Capacity Spectrum Analysis of R.C.C Structure with & without Shear wall

1: Introduction

Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools needs to be sharpened for analyzing structures under the action of these forces. In recent times, world has some severe earthquakes, which suggest that the level of ground acceleration is increased as compared to past. Therefore there is need to assess the capacity of the structure and take the necessary measure to improve the capacity of them as and when required. Although an elastic analysis provides a good estimation of the elastic capacity of the structure and indicates where first yielding will occur, it cannot predict failure mechanism and account for redistribution of forces during progressive yielding. In inelastic procedures help demonstrate how building really behave by identifying mode of failure and the potential for progressive collapse. Since structure will respond to the earthquake induced ground motion in an inelastic manner, the linear elastic equivalent lateral procedures do not provide direct method to assess the resulting maximum displacement and true failure modes. Capacity Spectrum Method is gaining a new dimension in the non-linear static analysis wherein pushover analysis and response spectra is to be considered. The Capacity Spectrum Method (CSM) was first introduced in the 1970s as a rapid evaluation procedure in a pilot project for assessing seismic vulnerability of buildings at the Puget Sound Naval Ship yard (Freeman et al., 1975). In the 1980s, it was used as a procedure to find a correlation between earth quake ground motion and building performance (ATC, 1982). The method was also developed into a design verification procedure for the Triservices (Army, Navy, and Air Force) “Seismic Design Guidelines for Essential Buildings” manual (Freeman et al., 1984; Army, 1986). Capacity Spectrum Method is seismic Analysis philosophy where in pushover analysis and response spectra are to be considered. The procedure compares the capacity of the structure (in the form of a push over curve) with the demands on the structure (in the form of response spectra). The graphical intersection of the two curves approximates the response of the structure. In this context capacity spectrum analysis which is an iterative procedure will be looked upon as an alternative for the orthodox analysis procedures.

This study focuses on pushover analysis (Capacity spectrum) & Response spectrum (Demand spectrum) of multi-storey RC framed buildings. To develop pushover analysis the building subjecting them to monotonically increasing lateral forces with an invariant height wise distribution until the pre set performance level (target displacement) is reached. 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 identified. 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. In the capacity spectrum method, the multi-story buildings are converted into the equivalent single degree of freedom (1-DOF) systems based on the output of pushover analysis. And the structural performance of buildings is represented by base shear versus horizontal displacement relationship of the equivalent 1-DOF systems. The relationship is referred to as the capacity spectrum.

In order to use the Capacity Spectrum Method, it is necessary to convert the capacity curve obtained from pushover analysis in terms of base shear $V_s$ and roof displacement $\Delta_{rooftop}$ to the capacity spectrum. Capacity spectrum is the representation of the capacity curve in ADRS (Acceleration Deformation Response spectra) format. To get the demand spectrum Response spectrum is converted from the standard $S_e$, $V_s$, $T$ into ADRS format. After getting the Capacity spectrum and Demand spectrum they are superimposed with each other to get the performance point. The performance point gives the behavior of structures to earthquake.

Seismic Analysis Method:

- Linear Methods
  - Linear Static
  - Linear Dynamic
- Nonlinear Methods
  - Nonlinear Static
  - Nonlinear Dynamic

Remark:

Although an elastic analysis gives a good indication of the elastic capacity of the structure and indicates where first yielding will occur, it cannot predict failure mechanism account for redistribution of forces during progressive yielding. Inelastic procedures help demonstrate how buildings really work by identifying modes of failure and the potential for progressive collapse. The use of inelastic procedures for design and evaluation an attempt to help engineer better understand how structure will behave when subjected to major earthquake, when its assumed that the capacity of the structure will be exceeded. In this study we are going to learn, the capacity spectrum method, a nonlinear static procedure that provides a graphical representation of the global force-displacement capacity curve of the structure and compares it to the responses spectra representations of the earthquake demands, is a very useful tool in the evaluation of the performance and retrofit design of existing concrete buildings. The graphical representation provides a clear picture of how various retrofit strategies, such as adding stiffness or...
strength, will impact the building’s response to earthquake demands.

2. LITERATUREREVIEW:

In literature review we will study the research papers which are related to capacityspectrum method for R.C.C. building to determine the performance level of structuresubjected to earthquake.

1. N. Lingeshwarana, at el (2018)“Comparative Analysis On Asymmetrical and Symmetrical Structures Subjected to Seismic Load”

The Objective Of Study Is To study the performance of different structures on application of loads. Analysis of buildings in ETABS software for storey drift, displacement of symmetric and asymmetric structures. Comparing storey displacement and storey drift. Here the study is carried out with different shapes for G + 9 building behavior. For the modelling general software ETABS wasused. More user-friendly and versatile program offering a wide range of features such as static and dynamic analysis, non-linear dynamic analysis and non-linear static pushover analysis, etc. The Conclusion Of the Study Was Symmetrical building perform better than asymmetrical buildings. As per results shown above T shaped building is more susceptible to seismic load compared to symmetrical building. The storey displacement at the first floor is relatively lower when compared to that of the top floor. L shaped and H shaped buildings are showing similar displacement under seismic load. Displacement is less for symmetric building than asymmetric building.

2. Sigmund A. Freeman at ISET (2004)“Review of The Development of The Capacity spectrum Method”

By means of a graphical procedure; in this paper the general procedure of capacity spectrummethod i.e. it compares the capacity of the structure with the demands of earthquake groundmotion on the structure is explained. The capacity of the structure is represented by an nonlinear force-displacement curve, sometimes referred to as a pushover curve. The baseshear forces and roof displacements are converted to equivalent spectral accelerations andspectral displacements, respectively, by means of coefficients that represent effective modalmasses and modal participation factors. These spectral values define the capacity spectrum. The demands of the earthquake ground motion are represented by response spectra. The graphical construction that includes both Capacity spectrum curve and Demand spectrumcurve results in an intersection of these two curves that estimates the performance of the structure.

3. Tatsuya 1 AZUHATA1 at WCEE 2000“Seismic Performance Estimation of Asymmetric Buildings Based on The Capacity Spectrum Method”

Which includes the procedure for seismic performance estimation of asymmetric buildings based on a concept of the capacity spectrummethod. Inorderto evaluate the torsionalseffect due to plansymmetry inelastic seismic responses of asymmetric buildings, the strength modification factor and the deformation amplification factor are introduced? The strength modification factor is used to quantify the decrease of strength capacity to horizontal seismic forces of asymmetric-plan stories, considering strength eccentricities and to signal strength capacities. The deformation amplification factor is used to quantify the amplification of story drifts in the damage-predicted sides of asymmetric-plan stories, based on linear and staticthree-dimensionalanalysis. The proposed procedure using these factors is verified by parametric studies for inelastic responses of Three-story asymmetric building’s models with some types of asymmetric-plan stories using a step by step time integration method. From the results, it was cleared that the torsional effect can be evaluated by using the introduced factors, and the story drifts at the perimeters in the damage-predicted sides of asymmetric-plan stories can be predicted conservatively and approximately by the proposed procedure.


Present results of a research project investigating the seismic evaluation of reinforced concrete structures with bearing walls. The investigation is based on the analysis of nonlinear structural models with the capacity spectrum method, an approximate nonlinear static analysis procedure, and time history analyses. The latter serve as reference. Efforts focus on the realistic modelling of reinforced concrete buildings with bearing walls and on the determination of the capacity spectrummethod. In this paper a study on the response of one example building named KJA is carriedout. It’s a residential building with 9 stories above ground and one basement. The KJA building was seismically evaluated for an earthquake loading according EC8, for 0.16g peakacceleration and soft soil class C. To apply the CSM, the capacity spectrum and the response spectrum are to intersect. Therefore, a NLDA with the EC8-acceleration time history was executed. The NLDA yielded a spectral target displacement of $S_0 = 33$ mm (45 mm roofdisplacement) and conclusion is that a good estimation of the equivalent damping is 10%. Forthe application of dispersion based analysis methods such as the CSM.

5. Mrugesh D. Shah at NCRTE (2011)“Performance Based Analysis of R.C.C Frames”

It is limited state designs extended to cover complex range of issues faced by earthquake engineers. Two typical new R.C.C. buildings were taken for analysis: G+4 and G+10 to cover the broader spectrum of low rise & high rise building construction. Different modelling issues were incorporated through nine model for G+4 building and G+10 building were: bare frame(without infill), having infill as membrane, replacing infill as an equivalent strut in previous model. All three conditions for 2x2, 3x3, 4x4 bays. Comparative study made for bare frame (with out in fill), having in fill as membrane, replacing
in fill as an equivalent strut. From the results for G+4 and G+10 stories in bare frame without infill have lesser later al load capacity (Performance point value) compare to bare frame within fill as membrane and bare frame with infill having lesser lateral load capacity compare to bare framing with Equivalent strut.

1. Nitin Choudhary1 at IOSR (2014) “Pushover Analysis Of R.C.C Framed Structure With Shear Wall”

In this paper the description of pushover analysis FEMA, ATC 40 are given. Also different methods of pushover analysis such as inelastic component behavior, Capacity spectrum method, Time history method are explained. Analysis in done for given building and conclusions are Provision of shear wall results in a huge decrease in base shear and roof displacement both symmetrical building and un-symmetrical building. In L-shaped building when shear wall is provided on the larger side of the building results in a decrease of 4.3% in base shear and 58.15% in roof displacement and when provided on smaller side results in a decrease of 7.97% in base shear and 55.43% in roof displacement. Hence in unsymmetrical buildings shear wall must be provided on smaller side of building. The performance based seismic design obtained by above procedure satisfies the acceptance criteria for immediate occupancy and life safety limit states for various intensities of earthquakes. Performance based seismic design obtained leads to a small reduction in steel reinforcement when compared to code based seismic design (IS 1893:2002) obtained by STAAD.Pro.


In this paper the different purposes of providing the shear wall in explained. The stiffness of the shear wall, just like its strength, depends on the combined stiffness of its three components: lumber, sheathing and fasteners. The size and grade of end stud(s), thickness and grade of sheathing, and the sheathing fastener diameter determine how flexible a wood shear wall will be. When present, hold own devices also contribute to the overall stiffness of the shear wall. If hold own devices stretch or slip, the top of the shear wall will move horizontally. This horizontal movement adds to the movement allowed by the lumber, sheathing and fasteners. Any additional movement from the hold own will reduce the effective stiffness of the shear wall. In this chapter a multistory building has been modelled and analyze with considering all loads like Dead load, Live load, Wind Load as per as IS standard and Seismic load as per as IS standard. With Different Position Of Shear Wall In this project it is concluded that the G+10 structure shear wall is generated less value of von-misses stress and deformation on structure at location 1 as compare to location 2.

8. Shruthi Indaragi1, at IRJET (2019)*“Response Spectrum Analysis of Symmetric and Asymmetric Structures in Seismic Zones” by

In this paper the different irregularities if structure is listed like plan irregularity and vertical irregularity. The objective of the study is To study the response spectrum method for Analysis of symmetric and asymmetric building structures and to study the effect of plan irregularity on the fundamental natural period of the building, its effects on performance of the structure during earthquake for different building models. Analyzing the regular and irregular structure and comparing the response parameters for both structures. The various conclusions are Story shear has maximum values in all cases in irregular building as compared to regular structure due to earthquake forces in seismic zones. Displacement in X and Y direction increases with increase in height of the structure in both buildings. Displacement is more in asymmetric structures as compared to symmetric structures in all zones. Storey drifts are Maximum in symmetric structures G+12 and G+15 and increases with increase in height of the structure in both zones. Overturning moment has maximum values in symmetric structures for G+15 at zone3 due to maximum number of storeys. Moment has maximum values in asymmetric structure or G+12 at zones 3&4 and for G+15at zone4 respectively. From results and graphs observed that maximum displacement, storey drifts, storey shear, and moments occurs in asymmetric structures not in regular building due to earthquake forces and irregularity of structures.

2.1 Outcomes from Literature Review

From the available literature it was observed that most of the studies are not on the Capacity Spectrum method for Different Postion of Shear Wall with Plan Symmetry and Asymmetry. Only a limited number of published works on multi-story R.C.C Building For mentioned Objective to find out the performance level buildings. Thus, after reviewing the existing literature it was felt that a comparative study on multi-story buildings With Different Position of Shear Wall IN Plan symmetry and asymmetry by-capacity-spectrum method analysis is required.

3. Objectives:-

The Objective of this Study is to carry out seismic analysis using capacity spectrum method for RCC multi-story building with shear wall and plan symmetry &To determine the performance level of building by considering structural capacity obtained from pushover analysis and earthquake demand obtained from response spectra (IS 1893-2002) is intended.

Following will be the objectives of the study:

1) To study the effect of providing shear walls, in RC framed building, using pushover analysis.
2) To compare the seismic response of building in terms of base shear, storey drifts, Storey displacements with and without shear wall.
3) Determination of performance point of building with and without shear wall.
4. Scope of Work:

Seismic analysis (Performance level) would be carried out for a RCC multi-story (G+10) building for the following various cases with the help of Etabs Software.

1) R.C.C building with Shear Wall Plan Symmetry.
2) R.C.C Building without Shear Wall Plan Symmetry.
3) R.C.C Building with Shear Wall Plan Asymmetry.
4) R.C.C Building without Shear Wall Plan Asymmetry.

5. Proposed Methodology:

The most widespread procedures for the assessment of building performance due to earthquake is the Capacity Spectrum Method (CSM). The Capacity Spectrum Method (CSM) by means of a graphical construction, compares the capacity of the structure with the demands of earthquake ground motion on the structure. The capacity of the structure is represented by a nonlinear force-displacement curve, referred as pushover curve. The base shear forces and roof displacements are converted to equivalent spectral accelerations and spectral displacements, respectively, by means of coefficients that represent effective modal masses and modal participation factors. These spectral values define the capacity spectrum. The demands of the earthquake ground motion are represented by response spectra. The capacity spectrum method (CSM) is a nonlinear static analysis method, which compares the global force-displacement capacity curve of a structure with an earthquake response spectrum in a graphical shape (Freeman, 1998), (Badoux, 1998). For this, both the capacity curve and the response spectra have to convert in to a spectral acceleration (S_a) spectral displacement (S_d) graph. Due to this transformation, the global building will be reduced to an equivalent SDF structure. By using a trial and error procedure one can estimate the performance point, which describes the spectral displacement of the building due to the given earthquake. A graphical construction that includes both capacity curve and demand curve results in an intersection of the two curves that estimates the performance of the structure to the earthquake.

Following methodology will be carrying out:

- Study of seismic zones.
- Literature study (searching codes, methods and techniques). 
- Defining objectives of the study.
- Referring IS Codes for loads applications.
- Model generation using Etabs.
- Applying loads and seismic parameters as assumed for this study.
- Analysis (Push Over) of building models to obtain the results (Performance Point, Drift, Base Shear, and Displacement).
- Comparison of the results and concluding the work with conclusion.

References:

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