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# PUSHOVER ANALYSIS OF R.C.C BUILDING

# A REVIEW

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**ABSTRACT**

*In this paper, in last 4 decayed experienced the seismic event has major destruction of R.C building as well as human life. Therefore the question raised about safety of R.C. building in future earthquake "how to make earthquake resistant structure?" there are no of ways to evaluate the building performance up to elastic limit but it is complicated to evaluate beyond elastic limit. So to assessment the performance of structure in future unpredictable earthquake event a static nonlinear pushover analysis performed. This method gives performance level of building.*

***KEY WORDS– seismic event, pushover analysis, performance level***

## I. INTRODUCTION

The term earthquakecan be used to describe any kind of seismic event which may be eithernatural or initiated by humans, which generates seismic waves. Earthquakes are causedcommonly by rupture of geological faults; but they can also be triggered by other events likevolcanic activity, mine blasts, landslides and nuclear tests.There are many buildings that have primary structural system, which do not meet the currentseismic requirements and suffer extensive damage during the earthquake. According to the Seismic zoning Map of IS: 1893-2002, India is divided into four zones on thebasis of seismic activities. They are zone II, zone III, zone IV and zone V.

Some industries usually make full-scale models and execute wide testing, before manufacturing thousands of identical structures that have been analyzed and designed with consideration of test results. Unluckily, this choice isn't available to building industry so that economy of huge scale creation is unfeasible. In India many existing structure design as per Indian standard code 456:2000 but to make building earthquake resistant IS 1893-2002 should be used to avoid future building vulnerable in earthquake.

Generally, loads on these structures are only gravity loads and result in elastic structural behavior. However, under a Strong seismic event, a structure may actually be subjected to forces beyond its elastic limit. Since. The recent earthquake in last 4 decayed in which many concrete structure have been harshly damaged or collapsed, it have indicated the need for evaluating the seismic suitability of present building or purposed building. Therefore structure vulnerable to damage must be determined. To make or attain this objective, simplified linear elastic methods are not suitable. Thus the structural designer has developed a new method of design and seismic procedure that include performance based structure towards nonlinear technique.

Analysis methods are classified as *linear static, linear dynamic, nonlinear static and nonlinear dynamic analysis [4]*. In these the first two is appropriate only if the structural loads are low and stress, strains within elastic limit. During earthquake the structural loading can reach to collapse load and therefore the material stresses are on top of yield stresses. Therefore during this case material nonlinearity and geometrical nonlinearity must to be incorporated into the analysis to acquire good results.

Pushover analysis provides simple approach to analyse nonlinear static behaviour of the building. So in this paper discus about pushover analysis with the help of performance levels, pushover curve,and pushover analysis procedure.

## II.PUSHOVER ANALYSIS

Elastic static analysis, or pushover analysis, has been the ideal method for seismicperformance assessment due to its easiness. It is a static analysis that directly includesnonlinear material characteristics. Inelastic static analysis procedures include Capacity SpectrumMethod, Displacement Coefficient Method and the Secant Method [9]. Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral loads is gradually increased, maintaining a predefined distribution arrangement along the height of the building. Pushover analysis can determine the behaviour of a building, including the ultimate load and the maximum inelastic deflection. Limited nonlinear effects are demonstrated and the structure is pushed until a collapse mechanism is developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve.[1] Hence it is imperative to use nonlinear static analysis approach by using specialized programs like SAP2000, ETABS, and IDARC etc. for seismic evaluation of buildings.

In pushover analysis with the monotonic increase in the magnitude of the loading, weak links and the failure modes of the structure are found. As the load and displacement increases, the element (beams, columns, etc.) begin to yield and deform inelastically [2]. The resulting graphic curve is an easy to visualize representation of the capacity of the building unlike in the case of conventional methods. Using this method, structures with predictable seismic performance can be produced.

## III. PERFORMANCE LEVELS.

### 1. Capacity curve

The overall capacity of a structure depends on the strength and deformation capacities of the singular elements of the structure. In order to determine capacities further than the elastic limits, some form of nonlinear analysis is required. This technique uses advanced elastic analysis, overlaid to approximate force-displacement diagram of the overall structure. The mathematical model of the structure is improved to account for reduced resistance of yielding components. A horizontal force distribution is again applied until additional components yield. A usual capacity curve is shown in fig.2

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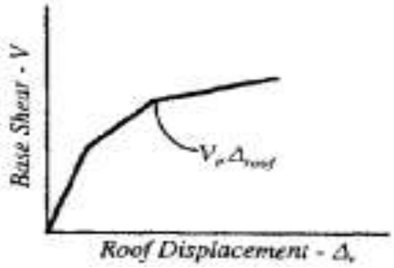



**Fig.1 Capacity curve [3]**

**2. Demand curve**

Ground motion during an earthquake produces difficult horizontal displacement patterns which may vary with time. Tracing this motion at every time step to determine structural design requirements is judge unpractical. For a given structure and a ground motion, the displacement demands are evaluation of the maximum probable response of the building during the ground motion. Demand curve is aillustration of the earthquake ground motion. It is given by spectral acceleration Vs. Time period (T) as shown in fig.3.

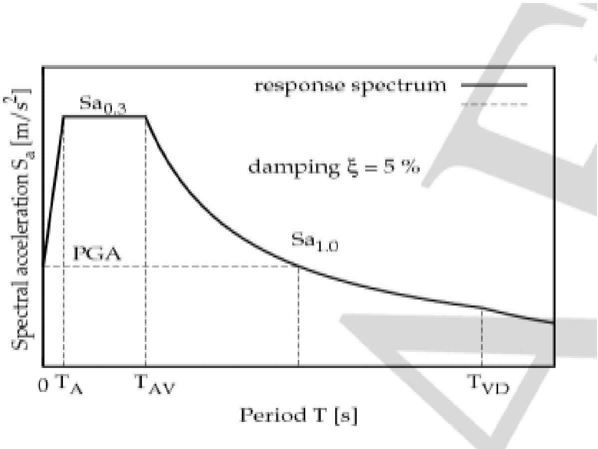
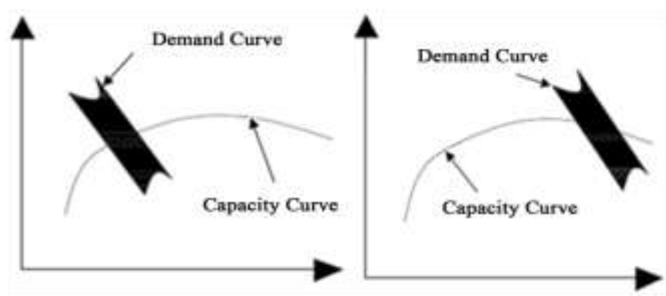



**Fig.2 Demand curve (Traditional spectrum) [3]**

**3.Performance point**

Performance point can be achieved by superimposing capacity spectrum and demand spectrum and the intersection point of these two curve is performance point. Fig.6. shows superimposing demand spectrum and capacity spectrum.




(a) (b)

**Fig 3. Typical seismic demand Vs. Capacity (a) Safe Design (b) Unsafe Design [6]**

Seismic performance of a structure is described by defining the maximum permissible damage state for an identified seismic vulnerability. ATC-40 describes standard performance levels for structural and non-structural systems and some commonly used arrangements of structural and non-structural levels as (a) Operational, (b) Immediate occupancy, (c) Damage control, (d) Life safety, (e) Structural stability and (f) Not considered

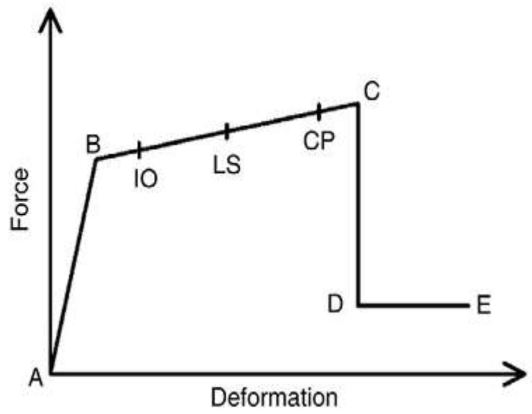



**Fig no 4. Force V/s Deformation curve [6]**

Point A parallels to unloaded condition and point B represents yielding of the element. The ordinate at C parallels to minimal strength and abscissa at C parallels to the deformation at which significant strength deterioration begins. The drop from C to D represents the first failure of the element and resistance to lateral loads further than point C is usually unpredictable. The residual resistance from D to E allows the frame elements to withstand gravity loads. Beyond point E, the maximum deformation capacity, gravity load can no longer be sustained.

## IV. HINGE MECHANISM

Hinges are points on a structure where one assumes cracking and yielding to occur in moderately higher intensity so that they show higher flexural/shear displacement, under a repeated loading.The concept of plastic hinges is very important in nonlinear analysis while a concrete element undergoes large deformations in the post yield stage it is assume that all the deformation take place at the point is called as a plastic hinge which is approximately a length of the order of effective depth. In sap2000 the default types include an uncoupled moment hinges, uncoupled axial hinges an uncoupled shear hinges and a coupled axial force and biaxial bending moment hinges.

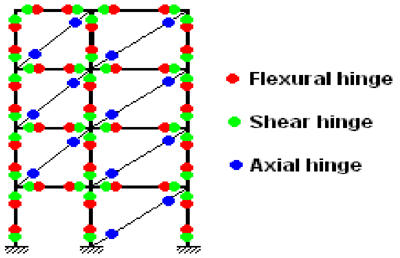



**Fig no 5 Hinges [4]**

## V. PUSHOVER ANALYSIS PROCEDURE

SAP2000 provides a good interface for nonlinear statics analysis of structures. Following are the steps followed for nonlinear static analysis of the buildings.

### Insight into structural modeling

The buildings are modelled by using SAP2000 finite element software. Line element having 6 DOF per node is used to model beams and columns. The slabs are not modelled and they are considered as rigid diaphragm. Self-weight due to slab is imposed directly on adjacent beams as dead load as per IS: 456-2000 yield line pattern. Infill walls are also not modelled but their dead weight is considered as uniformly distributed load on beams. Also, effect of soil structure interaction is ignored in analysis and bottom of each column is assumed to be fixed. Effective stiffness values for column and beams are taken from table no 6.5 from FEMA356 as shown below in table no 1.

**Table 1 Effective stiffness**

| Component | Flexure rigidity | Shear rigidity | Axial rigidity |
|---|---|---|---|
| Beams- nonpre-stressed | 0.5EcIg | 0.4EcAw | - |
| Columns with compression due to design gravity loads ≤0.3Agf'c | 0.5EcIg | 0.4EcAw | EsAs |
| Columns with compression due to design gravity loads ≥0.5Agf'c | 0.7 EcIg | 0.4EcAw | EcAg |

### Pushover analysis by using SAP2000

After designing and detailing of gravity buildings, a nonlinear statics pushover analysis is carried out using SAP2000. For this purpose a constant gravity load, equals to total dead load plus 25% of live load is applied on structure [46]. An inverted parabolic distribution over the height is used as the lateral load pattern at the end of gravity push as shown in fig.4.3. The geometrical nonlinearity of the structure due to P-Δ effects is considered.

### Nonlinear hinge assignment

In order to model nonlinear behaviour in any structural element, a corresponding nonlinear hinge required to be assigned in the building model. The beams and columns are modeled with concentrated plastic hinges at the column and beam faces, respectively. Beams have only moment (M3) hinges, whereas columns have axial load and biaxial moment (PMM) hinges. The moment-rotation relations and the acceptance criteria for the performance levels of the hinges are obtained from FEMA356 and are directly taken from the SAP2000 as auto hinges.

**Steps for pushover analysis**

The following steps are included in the pushover analysis. Steps 1 to 4 are to create the computer model, step 5 runs the analysis, and steps 6 to 9 review the pushover analysis results.

1. Create the basic computer model (without pushover data). The graphical interface of SAP2000 makes this quick and easy task. Assigned sectional properties and apply all the gravity loads i.e. dead load and live load on the structure.
2. Define hinges. The program includes several built in default hinge properties that are based on average values from ATC40 and FEMA356 for concrete members and for steel members. In this analysis, PMM hinges are defined at both the column ends and M3 hinges are defined at both the ends of all the beams
3. Locate the pushover hinges on the model by selecting all the frame members and assigning them one or more hinge properties and hinge locations.
4. Define the pushover load cases In SAP2000 more than one pushover load case can be run in the same analysis. Also a pushover load case can start from the final conditions of another pushover load case that was previously run in the same analysis. Typically the first pushover load case was used to apply gravity load and then subsequent lateral pushover load cases were 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. Typically a gravity load pushover is force controlled and lateral pushovers are displacement controlled. In this case a gravity load combination of DL+0.25LL has been used. This combination has been defined as PUSH GRAV X and PUSH GRAV Y. The lateral loads, have been applied to a case called PUSH-X and PUSH-Y
5. Run the basic static analysis. Then run the static nonlinear pushover analysis.
6. The pushover curve was made for control nodes at each storey level. This was done by defining a number of pushover cases in the same analysis, and displacement was monitored for a different node in each case.
7. The pushover curve obtained is. Result table gives coordinates of each step of the pushover curve and summarizes the number of hinges in each step (for example, between IO and LS, or between D and E)
8. The capacity spectrum curve obtained. The magnitude of the earthquake and the damping information on this form can be modified and the new capacity spectrum plot can be obtained immediately. The performance point for a given set of values is defined by the intersection of the capacity curve and the

single demand spectrum curve.

9. Output for the pushover analysis can be printed in a tabular form for the entire model or for selected elements of the model. The types of output available in this form include joint displacements at each step of the pushover, frame member forces at each step of the pushover, and hinge force, displacement and state at each step of the pushover.

## VI. CONCLUSION

1. The pushover analysis is a comparatively simple way to study the non-linear behavior of Buildings

2. The behavior of properly complete reinforced concrete frame building is acceptable 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 limited in the columns but with limited damage

3. The causes of failure of reinforced concrete during the earthquake may be credited to the quality of the materials

4. The results achieved in terms of demand, capacity and plastic hinges provided an insight into the actual behavior of structures.

5. Pushover analysis can recognize weak elements by calculating the failure mechanism and account for the rearrangement of forces during advanced yielding. It may help engineers take action for restoration work.

6. Thus performance of pushover analysis mainly depends upon choice of material models involved in the study.

7.Pushover analysis is an approximation method based on static loading. It may not exactlydenote dynamic phenomena.

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