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Study of Pushover Analysis of RCC Building with Soft Story at Different Elevations

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ABSTRACT:A recent catastrophic earthquake has exposed the vulnerability of existing reinforced concrete buildings in India. The Bhuj earthquake (2001) caused enormous damage to skyscrapers in downtown Gujarat. This poses a serious threat to many existing Indian RC buildings designed primarily for gravity loads. Following the damage and collapse of numerous concrete structures due to recent earthquakes, the need to evaluate the seismic resistance of existing structures is drawing attention. To assess vulnerabilities, countries such as India, which are prone to earthquakes, require very simplified procedures for assessment. From the perspective of life security and risk management, it is important to estimate the response of the building during an earthquake. The validity and performance of the building is checked by the code provisions of IS 1893: 2002. Procedures have been proposed to evaluate the seismic performance of existing buildings in India. The procedure is based on the capacitive spectral method (ATC 40) and the lateral force distribution used in the pushover analysis is described in IS1893 (Part 1): 2002. The proposed methodology is a typical reinforced concrete moment resistance frame (RC MRF) building. This procedure gives you a detailed understanding of the damage distribution and the overall failure mechanism.

KEYWORDS: Pushover analysis, Response spectrum analysis, ETABS, Hinges

I. INTRODUCTION

Performance-based design has taken a new dimension in seismic design. This study focuses on pushover analysis of multi-layer RC frame buildings that expose them to monotonically increasing horizontal forces with an invariant height distribution until preset performance levels (target displacements) are achieved. I am. The promise of performance-based seismic engineering (PBSE) is to create structures with the expected seismic performance. Achieving this requires extensive and well-coordinated efforts by experts in several disciplines. Performance-based engineering is not a modern technology. Automobiles, airplanes and turbines have been designed and manufactured for decades using this approach. Such applications typically produce one or more life-size prototypes of the structure and undergo extensive testingThe design and manufacturing process is then revised to match the lessons learned from the experimental evaluation. After a successful design, prototype manufacturing, testing, and redesign cycle, the product is manufactured on a large scale. For example, in the automotive industry, millions of vehicles with similar mechanical properties are manufactured according to their respective performance-based design procedures.

The idea of a performance-based seismic design approach has become the method of seismic design code. In this approach, nonlinear analysis procedures are important in determining the pattern and amount of damage, assessing the inelastic behavior and rupture patterns of structures in brutal seismic events. Static pushover analysis is a simplified non-linear procedure in which seismic patterns are applied stepwise to the structural frame until a plastic collapse mechanism is formed.

1.1 **Performance Based Design Approach:**

The performance-based design process primarily requires a visual distinction between expected performance goals. These goals correspond to seismic hazard levels and expected performance levels of the structure. In other words, the level of "acceptable risk" requirement needs to be clearly defined. "Risk" may be expressed in terms of vulnerabilities to seismic hazards and structural damage. Quantifying performance goals is sometimes referred to as "performance criteria." This means quantified acceptance criteria that are essential to achieving performance goals.In current times, the performance objectives other than 'Life Safety', which was the chief focus to reduce the threats to the life safety are



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also being considered. Such performance objectives may differ from 'Collapse Prevention' for the exceptional event of a large earthquake to an 'Operational Level' for frequent earthquakes of reasonable size. The various performance levels along with their force-displacement characteristics are given below in Fig.1.1



Fig.:-1 Structural Performance Level

A building performance goal as an expected performance level of a building given a certain level of predictable ground movement at a particular site to define the tolerance criteria for the structure. The basic process of PBD can be illustrated using the flowchart shown in Figure 1.2. In ETABS, frame elements are modeled as line elements with linear elastic properties, and the nonlinear force displacement properties of individual frame elements are modeled as hinges represented by a series of straight lines, as shown in Figure 1.1.

Point A represents the no-load condition and point B represents the yield of the element. The vertical coordinates of C represent the nominal strength, and the horizontal axis of C corresponds to the deformation where a significant decrease in strength begins. The C-to-D drop corresponds to the initial failure of the element, and resistance to lateral loads above point C is usually unreliable. The residual resistance from D to E allows the frame element to withstand gravitational loads. If the maximum deformation capacity of point E is exceeded, the gravitational load cannot be maintained.



Fig.: -2 Performance Based Seismic Process

1.2 Soft Story Failure:

Skyscrapers in big cities lack horizontal space and are costly, requiring ample space for vehicle parking, retail shopping, conference rooms and bank halls. Due to this functional requirement, the first floor is less strong and stiff than the upper floor, which is reinforced by masonry embedded walls. This feature of building construction causes problems with weak or soft floors in high-rise buildings. As the flexibility of the first floor increases, extreme



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deflection occurs, the force concentrates on the connections on the second floor, and large plastic deformations occur. In addition, most of the energy developed during the earthquake is dissipated by the soft story columns. In this process, a plastic hinge is formed at the end of the pillar, turning the soft story into a mechanism. In such cases, collapse is inevitable. Therefore, soft stories deserve special consideration in analysis and design. Investigations have shown that the damage is due to column collapse and buckling, especially if the parking lot is not properly covered. On the contrary, if the parking lot is properly covered, the damage will be greatly reduced. It is recognized that this type of breakage is due to a combination of several other unfavorable reasons, such as twisting, excessive mass on the upper floors, the P- Δ effect, and lack of ductility in the bottom layer.Figure 3 shows some examples of soft stories. The soft story concept has technical and functional advantages over traditional construction. The first is the decrease in spectral acceleration and base shear force due to the increase in the natural vibration period of the structure, similar to the seismic isolation structure. However, the price of this reduction in force is paid in the form of displacement of the structure and increased drift between floors, with a significant P- Δ effect that threatens the stability of the structure. Second, the second highest first floor may be needed for vehicle parking, retail shopping, and ample space for conference rooms and bank halls. This functional requirement makes the columns less rigid on the first floor compared to the rigid upper floor rooms, which are typically built with masonry embedded walls.



II. RELATED WORK

Mrugesh D. Shah, Atul N. Desai and Sumant B Patel (2011) A study of R.C.C. performance-based analysis was presented. flame. They considered two distinctive new R.C.Cs. The building was adopted for analysis: G + 4 and G + 10 to cover a wider area of low-rise and high-rise building construction. Nine models in the G + 4 and G + 10 buildings contained various modeling issues. It has a bare frame (no infill), an infill as a membrane, and replaces the infill as an equivalent strut on previous models. All three conditions of 2x2, 3x3 and 4x4 bays. Relative work done on bare frames (without infills) that have infills as membranes and replace infills as equivalent struts. From the results of G + 4 and G + 10 stories of bare frames without infills, they compared bare frames with infills as membranes and bare frames with less laterally load-bearing infills. , Showed that the lateral load capacity (performance point value) is small. Bare the frame with equivalent stanchions. They also concluded that increasing the number of bays increased the lateral load capacity, but increasing the number of bays did not increase the displacement. In all models, we conclude that base shear and displacement are maximal infill for diagonal struts with base shear increased by 50-55% and displacement increased by 50-60%.

Dimpleben P. Sonwane and Dr. Kiran B. Ladhane (2015) Beginning with the selection of performance goals, developing preliminary designs, reviewing whether the design meets performance goals, and finally redesigning and, if necessary, reassessing until the desired performance level is achieved. Did. In this study, an example of an RC frame building analyzed using pushover analysis (designed according to IS 456: 2000) and a modified analysis of the main reinforcements of different frame heights at different floor levels. Redesigned by doing. Pushover analysis was performed using SAP 2000, an international computer and structure product. This building is considered a special moment to resist a building with a frame, and the main purpose of this study is to see what



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kind of performance the building can offer when designed according to IS code. The best combination of reinforcements that are economical, effective, minimally damaging and ready to use is determined and is called a performance-based design. From this analysis, they concluded that increasing the reinforcement of the columns would improve performance and only significantly reduce the maximum displacement of the roof. The reduction in roof displacement is the largest internal column and is comparable for corner columns and central columns. It is observed that changing the reinforcement of the first floor affects the base shear more than the other floors. In addition, the provision of shear walls significantly reduces foundation shear and roof displacement of asymmetric buildings, and the performance-based seismic design obtained in the above procedure provides immediate occupancy and life safety limits for earthquakes of varying intensities. It is observed that the condition's tolerance criteria are met. It was observed that with increase in reinforcement of beams only, there is change in the base force varying from 5.24% to -16.6%, which the structure can carry. The percentage change in displacement varies from - 6.22% to -34.78%. However, the trends shown by increasing the reinforcement of columns only is a substantial increase in the roof displacement which varies from -0.8% to -37.77%

Ranjit V. Surve and D. S. Jagtap, Prof. Y. P. Pawar (2015) By considering G + 16 buildings, we considered a performance-based analysis of multi-story buildings with different levels of soft stories. They observed that shifting the soft floors to higher levels reduced the number of hinges. At the same time, displacement and base shear increase. Maximum yield is observed on the base floor because the largest plastic hinges are formed on the soft floors. Changing the soft story to a higher level results in less yield than a lower level soft story, and a low-strength hinge is formed after the maximum number of pushover steps. According to IS 1893-2002, empirical formulas for bare frames and full infill frames are shown, but no empirical relationship is shown for calculating the basic natural period of soft-story buildings. Hmm. Therefore, you need to use software such as SAP2000 to determine the basic frame period. The behavior of multistoried building is satisfactory as indicated by intersection of the demand and capacity curve. Most of hinges developed in the beam and few in the column. As they shifted soft storey to higher level it can be seen from push-over curve that Teff goes on reducing from 2.571 sec for 4th floor to 2.366 sec at 16th floor soft storey, which is around 8% decrease.

Dilip J. Chaudhari and Gopal O. Dhoot (2016) We investigated seismic design based on the performance of reinforced concrete buildings. In this task, we will investigate a four-story RC frame building in Zone IV. It consisted of two bays, 5 m each in the X direction, and two bays, 4 m each in the Y direction. The total height of the building is 14m. The building is modeled and designed according to SAP 2000v17 IS456: 2000 and analyzed for life safety performance levels. The analysis is performed according to ATC40 and finds floor drifts, pushover curves, capacitance spectrum curves, performance points, and plastic hinges according to SAP2000v17 FEMA273. From this analysis, the performance level of the building is estimated to be as expected. The need for performance based design compared to the force-based design approach studied, and the performance levels of the four buildings: operation, immediate occupancy, life safety, and collapse prevention were studied.Performance-based designs take into account multi-level seismic hazards with a focus on transparency of performance goals, ensuring improved performance and minimized lifecycle costs. Drift performance on the floors of multi-storey buildings has been recognized as an important measure of structural and non-structural damage to buildings under varying levels of ground motion. For the building under consideration, the floor drift needs specified in FEMA273 have been met. Therefore, the overall performance of the building was considered acceptable as a design goal. The authors have finished that performance-based seismic design provides a reliable methodology for seismic upgrades or refurbishment of existing buildings to achieve the required performance goals.

Md Tasleem and Dr. K. Narayan (2018) It was studied that soft story behavior was not observed if the building was designed according to the base shear correction codal rules and was designed with a capacitance design without infill strut elements, even if the soft story design rules were not applied. .. IS 1893 (Part 1): Soft floor formation is observed in all buildings when the coefficients proposed in 2002 are not applied to ground floor members. Considering the embedding effect, no plastic hinges are formed on the columns, and the ground floor members are designed with 2.5 times the floor shear and moment.

Objectives of investigation:

• To carry out Linear Dynamic Analysis using Response spectrum analysis for RCC building with soft story at different levels.



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- To carry out Non-Linear Static Analysis by performing Performance based seismic design using Capacity spectrum method (Pushover analysis) for RCC buildings with soft story at different levels.
- To study the effect of various response parameters as stated above for both the analysis.

III. METHODOLOGY

For present work seismic analysis is carried out for reinforced concrete moment resisting building frame having (P+G+12) storey situated in zone II for varying vertical asymmetry. The analysis is carried out using SAP2000 & ETABS.

The building is modeled by using the finite element software ETABS. The analytical model of the building includes all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of the beams, columns, slab, walls, and foundation. The non-structural elements that do not significantly influence the building behavior are not modeled. Also three models has been made considering soft story at bottom, middle and top.





Fig.:-4 Plan of the Building inAutoCAD & ETABS

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Fig. 5: 3D view of Building in ETABS with soft storey at bottom



Fig. 6: 3D view of Building in ETABS with soft storey at middle.



Fig. 7: 3D view of Building in ETABS with soft storey at top.

IV. RESULTS

Seismic performance evaluation is a complex phenomenon as there are several factors affecting the behavior of the building. The models given earlier are firstly analyzed by response spectrum analysis and then by nonlinear static procedure as mentioned in the previous chapter. The static and dynamic analysis is carried out for with building models. The main parameters considered in this study to compare the seismic performance of different models having are story shear, story displacement, base shear vs. monitored displacement, performance objectives on the basis of development



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of hinges, pushover curve for orthogonal direction, story stiffness and story drift. The results obtained from the analysis are discussed in this section.









Fig.: 9 (a) & (b) Variation of base shear for X & Y direction for RSA and PBA

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Performance Objectives on The Basis Of Hinges Formation

Performance objectives are clearly stated in the tables and figures given below. For better understanding the various acronyms for the data given in tables are listed below:

Immediate Occupancy (IO) Life Safety (LS) Collapse Prevention (CP) Structural Stability (SS)



Fig.: 13 A Typical Flexural Hinge Property, showing IO (Immediate Occupancy), LS (Life Safety) and CP (Collapse Prevention)

			Hinge Formation			
	A-B	B-C	C-D	D-E	>E	Total
Push X (SS at bottom)	12270	6	0	0	0	12276
Push Y (SS at bottom)	12260	16	0	0	0	12276
Push X (SS at middle)	12260	16	0	0	0	12276
Push Y (SS at middle)	12250	26	0	0	0	12276
Push X (SS at top)	12250	26	0	0	0	12276
Push Y (SS at top)	12254	22	0	0	0	12276

V. CONCLUSION

This paper presents a summary of the present study, for the buildings with vertical asymmetry. On the basis of the results and discussions obtained in this investigation, the following conclusions have been drawn.

- 1. Performance based analysis gives better insight to structure in terms of its ability to resist lateral loads as compared to Response spectrum analysis.
- 2. Pushover analysis is a reliable method in determination of the sequence of yielding of the components of a building, possible mode of failure, and final state of the building after a predetermined level of lateral load sustained by the structure.



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- 3. From results, it is found out that the value of story drift for performance based analysis was very less than that of response spectrum analysis.
- 4. From results, it is found out that the value of story shear in performance based analysis was found out to be 35-38% lesser than shear obtained from response spectrum analysis.
- 5. From results, it is found out that the value of story displacement through performance based analysis was found out to be almost equal in X direction and almost 30% less in Y direction as compared to response spectrum analysis.
- 6. Formation of hinges are less in columns than beams.
- 7. Performance objectives are well satisfied as some hinges falls in the life safety for the second case, while in first case maximum hinges falls in immediate occupancy and life safety zone.

Variation of storey drift in both the cases is parabolic with middle storeys showing maximum drift. When SSI is considered there is a magnification of storey drift in the middle storeys.Variation of lateral displacement in both the cases is maximum at top stories showing maximum displacement, also the displacement value increases when SSI is taken into consideration. The base shear for with soil structure interaction case is almost same as compared to fixed base case as there is no increase in seismic weight of the building.

VI. FUTURE SCOPE

A lot of research work is taking place in the globe to study the performance of structure due to heavy earthquake loading. Also use of floating column is a common practice for construction of buildings. Following are the some points for future scope of this study:

- 1. This study can further be extended for tall buildings.
- 2. Application of capacity spectrum method to structures in Indian terrain still requires due modifications and adoptions in the analysis and design process.
- 3. Research on PBA procedures should be encouraged to close the gap between researchers and practicing structural engineers.
- 4. Analysis of buildings with vertical asymmetry can be done using time history analysis i.e. for non-linear case.

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