 59.09 percent in roof displacement when shear wall is provided on the larger side and decrease of 58.92 percent on provision of shear wall on smaller side.

(JyotiPatil and Dr. D.K. Kulkarni 2015) The present work is based on comparing the bare frame model with models having a RC framed shear walls modeled by two different methods. The simplified shear wall is a single element throughout the building and refined model is a multi-layered membrane element. The shear walls are placed at different positions in the building along X and Y directions. The equivalent static and nonlinear static analysis (Pushover Analysis) are carried out using the software tool ETABS 2015. For the different load combinations available in IS 1893(part1):2002, the base shear, displacements, fundamental natural period and performance of the models are compared. [3]

Sr.No.	Description	Information
1	Plan dimension	24m x 18m
2	Thickness of slab	175m
3	Column size	500 x 500 mm
4	Beam size	300 x 500 mm
5	Beam size in LLRS	300 x 600 mm
6	Shear wall panel	2500 X100 mm
7	Grade of Concrete	M30
8	Grade of Steel	Fe415
9	Live Load	3 kN/m2 for middle floors and 1.5 kN/m2 for roof
10	Floor finish	0.75 kN/m2.
11	Seismic zone	V
12	Importance Factor(I)	1
13	Response reduction factor	5

Table 1: Data for the Building

1) Results and Discussions: Parameters such as Fundamental natural period and Lateral displacement and Base shear for various loading conditions are analyzed and compared in this literature. Effect of shear wall on base shear is given below. The results of simplified model, refined models and bare frame are compared.

Shear wall location	Bare frame	Simplified model	Refined model
At center	1464.240	1994.420	2159.110
Along Y Asix	1464.240	2333.580	2690.560
Along X Axis	1464.240	1492.670	1529.810

Table 2: Base Shear Values

2) Lateral Displacement: The percentage of reduction in displacements of bare frame model to simplified model and refined model is 18.57 percent and 21.33 percent respectively. The percentage variation of base shear between simplified and refined model is 3.25 percent.

3) Pushover Analysis: Pushover Analysis has been carried out for all the model and performance point for each model has been obtained and compared.

Conclusion :

The performance of reinforced concrete frames was investigated using the pushover analysis. The conclusion drawn from the analyses are: The fundamental time period of building increases due to provision of shear wall as provision of shear wall increases the global stiffness of building. The pushover analysis is a relatively simple way to explore the nonlinear behavior of buildings. The behavior of properly detailed reinforced concrete frame building is adequate as indicated by the intersection of the demand and capacity curves and the distribution of hinges in the beams and the columns. Most of the hinges developed in the beams and few in the columns but with limited damage.

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