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NON-LINEAR ANALYSIS OF REINFORCED CONCRETE FRAMED STRUCTURE USING SAP

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Abstract— **To model the complex behaviour of reinforced concrete analytically in its non-linear zone is difficult. This has led engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures.**

For structural design and assessment of reinforced concrete members, the non-linear analysis has become an important tool. The method can be used to study the behaviour of reinforced concrete structures including force redistribution.

This analysis of the nonlinear response of RC structures to be carried out in a routine fashion. It helps in the investigation of the behaviour of the structure under different loading conditions, its load deflection behaviour and the cracks pattern.

In the present study, the non-linear response of RCC frame using SAP2000 under the loading has been carried out with the intention to investigate the relative importance of several factors in the non-linear analysis of RCC frames. This include the variation in load displacement graph.

Index terms- **Non Linear, Pushover analysis, RC Framed structure,SAP2000.**

I. INTRODUCTION

A. INTRODUCTION TO PUSHOVER ANALYSIS:

B. GENERAL

Seismic hazard in the context of engineering design is generally defined as the predicted level of ground acceleration which would be exceeded with 10% probability at the site under consideration due to the occurrence of an earthquake anywhere in the region, in the next 50 years. A lot of complex scientific perception and analytical modelling is involved in seismic hazard estimation. A computational scheme involves the following steps: delineation of seismic source zones and their characterisation, selection of an appropriate ground motion attenuation relation and a predictive model of seismic hazard. Although these steps are region specific, certain standardisation of the approaches is highly essential so that reasonably comparable estimates of seismic hazard can be made worldwide, which are consistent across the regional boundaries. The **National Geophysical Research Institute (NGRI), Hyderabad,** India was identified as one such center, responsible for estimating the seismic hazard for the Indian region. As it is well known, earthquake catalogues and data bases make the first essential input for the delineation of seismic source zones and their characterisation. Thus, preparation of a homogeneous catalogue for a region under consideration is an important task. The data from historic time to recent can broadly be divided in to three temporal categories: 1) since 1964, for which modern instrumentation based data are available 2) 1900-1963, the era of early instrumental data, and 3) pre 1900, consisting of pre-instrumental data, which is based primarily on historical and macro-seismic information. In India, the scenario is somewhat similar. The next key component of seismic hazard assessment is the creation of seismic source models, which demand translating seismo-tectonic information into a spatial approximation of earthquake localisation and temporal recurrence. For this purpose, all the available data on neo-tectonics, geodynamics, morpho structures etc., need to be compiled and viewed, overlain on a seismicity map. These maps then need to be critically studied for defining areal seismic source zones and

active faults. An earthquake recurrence model is then fitted to these source zones, for defining the parameters that characterise the seismicity of the source region, which go as inputs to the algorithm for the computation of seismic hazard. It is an iterative process that begins with the selection of performance objectives, followed by the development of a preliminary design, an assessment as to whether or not the design meets the performance objectives, and finally redesign and reassessment, if required, until the desired performance level is achieved.

C. PUSHOVER ANALYSIS

Pushover analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. A two or three dimensional model which includes bilinear or trilinear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable. The roof displacement is plotted with base shear to get the global capacity curve.

Pushover analysis can be performed as force-controlled or displacement-controlled. In force-controlled pushover procedure, full load combination is applied as specified, i.e, force-controlled procedure should be used when the load is known (such as gravity loading). Also, in force-controlled pushover procedure some numerical problems that affect the accuracy of results occur since target displacement may be associated with a very small positive or even a negative lateral stiffness because of the development of mechanisms and P-delta effects.

Pushover analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure.

D. ANALYSIS PURPOSE OF DOING PUSHOVER

The pushover is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis. The following are the examples of such response characteristics:

- The realistic force demands on potentially brittle elements, such as axial force demands on columns, force demands on brace connections, moment demands on beam to column connections, shear force demands in reinforced concrete beams, etc.
- Estimates of the deformations demands for elements that have to form in elastically in order to dissipate the energy imparted to the structure.
- Consequences of the strength deterioration of individual elements on behavior of the structural system.
- Identification of the critical regions in which the deformation demands are expected to be high and that have to become the focus through detailing.
- Identification of the strength discontinuous in plan elevation that will lead to changes in the dynamic characteristics in elastic range.
- Estimates of the inter-story drifts that account for strength or stiffness discontinuities and that may be used to control the damages and to evaluate P-Delta effects.
- Verification of the completeness and adequacy of load path, considering all the elements of the structural systems, all the connections, and stiff non-structural elements of significant strength, and the foundation system.

E. BACKGROUND

Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes as the procedure is relatively simple and considers post- elastic behavior. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis. Although, pushover analysis has been shown to capture essential structural response characteristics under seismic action, the accuracy and the reliability of pushover analysis in predicting global and local seismic demands for all structures have been a subject of discussion and improved pushover procedures have been proposed to overcome the certain limitations of traditional pushover procedures. However, the improved procedures are mostly computationally demanding and conceptually complex that use of such procedures are impractical in engineering profession and codes. As traditional pushover analysis is widely used for design and seismic performance evaluation purposes, its limitations, weaknesses and the accuracy of its predictions in routine application should be identified by studying the factors affecting the pushover predictions. In other words, the applicability of pushover analysis in predicting seismic demands should be investigated for low, mid and high-rise structures by identifying certain issues such as modeling nonlinear member behavior, computational scheme of the procedure, variations in the predictions of various lateral load patterns utilized in traditional pushover analysis, efficiency of invariant lateral load patterns in representing higher mode effects and accurate estimation of target displacement at which seismic demand prediction of pushover procedure is performed. **(wang. et., 2007)**

F. DIFFERENT HINGE PROPERTIES IN PUSHOVER ANALYSIS ON SAP2000

There are three types of hinge properties in SAP2000. They are default hinge properties, user-defined hinge properties and generated hinge properties. Only default hinge properties and user-defined hinge properties can be assigned to frame elements. When these hinge properties are assigned to a frame element, the program automatically creates a different generated hinge property for each and every hinge.

Default hinge properties cannot be modified. They also cannot be viewed because the default properties are section dependent. The default properties cannot be fully defined by the program until the section that they apply to is identified. Thus to see the effect of the default properties, the default property should be assigned to a frame element, and then the resulting generated hinge property should be viewed. The built-in default hinge properties are typically based on FEMA-273 and or ATC-40 criteria.

User-defined hinge properties can be either be based on default properties or they can be fully user-defined. When user-defined properties are based on default properties, the hinge properties cannot be viewed because, again, the default properties are section dependent. When user-defined properties are not based on default properties, then the properties can be viewed and modified.

The generated hinge properties are used in the analysis. They can be viewed, but they cannot be modified. Generated hinge properties have an automatic naming convention of LabelH#, where Label is the fr`ame element label, H stands for hinge, and # represents the hinge number. The program starts with hinge number 1 and increments the hinge number by one for each consecutive hinge applied to the frame element. For example if a frame element label is F23, the generated hinge property name for the second hinge applied to the frame element is F23H2. The main reason for the differentiation between defined properties (in this context, defined means both default and user-defined) and generated properties is that typically the hinge properties are section dependent. Thus different frame section type in the model. This could potentially mean that a very large number of hinge properties would need to be defined by the user.

(SAP2000 tutorials)

G. SCOPE OF THE PRESENT STUDY

In the present study, modelling of the RCC frame under the loads has been analyzed using SAP2000 software and the results so obtained have been compared with available experimental results from the Push Over test conducted at CPRI (Central Power Research Institute) Banglore. The frame is analyzed using SAP2000 software up to the failure and the load deformation curves. In this study user defined hinges are used in beams and columns. The frame has been analyzed and results have been compared with the experimental results.

H. CLOSURE

The literature review has suggested that use of a pushover analysis of the RCC frame is feasible. So it has been decided to use SAP2000 for the modelling. With the help of this software study of RC frame has been done. It gives the load deflection curve of the building.

II. 3.PUSHOVER ANALYSIS

A. GENERAL

Pushover Analysis option will allow engineers to perform pushover analysis as per FEMA -356 and ATC-40. Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, 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 collapse condition. **(sermin, 2005)**

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. A series of iterations are usually required during which, the structural deficiencies observed in one iteration, are rectified and followed by another. This iterative analysis and design process continues until the design satisfies a pre-established performance criteria. The performance criteria for pushover analysis is generally established as the desired state of the building given a roof-top or spectral displacement amplitude.Static Nonlinear Analysis technique, also known as sequential yield analysis, or simply "pushover" analysis has gained significant popularity during the past few years. It is the one of the three analysis techniques recommended by FEMA-273/274 and a main component of the Spectrum Capacity Analysis method .

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B. .LEMENT DESCRIPTION OF SAP2000

In SAP2000, a frame element is modeled as a line element having linearly elastic properties and nonlinear force-displacement characteristics of individual frame elements are modeled as hinges represented by a series of straight line segments. A generalized force-displacement characteristic of a non-degrading frame element (or hinge properties) in SAP2000.

III. 4.MODELLING ON SAP2000

A. GENERAL DESCRIPTION OF STRUCTURE (reddy. et., 2010)

One of the major objectives of this work is to test a real-life structure under pushover loads. In order to keep the structure as close to reality as possible, no special design for the structure as such was performed and instead a portion of a real life existing office building was selected. Thus the structure tested in this work was a replica of a part of an existing office building. The portion was deliberately selected so that it had certain eccentricities and was un-symmetric in plan. Also the column sizes and sections were varied along the storey as in the case of original real life structure.

Although the geometry of the structure tested in this work was kept same as the portion of the original structure, there were few major differences in the reinforcement detailing as mentioned below:

1. Although the original structure was detailed according to new conforming seismic detailing practice as per IS 13920 (BIS, 1993), the structure for the experiment followed the non-seismic detailing practice as per IS 456 (BIS 2000). The reason for this is the fact that pushover analysis is mostly used for retrofit of old structures, which have not followed the seismic detailing practice. Consequently, special confining reinforcement as recommended by IS 13920(BIS, 1993) was not provided. Also no shear reinforcement in the beam- column joints was provided.

2. Since the structure tested is replica of a small portion of the large original structure, the continuous reinforcement in the slab and beams were suitably modified to fit as per the requirement.

3. Another major difference is in the foundation system. In order to avoid any nonlinear behavior of the foundation, a raft foundation with a number of rock anchors were provided.

B. MATERIAL PROPERTIES

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:

Modulus of Elasticity of steel, Es = 21,0000 MPa

Modulus of Elasticity of concrete, EC = 22,360.68 MPa

Characteristic strength of concrete, fck = 20 MPa

Yield stress for steel, fy = 415 MPa

Ultimate strain in bending, εcu =0.0035

C. MODEL GEOMETRY

The structure analyzed is a four-storied, one bay along X-direction and two bays along Y-direction moment-resisting frame of reinforced concrete with properties as specified above. The concrete floors are modeled as rigid. The details of the model are given as:

Number of stories = 4

Number of bays along X-direction =1

Number of bays along Y-direction = 1

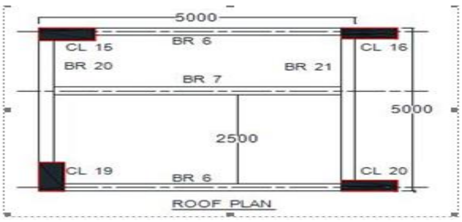
Storey height = 4.0 meters

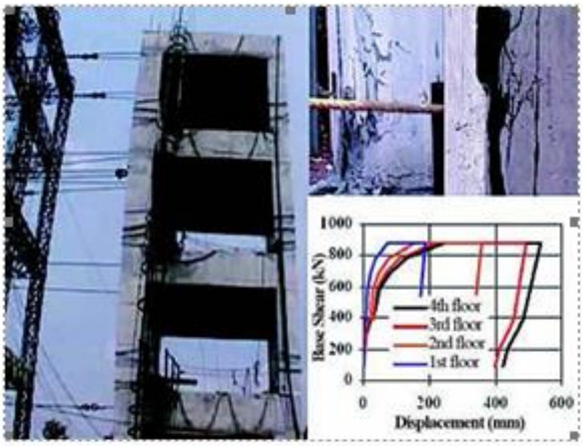
Bay width along X-direction = 5.0 meters

Bay width along Y-direction = 5.0 meters

D. . PLAN OF BUILDING

The plan of the building is shown in the Fig. 4.1 on next page. The bay width, column positions and beams positions can be seen below.





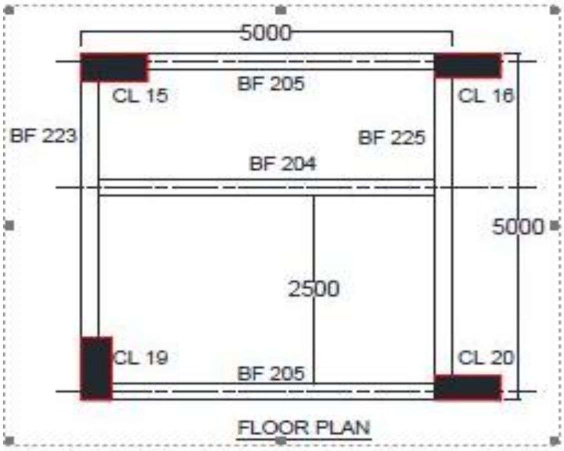


Fig. 4.1 Roof Plan and Floor Plan of Structure (Reddy. et., al, 2010)

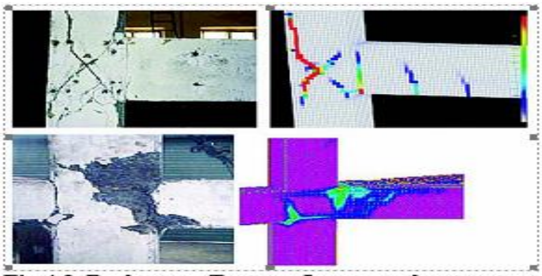


Fig.4.2 Push over Test on Large scale structure (Reddy. et., al, 2010)

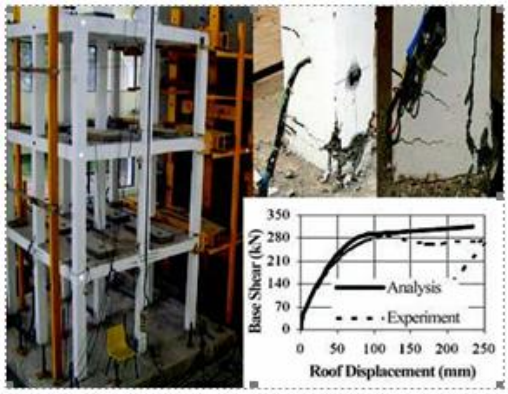


Fig.4.3 Experiment and analysis of Beam – Column joint(Reddy. et., al, 2010)

IV. .FUTURE WORK

5.1 Reinforcement Detailing
The reinforcement detailing of the above plan including sectional elevation will be provided.

5.2 Analysis of the structure
The above defined structure with all the necessary reinforcement details and material properties will be analyzed in SAP software.

5.3 Results and Discussion
The main observations and conclusions drawn are summarized.

V. CONCLUSIONS

1- **The main observations and conclusions drawn are summarized below:**

2- **The frame behaved linearly elastic up to a base shear value of around 235 KN. At the value of base-shear 670KN, it depicted non-linearity in its behaviour. Increase in deflection has been observed to be more with load increments at base-shear of 670 KN showing the elasto-plastic behaviour.**

3- **The joints of the structure have displayed rapid degradation and the inter storey deflections have increased rapidly in non- linear zone. Severe damages have occurred at joints at lower floors whereas moderate damages have been observed in the first and second floors. Minor damage has been observed at roof level.**

4- **The frame has shown variety of failures like beam-column joint failure, flexural failures and shear failures. Prominent failures are joint failures. Flexural failures have been seen in beams due to X-directional loading.**

5- **It has been observed that the top storey experienced major damages in this case opposite to the case of frame.**

6- **Micro cracks have been observed to appear even when the frame is in its elastic zone. The cracks have been found increasing with the increase in deflections).**

REFERENCES

[1] Shuraim, A. Charif. Performance of pushover procedure in evaluating the seismic adequacy of reinforced concrete frames. King Saud University ashuraim@gmail.com. (2007)

[2] Arora JS. Optimization of structures subjected to dynamic loads. In: Leondes CT, editor. Structural dynamic systems computational techniques and optimization. Gordon and Breach Science Publishers;pg. 1–73, 1999.

[3] Ashraf Habibullah and Stephen Pyle, Practical three dimensional nonlinear static pushover analysis. (Published in Structure Magazine, Winter, 1998)

[4] ATC. Seismic evaluation and retrofit of concrete buildings—volume 1 (ATC-40). Report No. SSC 96-01. Redwood City (CA): Applied Technology Council; 1996.

[5] Chan CM, Zou XK. Optimal inelastic drift design of reinforce concrete structures under pushover loading. In: The second China–Japan–Korea joint symposium on optimization of structural and mechanical systems, (2002).

[6] Dhileep. M, Trivedi. A, Bose. P.R. Behavior of high frequency modal responses in non linear seismic analysis. International Journal of Civil and Structural Engineering. Volume 1, No. 4, 2011.

[7] Fib Bulletin of TG7.2 (in press). Displacement-based design and assessment, (2003).

[8] Whittaker A, Constantnou M, Tsopelas P. Displacement estimates for performance-based seismic design. J Structure Div, ASCE; 124 (8):905–912, (2007).