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Performannce Base Analysis of Multy Storied Building

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Abstract: In India multistoried buildings are widely designed with the method suggested by Indian Standard IS1893: Part-1:2016, Criteria for the Earthquake resistance design of the structures: General Provision and Buildings for the calculation of equivalent horizontal load generated during earthquake. Response Spectrum method is widely used for the multistoried buildings with base shear scaled to get the equal value as calculated with the time period obtained by the empirical formula of time period of the buildings. The approach of the dynamic analysis is basically a linear approach. In this scenario we are totally relying on ductility of the structure. The concept for performing the Pushover Analysis is to analyze a structure with non linear approach and to find the behavior of structure beyond its ductile limit. Pushover analysis can help to demonstrate how progressive failure in building really occurs and to identify the mode of final failure of the buildings. Pushover analysis is commonly used to evaluate the seismic capacity of existing structures and appears in several recent guidelines for retrofit seismic design. It can also be useful for performance-based design of new buildings that rely on ductility or redundancies to resist earthquake forces. So basically Pushover analysis is non linear approach to estimate the strength capacity of the structure beyond Limit State. In this analysis we can predicts the weak areas in the building and keeping track of the sequence of damages of each and every member in the building/structure, thus can be performed for existing structure and also for performance base design, similarly for progressive collapse analysis.

The approach is easy to understand, when we designed or analyze a moment resisting frame as per IS 1893:2016 by Response Spectrum method with response spectrum method with the response reduction factor 5 i.e. R=5, we are basically designing the structure with 1/5th horizontal load (calculated with the empirical formula given in IS 1893:2016), the rest 4/5th load is basically taken care by the ductile behavior of the building. The ductile detailing suggested by the 13920:2016 will resist the full impact of seismic load without collapse. The distribution and impact of the full horizontal load can be analyzed with the non linear approach, and pushover analysis is one of them.

METHODLOGY: A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non linear force displacement relationship can be determined.

Key elements of the pushover analysis

1) ***Definition of plastic hinges, it includes hinges for uncoupled moment, hinges for uncoupled axial load, hinges for uncoupled shear force, hinges for coupled axial force and hinges for biaxial bending moment.***
2) ***Definition for control node, the node used to monitor the displacement of the structures. Pushover curve is obtained from the displacement verses base shear.***
3) ***Developing the pushover curve which includes the elevation of the forces distribution***
4) ***Estimation of the displacement demand.***
5) ***Evaluation of performance level for the structure.***

I. INTRODUCTION

One of the emerging fields in seismic design of structures is the Performance Based Design. The subject is still in the realm of research and academics, and is only slowly emerging out into the practitioner's arena. Seismic design is slowly transforming from a stage where a linear elastic analysis for a structure was sufficient for both its elastic and ductile design, to a stage where a specially dedicated non-linear procedure is to be done, which finally influences the seismic design as a whole.

The basis for the linear approach lies in the concept of the Response Reduction factor R. When a structure is designed for a Response Reduction factor of, say, R = 5, it means that only 1/5th of the seismic force is taken by the Limit State capacity of the structure. Further deflection is in its ductile behaviour and is taken by the ductile capacity of the structure. In Reinforced Concrete (RC) structures, the members (ie., beams and columns) are detailed such as to make sure that the structure can take the full impact without collapse beyond its Limit State capacity up to its ductile capacity. In fact we never analyse for the ductile part, but only follow the reinforcement detailing guidelines for the same.

The drawback is that the response beyond the limit state is neither a simple extrapolation, nor a perfectly ductile behaviour with pre-determinable deformation capacity. This is due to various reasons: the change in stiffness of members due to cracking and yielding, P-delta effects, change in the final seismic force estimated, etc. Although elastic analysis gives a good indication of elastic capacity of structures and shows where yielding might first occur, it cannot account for redistribution of forces during the progressive yielding that follows and predict its failure mechanisms, or detect possibility and location of any premature failure. A non-linear static analysis can predict these more accurately since it considers the inelastic behaviour of the structure. It can help identify critical members likely to reach critical states during an earthquake for which attention should be given during design and detailing.

The need for a simple method to predict the non-linear behaviour of a structure under seismic loads saw light in what is now popularly known as the Pushover Analysis (PA). It can help demonstrate how progressive failure in buildings really occurs, and identify the mode of final failure. Putting simply, PA is a non-linear analysis procedure to estimate the strength capacity of a structure beyond its elastic limit (meaning Limit State) up to its ultimate strength in the post-elastic range. In the process, the method also predicts potential weak areas in the structure, by keeping track of the sequence of damages of each and every member in the structure (by use of what are called 'hinges' they hold).

In order to understand PA, the best approach would be to first see the similarities between PA and the conventional seismic analysis (SA), both Seismic Coefficient and Response Spectrum methods described in IS:1893- 2002 for SA, which most of the readers are familiar with, and then see how they are different:

1) Both SA and PA apply lateral load of a predefined vertical distribution pattern on the structure. In SA, the lateral load is distributed either parabolically (in Seismic Coefficient method) or proportional to the modal combination (in the direct combination method of Response Spectrum). In PA, the distribution is proportional to height raised to the power of 'k', where k (equivalent to '2' in the equation under Cl. 7.7.1 in IS:1893-2002) can be equal to 0 (uniform distribution), 1 (the inverted triangle distribution), 2 (parabolic distribution as in the seismic coefficient method) or a calculated value between 1 and 2, the value of k being based on the time period T of the structure, as per the FEMA 356 (where k is given a value of 2 if $T \geq 2.5$ seconds, a value of 1 if $T \leq 0.5$ seconds and interpolated for intermediate values of T). The distribution can also be proportional to either the first mode shape, or a combination of modes.
2) In both SA and PA, the maximum lateral load estimated for the structure is calculated based on the fundamental time period of the structure. And the last point above is precisely where the difference starts. While in SA the initial time period is taken to be a constant (equal to its initial value), in PA this is continuously re-calculated as the analysis progresses. The differences between the procedures are as follows :
3) SA uses an elastic model, while PA uses a non-linear model. In the latter this is incorporated in the form of non-linear hinges inserted into an otherwise linear elastic model which one generates using a common structural analysis & design software package (like SAP2000 or STAAD.Pro), having facilities for Pushover Analysis.

II. SEISMIC ANALYSIS

It is necessary to carry out seismic analysis of the structure for the determination of seismic responses of the structure using different available methods.

The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. The analysis can be further classified as:

1) Linear Static Analysis
2) Nonlinear Static Analysis
3) Linear Dynamic Analysis
4) Nonlinear Dynamic Analysis

For regular structure with limited height, linear static analysis or equivalent static method can be used. Linear dynamic analysis can be performed by response spectrum method.

The significant difference between linear static and linear dynamic analysis is the,

a) level of the forces and
b) Distribution along the height of structure

Nonlinear static analysis is an enhancement over linear static or dynamic analysis in the manner that it allows inelastic behavior of structure.

A nonlinear dynamic analysis is the only method to define the actual behavior of a structure during an earthquake. This method is based on the direct numerical integration of the differential equations of motion, considering the elasto-plastic deformation of the structural element

A. Equivalent Static Analysis

This method does not require dynamic analysis, but it account for the dynamics of building in an approximate manner. The static method is the simple method which requires less computational efforts. It is based on formulate given in the code of practice. Initially, the design base shear is computed for the whole building, and then it is distributed along the height of the building. The lateral forces at each floor level obtained are then distributed to individual's lateral load resisting elements.Nonlinear Static Analysis

In this approach, analysis is carried out under permanent vertical loads and gradually increasing lateral loads which determines the deformation and damage pattern of the structure. It is the method of seismic analysis in which behavior of the structure is characterized by capacity curve which represents the relation between base shear force and the displacement of the roof. This method is also known as Pushover.

B. Linear Dynamic Analysis

Linear dynamic analysis method is the Response spectrum method. In this method the peak response of structure during an earthquake is determined directly from the earthquake response. This method is quite accurate for structural design applications.

C. NonLinear Dynamic Analysis

It is also known as Time history analysis. It is an important procedure for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative.

D. Non Linear Dynamic Analysis

Nonlinear dynamic analysis methods generally provide more realistic models of structural response to strong ground shaking and, thereby, provide more reliable assessment of earthquake performance than nonlinear static analysis. Nonlinear static analysis is limited in its ability to capture transient dynamic behavior with cyclic loading and degradation. Nevertheless, the nonlinear static procedure provides a convenient and fairly reliable method for structures whose dynamic response is governed by first-mode sway motions. One way to check this is by comparing the deformed geometry from a pushover analysis to the elastic first-mode vibration shape. In general, the nonlinear static procedure works well for low-rise buildings (less than about five stories) with symmetrical regular configurations. FEMA 440, FEMA 440A, and NIST (2010) provide further details on the simplifying assumptions and limitations on nonlinear static analysis. However, even when the nonlinear static procedure is not appropriate for a complete performance evaluation, nonlinear static analysis can be an effective design tool to investigate aspects of the analysis model and the nonlinear response that are difficult to do by nonlinear dynamic analysis. For example, nonlinear static analysis can be useful to (1) check and debug the nonlinear analysis model, (2) augment understanding of the yielding mechanisms and deformation demands, and (3) investigate alternative design parameters and how variations in the component properties may affect response.

E. The Role and use of Nonlinear Analysis in Seismic Design

While buildings are usually designed for seismic resistance using elastic analysis, most will experience significant inelastic deformations under large earthquakes. Modern performance based design methods require ways to determine the realistic behaviour of structures under such conditions. Enabled by advancements in computing technologies and available test data, nonlinear analyses provide the means for calculating structural response beyond the elastic range, including strength and stiffness deterioration associated with inelastic material behaviour and large displacements. As such, nonlinear analysis can play an important role in the design of new and existing buildings.
Nonlinear analyses involve significantly more effort to perform and should be approached with specific objectives in mind. Typical instances where nonlinear analysis is applied in structural earthquake engineering practice are to:

1) Assess and design seismic retrofit solutions for existing buildings;
2) Design new buildings that employ structural materials, systems, or other features that do not conform to current building code requirements;

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3) Assess the performance of buildings for specific owner/stakeholder requirements. If the intent of using a nonlinear analysis is to justify a design that would not satisfy the prescriptive building code requirements, it is essential to develop the basis for acceptance with the building code authority at the outset of a project. The design basis should be clearly defined and agreed upon, outlining in specific terms all significant performance levels and how they will be evaluated.

Once the goals of the nonlinear analysis and design basis are defined, the next step is to identify specific demand parameters and appropriate acceptance criteria to quantitatively evaluate the performance levels. The demand parameters typically include peak forces and deformations instructural and nonstructural components, story drifts, and floor accelerations. Other demand parameters, such as cumulative deformations or dissipated energy, may be checked to help confirm the accuracy of the analysis and/or to assess cumulative damage effects.

In contrast to linear elastic analysis and design methods that are well established, nonlinear inelastic analysis techniques and their application to design are still evolving and may require engineers to develop new skills. Nonlinear analyses require thinking about inelastic behavior and limit states that depend on deformations as well as forces. They also require definition of component models that capture the force-deformation response of components and systems based on expected strength and stiffness properties and large deformations. Depending on the structural configuration, the results of nonlinear analyses can be sensitive to assumed input parameters and the types of models used.

It is advisable to have clear expectations about those portions of the structure that are expected to undergo inelastic deformations and to use the analyses to

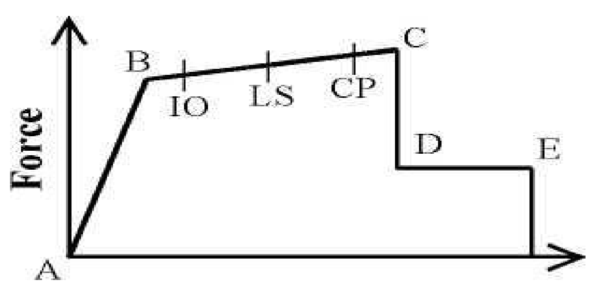
a) Confirm the locations of inelastic deformations and
b) Characterize the deformation demands of yielding elements and force demands in non-yielding elements.

In This regard, capacity design concepts are encouraged to help ensure reliable performance while nonlinear analyses can, in concept, be used to trace structural behavior up to the onset of collapse, this requires sophisticated models that are validated against physical tests to capture the highly nonlinear response approaching collapse.

Since the uncertainties in calculating the demand parameters increase as the structure becomes more nonlinear, for design purposes, the acceptance criteria should limit deformations to regions of predictable behavior where sudden strength and stiffness degradation does not occur.

The recent advent of performance based design has brought the nonlinear static pushover analysis procedure to the forefront. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behavior and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by thestructural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.The ATC-40 and FEMA-273 documents have developed modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force-deformation criteria for hinges used in pushover analysis. As shown in Figure 1, five points labeled A, B, C, D, and E are used to define the force deflection behavior of the hinge and three points labeled IO, LS and CP are used to define the acceptance criteria for the hinge. (IO, LS and CP stand for Immediate Occupancy, Life Safety and Collapse Prevention respectively.) The values assigned to each of these points vary depending on the type of member as well as many other parameters defined in the ATC-40 and FEMA-273 documents.

This article presents the steps used in performing a pushover analysis of a simple three-dimensional building. Etabs, a state-of-the-art, general-purpose, three-dimensional structural analysis program, is used as a tool for performing the pushover. The Etabs static pushover analysis capabilities, which are fully integrated into the program, allow quick and easy implementation of the pushover procedures prescribed in the ATC-40 and FEMA-273 documents for both two and three-dimensional buildings.



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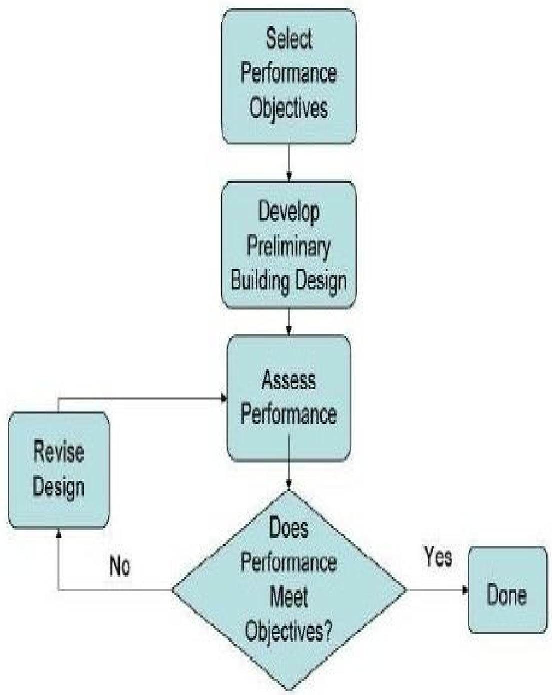
F. Deformation

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 modeling is involved in seismic hazard estimation. A computational scheme involves the following steps: delineation of seismic source zones and their characterization, selection of an appropriate ground motion attenuation relation and a predictive model of seismic hazard. Although these steps are region specific, certain standardization 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.



G. Pushover Analysis for Buildings

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.

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 (ATC-40). Proper application can provide valuable insights into the expected performance of structural systems and components. Misuse can lead to an erroneous understanding of the performance characteristics. Unfortunately, many engineers are unaware of the details that have to observe in order to obtain useful results from such analysis.

Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behavior and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design. Pushover analysis is a performance based analysis. According to ATC 40, there are two key elements of a performance-based design procedure - demand and capacity. Demand is the representation of earthquake ground motion or shaking that the building is subjected to. In nonlinear static analysis procedures, demand is represented by an estimation of the displacements or a deformation that the structure is expected to undergo.Capacity is a representation of the structure's ability to resist the seismic demand. The performance is dependent on the manner that the capacity is able to handle the demand. In other words, the structure must have the capacity to resist demands of the earthquake such that the performance of the structure is compatible with the objectives of the design. Pushover analysis is performed by Displacement coefficient method/Capacity spectrum method..The Capacity Spectrum Method (CSM), a performance-based seismic analysis technique, can be used for a variety of purposes such as rapid evaluation of a large inventory of buildings,design verification for new construction of individual buildings, evaluation of an existing structure to identify damage states, and correlation of damage states of buildings to various amplitudes of ground motion. The procedure correlation of damage states of buildings to various amplitudes of ground motion. The procedure compares the capacity of the structure (in the form of a pushover curve) with the demands on the structure....Objective of Displacement coefficient method is to find target displacement which is the maximum displacement that the structure is likely to be experienced during the design earthquake. It provides a numerical process for estimating the displacement demand on the structure, by using a bilinear representation of capacity curve and a series of modification factors, or coefficients, to calculate a target displacement.

H. Advantages of Pushover Analysis

Pushover analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is 5 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 expectation from pushover analysis is to estimate critical response parameters imposed on structural system and its components as close as possible to those predicted by nonlinear dynamic analysis. Pushover analyses provide information on many response characteristics that cannot be obtained from an elastic static or elastic dynamic analysis..These are:

1) 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 deep reinforced concrete spandrel beams, shear force demands in unreinforced masonry wall piers, etc.
2) Estimates of the deformations demands for elements that have to form inelastically in order to dissipate the energy imparted to the structure.
3) Consequences of the strength deterioration of individual elements on behavior of structural system.
4) Consequences of the strength detoriation of the individual elements on the behaviour of the structural system.
5) Identification of the critical regions in which the deformation demands are expected to be high and that have to become the focus through detailing.
6) Identification of the strength discontinuities in plan elevation that will lead to changes in the dynamic characteristics in elastic range.
7) Estimates of the interstory drifts that account for strength or stiffness discontinuities and that may be used to control the damages and to evaluate P-Delta effects.
8) Verification of the completeness and adequacy of load path, considering all the elements of the structural system, all the connections, the stiff nonstructural elements of significant strength, and the foundation system.
9) Estimates of inter-story drifts and its distribution along the height.

Pushover analysis also exposes design weaknesses that may remain hidden in an Elastic analysis. These are story mechanisms, excessive deformation demands, strength irregularities and overloads on potentially brittle members.

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis, and comparing these demands to available capacities at the performance levels of interest. The evaluation is based on an assessment of important performance parameters, including global drift, interstory drift, inelastic element deformations (either absolute or normalized with respect to a yield value), deformations between elements, and element connection forces (for elements and connections that cannot

sustaininelastic deformations), The inelastic static pushover analysis can be viewed as a method for predicting seismic force and deformation demands, which accounts in an approximate manner for the redistribution of internal forces that no longer can be resisted within the elastic range of structural behavior.
The last item is the most relevant one as the analytical model incorporates all elements, whether structural or non structural, that contribute significantly to the lateral load distribution. Load transfer through across the connections through the ductile elements can be checked with realistic forces; the effects of stiff partial-height infill walls on shear forces in columns can be evaluated; and the maximum overturning moment in walls, which is often limited by the uplift capacity of foundation elements can be estimated.

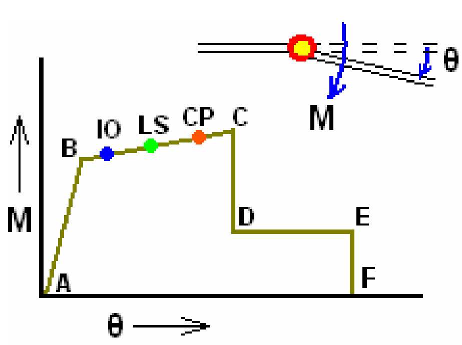
I. Limitations of Pushover Analysis

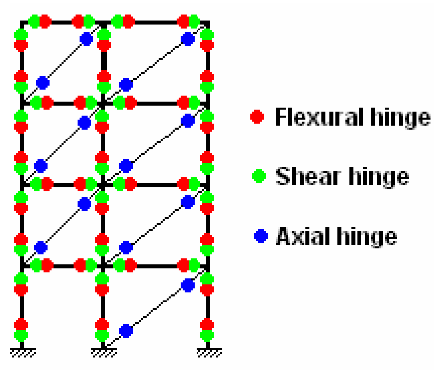
Although pushover analysis has advantages over elastic analysis procedures, underlying assumptions, the accuracy of pushover predictions and limitations of current pushover procedures must be identified. The estimate of target displacement, selection of lateral load patterns and identification of failure mechanisms due to higher modes of vibration are important issues that affect the accuracy of pushover results. Target displacement is the global displacement expected in a design earthquake. The roof displacement at mass centre of the structure is used as target displacement. The accurate estimation of target displacement associated with specific performance objective affect the accuracy of seismic demand predictions of pushover analysis. However, in pushover analysis, generally an invariant lateral load pattern is used that the distribution of inertia forces is assumed to be constant during earthquake and the deformed configuration of structure under the action of invariant lateral load pattern is expected to be similar to that experienced in design earthquake. As the response of structure, thus the capacity curve is very sensitive to the hoice of lateral load distribution, selection of lateral load pattern is more critical than the accurate estimation of target displacement. The lateral load patterns used in pushover analysis are proportional to product of story mass and displacement associated with a shape vector at the story under consideration. Commonly used lateral force patterns are uniform, elastic first mode, "code" distributions and a single concentrated horizontal force at the top of structure. Multi-modal load pattern derived from Square Root of Sum of Squares (SRSS) story shears is also used to consider at least elastic higher mode effects for long period structures. These loading patterns usually favour certain deformation modes that are triggered by the load pattern and miss others that are initiated and propagated by the ground motion and inelastic dynamic response characteristics of the structure. Moreover, invariant lateral load patterns could not predict potential failure modes due to middle or upper story mechanisms caused by higher mode effects. Invariant load patterns can provide adequate predictions if the structural response is not severely affected by higher modes and the structure has only a single load yielding mechanism that can be captured by an invariant load pattern.FEMA-273 recommends utilising at least two fixed load patterns that form upper and lower bounds for inertia force distributions to predict likely variations on overall structural behavior and local demands. The first pattern should be uniform load distribution and the other should be "code" profile or multi-modal load pattern. The 'Code' lateral load pattern is allowed if more than 75% of the total mass participates in the fundamental load. The invariant load patterns cannot account for the redistribution of inertia forces due to progressive yielding and resulting changes in dynamic properties of the structure. Also, fixed load patterns have limited capability to predict higher mode effects in post-elastic range. These limitations have led many researchers to propose adaptive load patterns which consider the changes in inertia forces with the level of inelasticity. The underlying approach of this technique is to redistribute the lateral load shape with the extent of inelastic deformations. Although some improved predictions have been obtained from adaptive load patterns, they make pushover analysis computationally demanding and conceptually complicated. The scale of improvement has been a subject of discussion that simple invariant load patterns are widely preferred at the expense of accuracy. Whether lateral loading is invariant or adaptive, it is applied to the structure statically that a static loading cannot represent inelastic dynamic response with a large degree of accuracy.

III. HINGES

Hinges are points on a structure where one expects cracking and yielding to occur in relatively higher intensity so that they show high flexural (or shear) displacement, as it approaches its ultimate strength under cyclic loading.
These are locations where one expects to see cross diagonal cracks in an actual building structure after a seismic mayhem, and they are found to be at the either ends of beams and columns, the ‘cross’ of the cracks being at a small distance from the joint – that is where one is expected to insert the hinges in the beams and columns of the corresponding computer analysis model. Hinges are of various types – namely, flexural hinges, shear hinges and axial hinges. The first two are inserted into the ends of beams and columns. Since the presence of masonry infills have significant influence on the seismic behaviour of the structure, modelling them using equivalent diagonal struts is common in PA, unlike in the conventional analysis, where its inclusion is a rarity. The axial hinges are inserted at either ends of the diagonal struts thus modelled, to simulate cracking of infills during analysis.

Basically a hinge represents localised force-displacement relation of a member through its elastic and inelastic phases under seismic loads. For example, a flexural hinge represents the moment-rotation relation of a beam of which a typical one is as represented in Fig.1. AB represents the linear elastic range from unloaded state A to its effective yield B, followed by an inelastic but linear response of reduced (ductile) stiffness from B to C. CD shows a sudden reduction in load resistance, followed by a reduced resistance from D to E, and finally a total loss of resistance from E to F. Hinges are inserted in the structural members of a framed structure typically as shown in Fig.2. These hinges have non-linear states defined as 'Immediate Occupancy' (IO), 'Life Safety' (LS) and 'Collapse Prevention' (CP) within its ductile range. This is usually done by dividing B-C into four parts and denoting IO, LS and CP, which are states of each individual hinges (in spite of the fact that the structure as a whole too have these states defined by drift limits). There are different criteria for dividing the segment BC. For instance, one such specification is at 10%, 60%, and 90% of the segment BC for IO, LS and CP respectively (Inel& Ozmen, 2006).

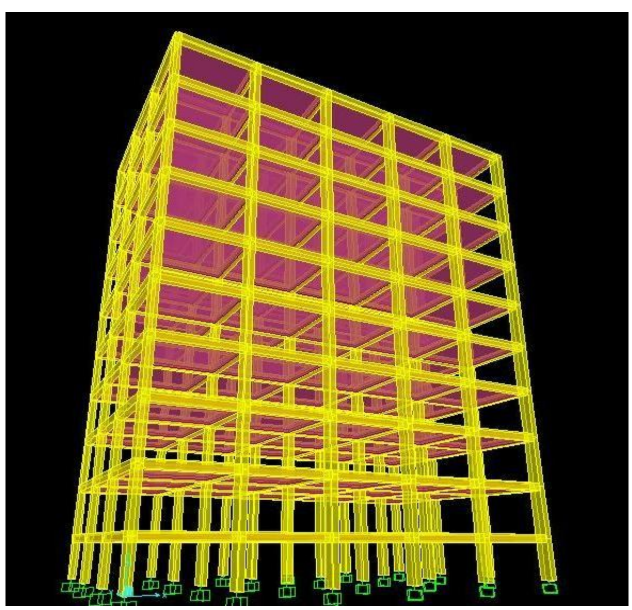




IV. BUILDING DISCRIPTION

In my report I have choose a G+8 story height office building with floor to floor height of 3.9 m, The plansize of building 18m width and 36 m long regular building. The structural system used in building is special moment resisting frame (beam columnsystem).

The building is situated in earthquake zone4. The material used in columns are M35 grade of concrete and M25 for other structural components. The 230 mm brick wall at outer peripheral beams only, all inner area has no permanent partition walls there is only movable partition proposed. The dead load of structure is calculated by software with 2500kg/cu.m given density of reinforced concrete. The superimposed dead load for floor finishing and false ceiling is 200kg/ sq.m as floor load and for 230 mm brick work 500kg/sq.m/r.m.as member load considered.The live load 400 kg/sqm as floor load considered.



V. DISCUSSION AND CONCLUSION

A. It has been observed that on increasing the reinforcement of ground storey beam, structure performance also improved.

B. On increasing the reinforcement of first storey beam, structure performance increases up to some limit then after its performance remain same. And it is observed that, there is no effect in performance of building on increasing the reinforcement of second and third floor.

C. Roof displacement decreases on increasing reinforcement of ground floor beam and first floor beam but there is no variation of roof displacement in cases of second and third storey.

D. There is a variation in base force on increasing the reinforcement of ground storey and first storey beam. While there is no variation in base force is found on changing the reinforcement of second and third storey beams.

E. It has been observed that there is appreciable change in roof displacement on increasing reinforcement of ground and first storey columns while there is no change in roof displacement if we increase the reinforcement of second and third storey columns.

F. There is large increase in base force when reinforcement of ground and first storey column is increased but there is no change in base force when reinforcement of second and third storey is increased.

G. It has been observed that, by providing shear wall there is an appreciable decrease in roof displacement of the building.

H. There is an increase in base force by on providing shear wall in the building.

I. After doing all the arrangement it has been observed the building is coming in acceptance criteria of immediate occupancy for various level of earthquake in zone four.

J. It has been observed that in performance based seismic design, there is a decrease in reinforcement in some members of the structure when compared to building designed by IS 1893:2002.

K. It has been observed that for the building to be in immediate occupancy level, reinforcement of ground and first storey floor has been increased but reinforcement of second and third floor members had been reduced as compared to reinforcement designed by of IS1893:2002.

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