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NON-LINEAR STATIC ANALYSIS (PUSHOVER ANALYSIS) A REVIEW

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Abstract*: *In recent years,an extensive examination going on performance of structure during a seismic event.During seismic action,building will deform in in-elastic zone, soits required evaluationwhich consider post-elastic behavior of structure.Performance based seismic design is a modern technique to earthquake resistance whichcan predict performance of structure using rigorous non-linear static analysis.

Easy and most used method to evaluate performance of structure is non-linear static analysis widely known as pushover analysis.As name implies,it's a process of pushing structure horizontally,with a prescribed loading pattern incrementally, i.e "pushing" structure & plotting total applied shear force & associated lateral displacement at each increment,until structure reaches a limit state or collapse condition.It provides better understanding of seismic performance of building & also give identificationof progression of damage and subsequently failure of building's structural element .By pushover analysis, One can get behavior of building in non-linear zone,which is not covered in conventional elastic design.

Keywords: **Non-linear Static Analysis, Formation of plastic hinge,Performance based design,**

I. INTRODUCTION

Recent earthquakes in which many concrete structures have been severely damaged or collapsed,hasindicated need for seismic adequacy of existing building.One can't avoid future earthquakes,but safe building construction practices can surely reduce extent of damage and loss.In order to strengthen & resist buildings for future earthquakes,some procedure have to be adopted.

Static pushover analysis which is becoming a popular tool for seismic performance of existing & new structures.A two or three dimensional model which includes bilinear or tri-linear 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 building height is then applied,these lateral forces are increased until some members yield. Structural model is modified to account for 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). 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.

The area of interest where non-linear analysis is applied are as follows:

1.To analyze and design seismic retrofit solutions for existing buildings.

2.To assess the performance of buildings for specific owner requirement.

3.To analysis and design for new buildings.

II. PERFORMANCE BASED DESIGN

Performance based Performance-based design is a major shift from traditional structural design concepts and represents the future of earthquake engineering. The procedure provides a method for determining acceptable levels of earthquake damage. Also, it is based on the recognition that yielding does not constitute failure and that preplanned yielding of certain members of a structure during an earthquake can actually help to save the rest of the structure.

II. STATIC NON-LINEAR ANALYSIS

In performance based design response of structure is considered beyond elastic limit as opposed to code based approach. Static non-linear analysis is one of the analysis technique used for performance based design. Two types of pushover analysis are as:

- **Force controlled**

Used when load is known and structure is desired to support this load. For gravity load on structure force controlled, push over analysis is used.

- **Displacement controlled**

Used when load is unknown but displacement is known and structure is desired to lose their strength and become unstable. For lateral load on structure displacement controlled, pushover analysis is used.

Three main steps involved in this analysis procedure.

1. Evaluation of Capacity of building i.e. Representation of the structure's ability to resist a force.
2. Evaluation of Demand curve i.e. Representation of earthquake ground motion.
3. Determination of Performance point i.e. Intersection point of demand curve and capacity curve.

Capacity

Fig. is represents the increasing lateral displacement as a function of the force applied monotonically from zero to the ultimate level corresponding to the incipient collapse of the structure and response behavior is gauged by measurement of strength of structure. The simplified non-linear procedure is followed for the generation of the capacity curve.

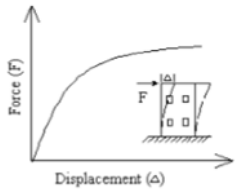

Fig.capacity curve

Demand

Spectral Acceleration (Sa) versus Time Period (T) curve is given in IS:1893(Part1)-2002 which is converted in to Spectral Acceleration (Sa) versus Spectral Displacement (S_d) curve. Capacity curve and Demand curve are generated in spectral coordinates to find out performance point.

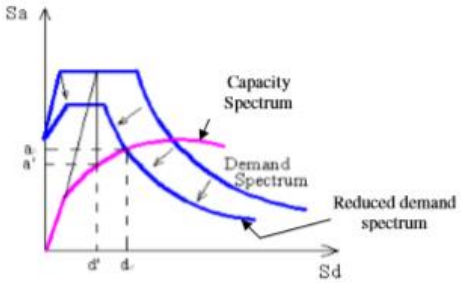

Fig. Demand Spectrum Curve

Performance

The intersection of the pushover capacity and demand spectrum curves defines as the "performance point" as shown in fig.

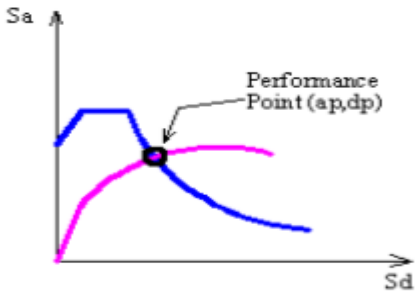

Fig. Performance Point

III. LITERATURE REVIEW

Various literature reviewed on pushover analysis is presented in this section.

The publication of **Applied Technology Council (ATC 40)** provides guidelines for performance based design of building. It includes objectives, retrofit strategies, linear as well as nonlinear analysis procedure, modelling rules, foundation effect on performance design and descriptive limits of expected performance. It also includes example of inelastic analysis of building.

The publication of **FEMA 273** provides technical guidelines for the seismic rehabilitation of building. This document covers modelling and procedure of linear static analysis, linear dynamic analysis, nonlinear static analysis and nonlinear dynamic analysis. This document includes the performance based design for retrofit of an existing structure. This method can also be applicable for the new design. It also gives information regarding to foundations and geotechnical aspects.

Mohommed Anwaruddin Md. Akberuddin and Mohd. Zameeruddin Mohd.Saleemuddin(2013) carried out the study on G+3 bare frame model & G+3 bare frame with vertical irregularity models.

They concluded that, the bare frame without vertical irregularity having more lateral load capacity compare to base frameswith vertical irregularity i.e. the vertical irregularity reduces the flexure & shear demand.The also concluded that, the lateral displacement of the building is reduced as the percentage of irregularity increase.

A.kadid and A.Boumrkik concluded that the pushover analysis is a relatively simple way to explore the non-linear behavior of buildings. The behavior of properly detailed reinforced concrete frame building is adequate 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 few in the columns but with limited damage.

Srinivasu and Dr Panduranga Rao concluded that the frame has shown variety of failure like beam -column joint failure, flexural failure and shear failure. Flexural failure have been seen in beams .It has been observed that one sub sequent push to building ,hinges started forming in beams first, initially hinges were in A-B stage and sub sequently proceeding to B-IO stage.Out of 198 hinges 194 in A-B stage,4 in B-IO stage . Overall performance of building is said to be B-IO stages.

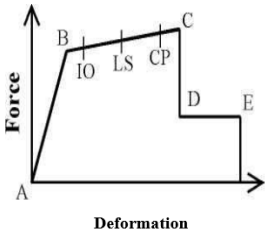

Fig: Performance Level

Nitin Choudhary and Prof. Mahendra Wadia performed pushover analysis of RC frame building with shear wall. They conducted their study on two multistoried RC frame building. One building is symmetrical in plan while other is „L" shaped unsymmetrical in plan. Their study shows the effect of shear wall on RC building frame when shear wall providing along the longer and shorter side of the building. Their study concluded that by providing shear wall in both the buildings, there is considerable decrease in base shear and roof displacements.

T.Madhi &V.Bahreini conclude that the bare frames are more vulnerable than infilled frames and omitting infills in the floor makes the columns of this floor more vulnerable. He also conclude that failure of infills occur in the early stages of an earthquake, their presence is beneficial since the energy resulted from the quake is dissipated by the damaged infill walls.

Dakshes. J.Pambhar have performed the analysis for G+4 and G+10 storey in bare frame without infill having lesser lateral load capacity compare to bare frame with infill as

membrane and bare frame with infill having lesser lateral load capacity compare to bar frame with equivalent strut.

He also conclude that as the number of bays increases lateral load carrying capacity increases but with the increase in bays corresponding displacement is not increases. He also explained that as the number of storey increases lateral load carrying capacity does not increase but corresponding displacement increases.

IV. CONCLUSION

A brief review of several literatures presented shows that non-linear static analysis (pushover analysis) proves to be efficient method for studying the performance based analysis and for behaviour of structure in in-elastic zones.This method also gives the data about the sequence of damage of different elements of building.As per the most literatures they concluded that,the plastic hinge is form more in beam rather than column.so Higher stage hinge formation in beam element compared to column element indicate strong column week beam behavior under pushover analysis considering default hinge properties.

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