

EVALUATION OF CAPACITY OF RCC FRAMED STRUCTURE WITH DIFFERENT BRACE CONFIGURATIONS USING PUSHOVER ANALYSIS

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Abstract - The static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The existing building can become seismically deficient since seismic design code requirements are constantly upgraded and advancement in engineering knowledge. Further, Indian buildings built over past 20 years seismically deficient because of lack of awareness regarding the seismic behavior of structures during the earthquake, and also due to the bad construction practice, so it is very to increase the earthquake resistance capacity of the existing and new buildings to the future earthquake by introducing some lateral load resisting components in the buildings. The widespread damage especially to RC buildings during earthquakes around the world generated a great demand for developing a simple yet **efficiently accurate new method known as "pushover analysis" for seismic evaluation. The expectation is that the "non-linear static analysis" popularly known as "pushover analysis" will provide adequate information on seismic demands imposed by the design ground motion on the structural system and its components and consumes very less time compared to non-linear dynamic analysis.**

Modeling for such analysis requires the determination of the nonlinear properties of each component in the structure, quantified by strength and deformation capacities, which depend on the modeling assumptions. Pushover analysis is carried out for either user-defined nonlinear hinge properties or default-hinge properties, available in some programs based on the FEMA-356 and ATC-40 guidelines

Keywords; nonlinear static pushover analysis, default hinge properties, sap2000, braces, eccentric diagonal bracings, inverted eccentric v bracings, diagonal bracings.

I. INTRODUCTION

The pushover analysis is a method to observe the successive damage states of a building. The method is relatively simple to be implemented, and provides information on strength, deformation and ductility of the

structure and distribution of demands which help in identifying the critical members likely to reach limit states during the earthquake and hence proper attention can be given while designing and detailing as per ajay.d goudar [1]. this method assumes a set of incremental lateral load over the height of the structure. Local nonlinear effects are modeled and the structure is pushed until a collapse mechanism is developed. With the increase in the magnitude of loads, weak links and failure modes of the buildings are found At each step, the base shear and the roof displacement can be plotted to generate the pushover curve as per Ashraf Habibullah [2]. This method is relatively simple and provides information on the strength, deformation and ductility of the structure and distribution of demands. This permits to identify the critical members likely to reach limit states during the earthquake by the formation of plastic hinges. On the building frame load/displacement is applied incrementally, the formation of plastic hinges, stiffness degradation, and lateral inelastic force versus displacement response for the structure is analytically computed.

To perform a pushover analysis, a lateral load versus deformation curves for the member is required. The results from a pushover analysis will give the load versus deformation curves. Moreover, the pushover analysis gives only curve of the base shear versus roof displacement behaviour of a building. The actual performance of a building may differ from the calculated performance, since the load versus deformation curves and the earthquake levels used in the analysis are estimates as per Yusuf dinar [3].

The structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis described in FEMA-356[4] and ATC-40[5]. when pushover analysis is used carefully it provides useful information that cannot be obtained by linear static or dynamic analysis procedure

II. PUSHOVER ANALYSIS OF STRUCTURE

2.1 Scope of the study; the significant of the present study is to evaluate the difference in behavior of G+3 reinforced concrete frame subjected to earthquake force in zone II. The concrete frames are analyzed by nonlinear

static analysis method i.e. pushover analysis method using SAP2000 software. The braces were introduced in the frame to study the behavior of pushover curve, analysis were carried with and without braces, with the default hinge properties in SAP 2000. It shows the performance level, behavior of components and failure mechanism in a building. It also shows the type of hinges formation, the strength and capacity of the frame in the x direction.

2.2 Performance Based Design for Nonlinear Static

Pushover Analysis : Create the basic computer model of four storey building frame structure. Define properties and acceptance criteria for the pushover hinges. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members. These built-in properties can be useful for preliminary analyses, but user defined properties are recommended for final analyses. Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties. Define the pushover load cases. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover. Pushover load cases can be force controlled, that is, pushed to a certain defined force level, or they can be displacement controlled, that is, pushed to a specified displacement.

2.3 Pushover Methodology:-

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behaviour of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modelled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building.

2.4. Nonlinear Plastic Hinges Properties:-

The building has to be modelled to carry out nonlinear static pushover analysis. This requires the development of the force - deformation curve for the critical sections of beams, columns. The Nonlinear properties of beams and columns have been evaluated using the section designer and have been assigned to the computer model in SAP2000 as per s.n tande [7]. The flexural default hinges (M3) and shear hinges (V2) were assigned to the beams at two ends. The interacting (P-M2-M3) frame hinges type a

coupled hinge property was also assigned for all the columns at upper and lower ends as per [8]

III. PERFORMANCE LEVEL OF A STRUCTURE

The structural and non- structural components of the buildings together comprise the building performance. The performance levels are the discrete damage states identified from a continuous spectrum of possible damage states. The structural performance levels based on the roof drifts are as follows:

Five points labelled A, B, C, D and E are used to define the force deflection behaviour of the hinge and these points labelled as

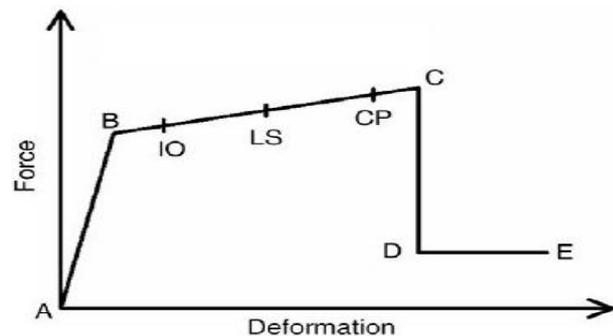


Fig.1 typical force vs. deformation curve

The performance levels of a structural element are represented in the load versus deformation curve as shown below,

1. A to B – Elastic state,
 - i) Point 'A' corresponds to the unloaded condition.
 - ii) Point 'B' corresponds to the onset of yielding.
2. B to IO- below immediate occupancy,
3. IO to LS – between immediate occupancy and life safety,
4. LS to CP- between life safety to collapse prevention,
5. CP to C – between collapse prevention and ultimate capacity,
 - i) Point 'C' corresponds to the ultimate strength
6. C to D- between C and residual strength,
 - i) Point 'D' corresponds to the residual strength
7. D to E- between D and collapse
 - i) Point 'E' corresponds to the collapse.

IV. MODELLING AND ANALYSIS.

The general finite element package SAP2000 (version-14) has been used for the modeling and analysis. It is a versatile and user-friendly program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, etc. These features and many more, make SAP2000 the state-of-the-art in structural analysis programs.

4.1 Details of the structural models:- Material:- The material used for construction is Reinforced concrete with

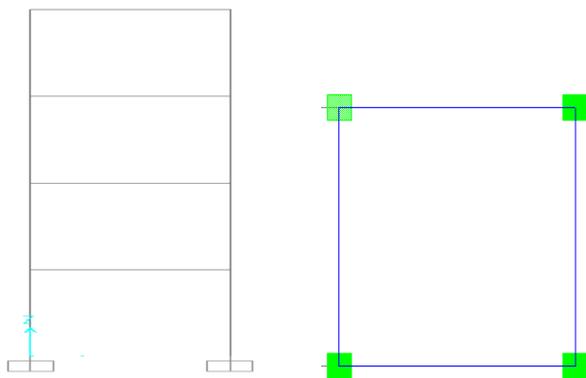
M-20 grade concrete and fe-415 grade reinforcing steel. The Stress-Strain relationship used is as per I.S.456:2000. The basic material properties used are as follows: $E_s = 21,0000 \text{ MPa}$, $E_C = 22,360.68 \text{ MPa}$, $f_{ck} = 20 \text{ MPa}$, $f_y = 415 \text{ MPa}$

For numerical modeling a simple G+3 frame of RC frame is, the bay length and width are 3m x 3m in both the direction with each storey height 3m,

The eccentric diagonal and inverted v bracings are introduced to enhance the lateral load carrying capacity of the frame

4.2 Section properties ; beams = 300mm x 300 mm, columns = 300mm x 300mm with 3-16Φ at top and bottom in case of beam and 4-20Φ at corners and 4-16Φ in case of columns, the transverse reinforcement for both column and beams 8Φ100mm c/c and

Braces sizes introduced = 150mm x 150mm with reinforced with 2-16mm at top and bottom,



3m x 3m with each floor height of 3m

Fig.2 Elevation of the frame. Fig. 3 plan of the frame

4.3 Bracing configuration:

UBC 2211.10.2 the selection of a bracing system configuration is related to various elements. These factors encompass the size and position of required open areas in the framing elevation and the height to width proportions of the bay elevation. These constraints may substitute structural optimization as designing criteria. UBC 2211.10.2 requires at least one end of every brace to frame into a link. There are many frame configurations which meet this Criterion.

4.4 Frame proportions:

Michael D.Engelhardt, and Egorp.popov, p. 504 (1989) in designing EBF systems, the proportions of frames are typically opted to increase the application of the high shear forces in the link. Shear yielding is very ductile and its capacity for inelastic behaviours is very high. This characteristic, as well as the benefits of frames with high

stiffness, generally make short lengths desirable. The desirable angle of the brace as shown in the above picture should be kept between 35° and 60°. If the angle is beyond or below this range, then it will result in awkward details at the brace- to- beam and brace-to-column connections. Meanwhile small angles are also apt to result in a huge axial force member in the link beams (Michael. Engelhardt, and Egorp.popov, p. 504) (1989)

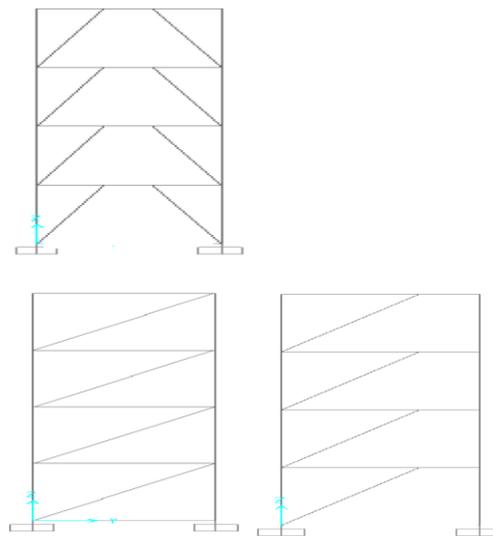


Fig.4 different brace configurations

1. Inverted v eccentric braced frame system.
2. Eccentric diagonal brace system
3. Diagonal braced frame system

4.5 Braces hinge properties

Nonlinear behavior of brace elements can be best modeled by assuming a hinge (being made under pure axial load) in the middle of the element as per tande[7]. An axial load plastic hinge is modeled in the relative distances of all bracing elements as per Table 5-6 of FEMA 356 [Appendix] in this study.

V .RESULTS

The process of frame modelling and their analysis were finished, pushover curves obtained from the analysis are.

1. Normal concrete frame

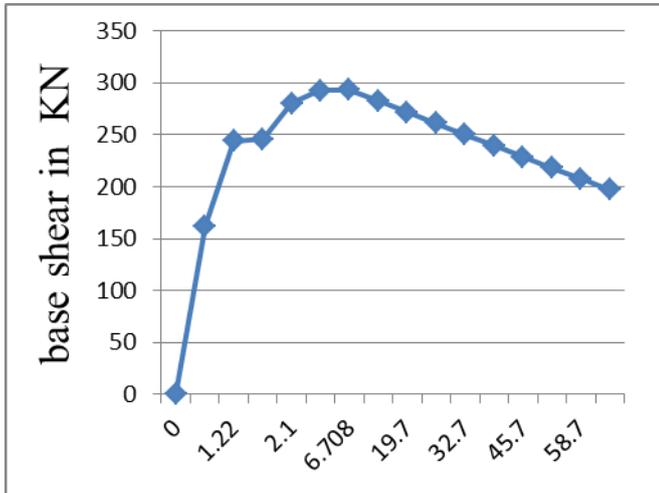


Fig4. Pushover curve

2. Eccentric diagonal braced frame

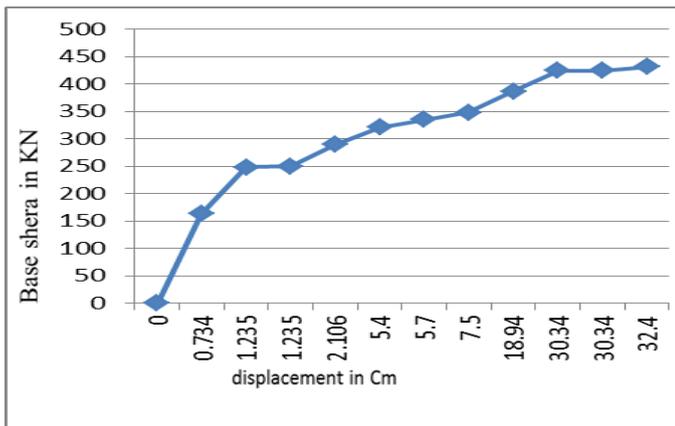


Fig5. pushover curve

curve

3. Eccentric inverted V braced frame

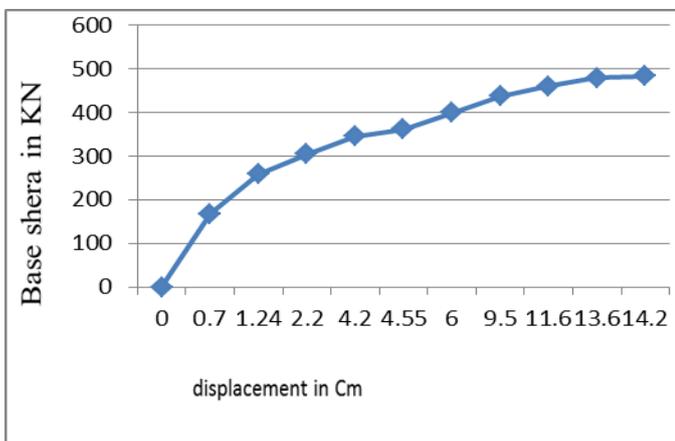


Fig6. pushover curve

4. diagonal braced frame

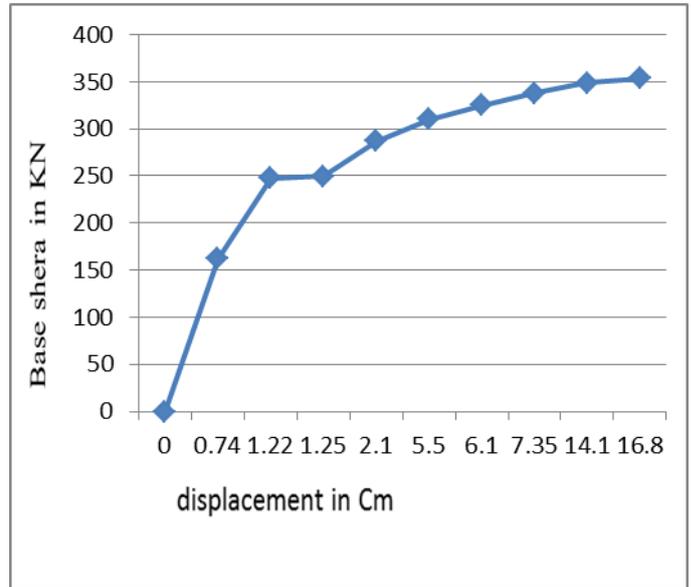


Fig.7 pushover curve

4.1 Capacity spectrum is the capacity curve spectral acceleration Vs spectral displacement (S_a Vs S_d) coordinates. The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates

Table.1 performance point data of the frames

Types of frames	Force at performance point in KN	Displacement at performance point in mm
Frame without braces	275	23
Eccentric diagonally braced frame	292	25
Eccentric inverted v braced	313	30
Diagonal braced frame	290	26

VI. CONCLUSION

Summarizing the result lead to the discussion that, with the introduction of braces with different configuration significantly affects the performance of structure, under performance based analysis which is pushover, with the presence of braces in the frame increase the performance

overall and braces induced frames having the resistance against the lateral load, compared to the frame without braces.

These are the conclusion drawn from the analysis

- The pushover analysis is a simple procedure to visualise the nonlinear character of the building.
- Structural performance are significantly increased by different bracing configurations and there frame proportion in placing the bracings.
- The pushover curve obtained for the different frame configurations shows that,
 1. For the normal concrete frame the max displacement obtained is 650mm for the base shear value of 300KN in x direction
 2. For the frame with eccentric diagonal braces shows the lesser displacement value of 324mm for the base shear value of 431,2KN compared to the normal frame
 3. For the inverted braced frame displacement obtained is 142mm with base shear value of 484KN
- From the above points it is shows that with the introduction of braces to the frames, frame shows the lesser displacement value compared to the frame without braces hence the braces are effectively working in resisting the lateral loads coming on the building during the earthquake ground motion
- Eccentric diagonal braced frame is highly economical hence, the weight of the diagonal braces is less compared to the v braced frames, and also effectively reduces the displacement due to the lateral load.
- Diagonally braced frame is more effective than the eccentrically braced frame system..
- From the above graphs it is shows that the normal concrete frame without braces shows a maximum displacement for the lower value of base shear value
- The results obtained in terms of pushover demand, capacity spectrum and plastic hinges the real behaviour of structures. In a four storey building seismic zone -II is designed and constructed using IS-456-1978 and the revised code IS-1893- 2000 provisions. Hinges have developed in the beams and columns showing the three stages immediate occupancy, Life safety, Collapse prevention. The column hinges have limited the damage.

VII. REFERENCE

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