Journal of Engineering, Science and Mathematics

Volume 01, No 02, Pages 25-34, Year 2021
https://jesm.in/archives/

Review Paper

Pushover Analysis- An overview

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Received 23-03-2021; Accepted 28-03-2021; Published 31-03-2021

Handling Editor: Vishal Jagota

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Pushover analysis was started used widely in the year 1970 but it's capability and excellent performance was identified in last 20 years. This technique is majorly used to predict the potency and glide capability of already existing arrangement and shaking requisite for the same existing structure which are subjected to extremely strong earthquakes. This technique can also be employed for verifying capability newly presented structural design. Because of pushover analysis being effective it brought changes to various guidelines like ATC-40 and FEMA-356 and also some changes to design codes like Euro Code 8 and PCM 3724 in past some years.

1. Introduction

Pushover analysis is distinct as an examination in which a mathematical representation openly including the nonlinear weight bending distinctiveness of entity mechanism and fundamentals of the structure shall be subjected to monotonically rising imaginative loads representing inactivity services in a shaking until an objective dislocation is going beyond. Maximum disarticulation of the structure is the target displacement which is at the roof and is predictable under various selected ground motion of earthquake. Pushover analysis technique usually examines the presentation by predicting the power and bending tendency and shaking requisite by using the nonlinear stagnant examination algorithm. Various seismic demand parameters are

- Storey waft
- Universal displacement
- Forces of storey
- Forces of components
- Bending components.

The examination accounts for inelasticity of a material, nonlinearity of geometry and reallocation of forces. Various response individuality that can be find from the pushover analysis are as follows:

a) Prediction of energy and dislocation tendencies of the arrangement. Progression of the acquiescent of the constituent and improvement of the overall curve of capacity

b) Predicts the various forces like axial force, shear force and moment force requisite on potentially weak elements and bending requisite on malleable elements.

c) Prediction of comprehensive dislocation requisite, matching inter storey glide and damages on structural and nonstructural fundamentals anticipated under 20 seismic activity ground movement in context.

d) Effect on whole constancy of the structure and arrangement of failure of elements.

e) Detection of the most important region that is the critical region and that too at that time when the inelastic buckling is very much high and identification of power irregularities of the structure. Pushover analysis transports all these remuneration for an supplementary computational attempt (modeling nonlinearity and modification in examination algorithm) over the linear motionless examination.

2. PROCEDURE OF PUSHOVER ANALYSIS

There are two different ways of performing the pushover analysis either by controlling the force or either by controlling the dislocation which depends on the corporeal scenery of the weight and performance to be predicted by the structure. Method of force controlling is more useful when the loads are known and structure has the capability to support the loads. Dislocation controlled technique is useful when particular drifts are required and when the enormity of the load applied is not at all known in advance or we can say it can be used at that time when the structure is predicted to lose the strength. A displacement or dislocation proscribed pushover analysis is primarily collected of following steps.

- Creation of 2 or 3-dimensional model which represent complete performance of the structure.
- Defining the diagrams of all bilinear or trilinear deflection of all compulsory components that upshot the tangential response.

- Applying gravity loads like dead loads and some portion of live loads on the structural model.
- A pre-defined lateral weight arrangement to be equally shared along the height of the building is then applied on the structural model.
- Increasing the lateral loads as some of the members capitulate beneath the merging effects of both gravity type laods and lateral loads.
- Recording of the first acquiescent is done at the bottom shear and roof dislocation.
- Modification of the structural model is done in order to minimize inflexibility of capitulate members. Keeping a record that separate or different assessment is done with first conditions as zero and is worked on a structural model which is modified. The results obtained of every increasing weight assessment are superimposed.
- Correspondingly the lateral load augmentation and the roof dislocation augmentation are summed up with values obtained earlier in order to attain build up values bottom shear and roof dislocation.
- Above 3 steps before this step are repeated in order to attain a roof displacement of reaching certain stage or structure becoming unstable.
- The roof dislocation is plotted with the bottom shear to obtain the inclusive competence or pushover curve of the constitution.

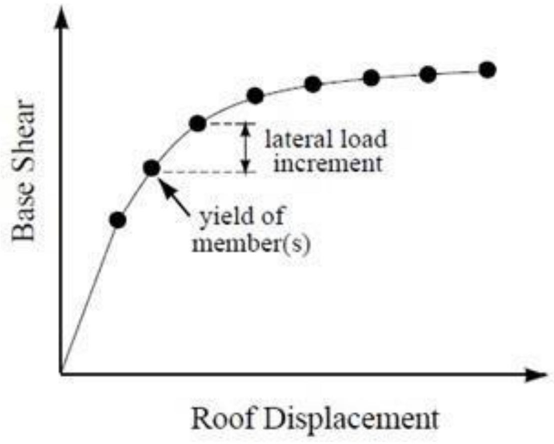

Figure 1: Curve of structure pushover capacity

2.1 Staad Pro V8i Procedure for pushover analysis

In this study the pushover analysis was done using the Staad Pro v8i to obtain necessary results and to check the seismic performance of the structure. The steps of pushover analysis using Staad Pro v8i are as follows:

- Start the Staad Pro and select structure wizard. In the model type select the frame model and put the geometrical properties according to your requirement. Select bay frame and apply it.

- In the modeling section select geometry and check the nodes dimensions and beam dimensions.
- Select the general in the same modeling section and after that select section database and select the code option according to your requirement. Also select the material type which is mostly steel. After doing so slect assign to view and assign it to the structure.
- In the modeling section select the supports to fixed type in certain direction on the structure. Assign the selected supports to selected nodes.
- In the modeling section select the loads and supports. In the definition of loads select pushover definition and then add the input, loading pattern, spectrum details, hinge properties and solution control. In the load case details select the gravity loads in order to perform the pushover analysis and add the self-weight and other details according to your requirement. Later add these all to selected beams in particular direction and selected nodes in particular direction.
- In the modeling section select the analysis and print and add the perform pushover analysis. After doing so run the analysis in analyses section in the above edit bar and get the results of complete pushover analysis being performed.
- View the output file and look for various errors if any and remove them to get the perfect results.
- Now in the postprocessing section check for deflection if any on any beam or column or even the node. Check the loads on each pushover steps. In the same step check the capacity curve of pushover analysis.
- Therefore, the pushover analysis is completed and get your results plotted graphically and in tabular format.

2.2 Lateral load profile

The results obtained after analysis are responsive to the assortment of the nodes that are controlled and also the pattern of lateral loads which are selected. More importantly the middle of weight location at top of the structure are considered as nodes that are controlled. For selection of loads guidelines are set in FEMA 356. For examination actual behavior of combined dead and live loads the lateral loads are usually applied in both positive and negative directions. Various types of lateral loads used in past 10 years are as follows

- **Uniform type lateral load pattern**

The lateral forefront at any storey is relative to the collection at that storey. Formulae for it is as follows

$$F_i = m_i / \sum m_i$$

Where Fi is equal to lateral force at i-th storey and

Mi is equal to mass of i-th storey

- **First Mode of Elastic Lateral Load Pattern**

  The lateral force at any storey is relative to the artifact of the amplitude of the expandable first form and collection at that storey. Formulae for it is as follows

$$F_i = m_i \Psi_i / \sum \Psi_i$$

Where Ψ_i is equal to amplitude of first mode at ith storey.

Uses of pushover analysis

Pushover analysis has been the favored technique for seismic presentation assessment of configuration by the main psychoanalysis strategies and system since it is accurate on the basis calculation and perception. Pushover examination permits tracing the succession of acquiescent and collapse on component and structural height as well as the improvement of general competence bend of the construction. The anticipation from pushover examination is to approximate decisive comeback constraint forced on structural classification and its mechanism as secure as potential to those calculated by nonlinear vibrant examination. The information regarding the response features are provided using the pushover analysis which are not provided by elastically static examination or elastically dynamic examination. Some of the most important uses of the pushover analysis are as follows:

- Prediction of inter storey drifts and it's sharing all along its height.
- Knowing the demand of forces on brittle members and these demands are demands by force on columns, connection between beam and columns which are termed as moment demands.
- For knowing the ductile members which are termed as bending demands.
- For locating the weak points for detecting the impending failure modes of the structure.
- Effort of an achievement power weakening of character component on the performance of structural classification.
- In diagram or altitude detection of power discontinuities that will

guide to alter in self-motivated individuality in the inelastic assortment.

- Confirmation of the wholeness and sufficiency of weight passageway. Pushover analysis also depicts plan flaw that may remain concealed in an stretchy examination. They are storey mechanisms, extreme buckle anxiety, indiscretion power and surplus on potentially fragile component.

2.3 Limitations of pushover analysis

A s we know that pushover analysis has many advantages over the elastic examination methods, it is very important to know whether the results obtained from pushover analysis are accurate or not. Lateral load pattern selection and detection of failure method for predicting the dislocation aim due to upper nodes of quivering are mandatory issues which effect the perfectness of the results obtained by pushover analysis. In a propose shaking objective dislocation are comprehensive dislocation which are anticipated. The heap midpoint of top dislocation structure is used as intentional dislocation. The assessment of objective dislocation preciseness connected with definite presentation purpose influence the correctness of seismic stipulate calculation of softy psychoanalysis. Target dislocation is the worldwide dislocation predictable in a propose trembling. The approximation of objective dislocation, recognition of breakdown apparatus due to advanced form of shaking are significant subject that have an effect on assortment of lateral weight prototype and the correctness of pushover results.

2.4 Behavior factor (R)

The behavior factor is represented by “R” and is the defined as ratio of potency mandatory to preserve the structure resilient to the inelastic propose potency of structure. It can also be termed as power reducing factor which is used to diminish the linear flexibility rejoinder band to the nonflexibility rejoinder band. I t is detected by using pushover analysis that behavior factor (R) can be accounted for natural ductility, over strength of the structure and divergence in the level of the pressure observed in its design. It is generally presented in the following form taking into account the below three constituents:

$$\mathbf{R = R_u * R_S * Y}$$

Where Ru is termed as ductility reduction factor, Rs is over strength factor and Y is called as allowed stress factor.

2.5 Base isolation

The base isolation procedure is a seismic intend move towards in which because of the inclusion of a stretchy coating sandwiched between the groundwork and the superstructure the basic occurrence of the arrangement reduces to a importance inferior than the major force including frequencies of tremor earth movement. Additionally the capacity of damping which is provided usually by damping system helps in dispersing the power conveying while the occurance of seismic activities. Seismic base machinery which is now known as the most important and resourceful machinery can be used for improvement of seismic presentation of most valuable building-like schools, hospitals, industries and high rise buildings. For reducing the drifts between inter storey and for minimizing the acceleration of floors the technique of base isolation is mostly employed.

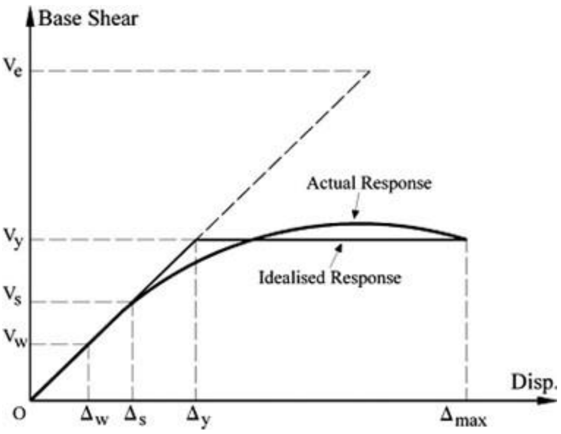

Fig 2: Pushover rejoinder curves for assessment of behavior factor

2.6 Types of base isolation devices

In this study three different base isolation devices were incorporated along with the steel frames.

- **High Damed Rubber Bearing**

High damped rubber bearing is the type of elastomeric attitude. This type of bearing usually comprises of slim sheet of highly damped rubber and plates of steel constructed in separate layers. Parallel stiffness of bearing is usually controlled by small trimmed modulus of elastomers but plates made of steel presents very high vertical stiffness and also it prevents stuffing of rubber. Damping in the range between 10-20 % is provided by high damped rubber bearing.

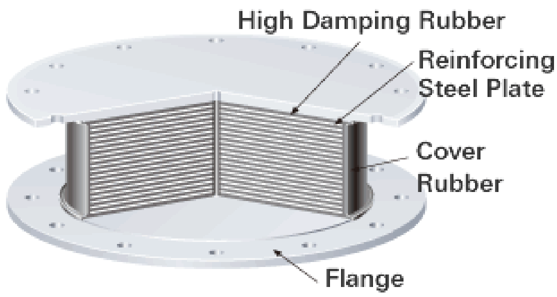

Fig 3: Overview of High Damping Rubber Bearing

- **Low Damping rubber bearing**

Low damping rubber bearing is that rubber bearing which comprises of endplates made of steel of two different categories and numerous slim shims made of steel and interbedded with the rubber. Capability of perpendicular stiffness can be affected by shims made of steel but these steel shims make no impact on the straight stiffness which is always conquered by shear modulus of the elastomer. The damping provided by this type of bearing is in the range of 3-4%. We can also produce isolators with damping equal to zero using the low damping rubber bearing which also implies that isolators made using this technique have linear shear behavior.

Fig 4: Low damping rubber bearing

- **Lead rubber bearing**

A lead rubber bearing made up of lead which is forcibly closed in an early formed gap in an elastomeric comportment. The core made up of lead provides inflexibility below various service loads and discharge of energy is done below various highly moderated lateral loads. When lead rubber bearing is subjected to weak lateral loads e.g., earthquakes of low intensity the bearing of this type becomes flexible both crossways and perpendicularly. The lateral flexibility results with the help of high expandable flexibility of plug made up of lead and crossways rigidity. The most important property of lead rubber bearing is that it combines the load levels of different criteria into single compressed component. These two load levels include earthquake load level and serviceable load level.

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