STUDY OF SEISMIC ANALYSIS METHODOLOGIES AND THEIR FEASIBILITY IN STRUCTURAL ENGINEERING

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Abstract: *No design in civil engineering is complete without using the word Factor of Safety (FOS). Every civil engineer knows the importance of FOS. We live in a world of unpredicted natural phenomena. Many times we will not be able to oversee these and hence while designing, we design a structure so that it will maintain its stability and durability to some extent even if there are some unprecedented occurrences. One such phenomenon is the destruction caused due to the seismic waves emerging from the epicenter due to the slippage between different layers of earth. These waves in the form of energy, on reaching the earth surface, cause damage, depending upon the magnitude or the strength of those waves. This in general language is termed as an Earthquake. The magnitude of earthquake, population density, natural topography, construction above the zone, direction of waves, etc. plays an important role in determining the maximum possible forces these waves can exhibit on a structure. We perform many different studies for analysis of earthquakes such as the time-history analysis, response spectrum analysis, pushover analysis, etc. This paper focuses on the design of structures using pushover analysis. Pushover analysis mainly deals with the resistance of structural deformation of members and the ductile property of a structure i.e. to come back to its original shape after the removal of forces. Practically no material is ideally elastic and hence some deformations are seen, reducing the strength of the structure. It also deals with the re-strengthening of this existing structure by retrofitting methods. One of the major disadvantages of seismic analysis is that the structure becomes heavy and uneconomical. It should also be noted that earthquake-like phenomena usually occur once or twice in a lifetime of structure. Considering seismic analysis is highly debatable but in the author's view, along with frequent earthquake zones, seismic analysis should be considered for high rise structures and densely populated areas as well.*

Keywords- *Time-History Analysis, Pushover Analysis, Response Spectrum Analysis*

1. INTRODUCTION

Simulation has been the backbone of the civil engineering industry in the 21st century. With the help of data collecting, analysis, design and simulation softwares we can easily test the structure in different environmental, topographic as well as any disastrous conditions. Soil conditions, water table, bearing capacity, wind zone, topographic conditions and seismic conditions can all be simulated. But among all, the seismic is not visible or predictable for anyone while designing as it emerges as waves through the focus and reaches the earth surface in the form of energy. To avoid the destruction caused due to these forces known as seismic forces which act in the lateral direction, different factors of safety are considered. Different methods of analysis are discussed in this paper along with suggestions on using different methods of analysis for different conditions of structure.

A basic structure should be stiff enough to resist all the bending moments acting upon it as well as flexible enough to resist the displacement caused due to unprecedented lateral forces. The members should be ductile enough to come back to their original position post any earthquake. Hence to maintain this ductility of the structure, hinges are provided at the ends of members. Among all the methods, the push over analysis using non-linear material properties and dynamic loading pattern is the most accurate method, but it takes a lot of time for simulation and hence not feasible in certain cases. The following paper is an attempt at collation of different studies done with regard to using different analysis methodologies with their advantages and disadvantages.

2. LITERATURE REVIEW

Jami Lakshmi Sudha[1], Dr. Dumpa Venkateswarlu[1] (2016), mentioned that modification of the seismic waves is not possible at this stage and hence, the earthquakes cannot be prevented. Even the magnitude can be only predicted and not confirmed. But they argued that the damage caused to any structure due to an earthquake can be controlled significantly, though it makes the structure quite uneconomical and heavy for a phenomenon whose probability during the life span of the structure is less. They varied the percentage of reinforcement steel and concrete of a 5 story Reinforced Cement Concrete (RCC) Structure for different seismic zones in India.

The typical behavior of a structure is generally dependent upon the nature of supports it is provided with. Statistically 54% of India is under the threat of major and minor earthquakes. The basic principle of carrying out seismic analysis is considering a combination of lateral loads along with the gravity loads. The effect of this seismic design not only increases the material, labor and construction cost but also increases the dead load of the structure. The fundamental units which need to be checked in order to minimize the damage are building configuration, distribution of rigidity, ductility, strength and type of foundation and quality of construction.

They observed in their report, that as we move from Seismic Zone II to V for a G+4 structure, the support reactions increase significantly in external columns. This increase is more for internal columns. For Zones III, IV and V, the concrete volume increases sharply. With this it was also found that the percentage steel increases in the edge, interior and external column footings. The steel change also varies more in internal beams as compared to external beams. It was also found that for both seismic and non-seismic designs, the longitudinal rebar in tension does not show any significant change at all. They ended their report, presenting that if the total cost for an earthquake resistant design structure per square meter in zone II was approximately 9350 Rs. whereas for same safety parameters in zone V, the cost per square meter goes on to 10450 Rs. Considering the ductile detailing, the cost of structure increases by approximately 4%.

Shrikar S. Nayak[2], Ratnesh Kumar[2], and Ranjan S. Sonparote[2] (2014), in their paper argued that there is a significant difference between the structural analysis done through loads applied sequentially and non-sequentially. They considered 4 different structures with different heights so as to study the effect of wind and seismic loads which contribute towards the lateral loads and change with respect to time. Initially, only dead gravity load was considered for all the structures. We know that as the loads get added sequentially as opposed to at once addition of load in software, the lower members are subjected to more increase of load with respect to time.

The solution offered for this increased values of acting moments due to sequential addition of loads was to increase the rebar percentage. As soon as we consider the seismic lateral loads, the combination decreases the factored load thus resulting in reduction of factored bending moment and ultimately the rebar percentage. As the height of structure increases, the first fundamental mode period of vibration also increases. They concluded that the difference between response parameters of sequential and non-sequential analysis for seismic loads has a significant difference. On the contrary, it was observed that for both sequential and non-sequential analysis, a change of around 10-20% rebar is seen with application of seismic loads.

Yasser Alashker[3], Sohaib Nazar[3], Mohamed Ismaiel[3] (2015), considered the effect of earthquakes on change of shape, size and geometrical configuration of structure. As the seismic waves produce force which cause different effects on a structure depending upon its magnitude and direction of application. The structure should be stiff enough to withstand the inelastic deformation caused due to the earthquake force. They used nonlinear pushover analysis on three different structures with equal heights and area, but different shape and configuration. Changing the seismic load pattern is carried out to find the base shear capacity and henceforth different floors are analyzed for displacement and plastic hinge formation. The authors varied the aspect ratio 1, 1.5, 2 and 4.

In pushover analysis, lateral loads are varied and simulated as lateral earthquake loads. As the lateral load increases, the material behavior of structure changes and loss of stiffness occurs resulting in yielding of structural members. The ultimate aim of pushover analysis is to approximate a target displacement based on the capacity curve developed considering an earthquake like condition. The general trend of the lateral displacement graph and building height indicated that as the Aspect ratio increases, the lateral displacement increases with increase in height of building.

They also concluded that the maximum displacement in high rise structures is approximately around half the height of structure. In their paper, they observed that the configuration of a structure highly impacts the seismic resisting behavior of any structure. As the aspect ratio increases, the base shear increases significantly along with inter story drift. Increased aspect ratio also contributed towards an increased number of plastic hinges at different positions.

Petr Čada[4], Jiří Máca[4] (2017), Performed simple seismic analysis with different methods on two different structures. The methods which were considered are nonlinear static or pushover analysis, nonlinear dynamic or time-history analysis, modal response spectrum and lateral force method. They observed that the lateral force method uses linear material properties which should be used for symmetrical structures with known behavior. The response spectrum method is also a linear method and gives comparatively better results than lateral force method. It can be used for complex structures.

As soon as we bring in nonlinear analysis, there's a significant change in values. Time history analysis uses old records of earthquakes to predict the direction and magnitude of the earthquake and simulate similar patterns on the structure. They concluded their paper by mentioning that the lateral force method shows no deformation in flexible members whereas it shows some lateral displacement in rigid members. Time history analysis shows an increase of around 23.18% in flexible members as compared to response spectrum analysis. Contradicting the flexible beams, the rigid beams in time history analysis shows a decrease in horizontal displacement by 5.7%. As soon as we consider nonlinear analysis, pushover analysis shows higher values of horizontal displacement for both flexible and rigid beams.

Ahmed Yousef Alghuff[5], Samir Mohammed Shihada[5] and Bassam A. Tayeh[5] (2019), Tried studying the ideal conditions for using different analysis methods for performance of a structure under seismic loads. The Shear force and bending moments are calculated for two structures, one of 75m and one of 24m. The displacements under seismic loading in both X and Y direction are calculated and collated. It was observed that for high rise structures, the displacement values in X direction for response spectrum analysis is approximately 70% less than those in static analysis.

This difference goes further till 80% for displacement in Y direction. For low rise structures, the percentage change in X direction is around 35% and that of Y direction is 38%. The shear force, bending moments and displacement values for response spectrum analysis are always less than that of static analysis in both X and Y direction for both the structures. Further they recommended that for low rise structures, static analysis be used. For higher structures, dynamic analysis should be considered since for high rise, static analysis will be uneconomical.

Katta Venkataramana[6], Shreyasvi C[6] (2018), pointed out that the Indian Plate is subduing under the Eurasian plate which makes the Indian subcontinent earthquake prone. The waves generated at the focus and travel through the earth and reach the earth surface are very random in nature. This randomness can cause huge damage to human life as well as financial losses. They considered that the destruction caused by an earthquake varies from region to region depending upon the loss. They considered an earthquake of high magnitude in a non-populated zone to be harmless but even a moderate earthquake in a densely populated area can cause heavy damage. The waves of earthquakes propagate in all directions, but the most significant of these is the lateral effect.

The authors influenced upon use of locally available and economical materials to be used to resist the lateral forces. They suggested use of different materials and methods such as seismic dampers, steel plate shear-walls, carbon fibers, blue mussels, seismic invisibility cloak, cardboards, levitating houses, eco-friendly ductile cementitious composite sprays (EDCC), bamboo etc. The main aim of the authors is to use indigenous materials to resist the lateral loads caused by earthquakes which can reduce the dead weight of any structure.

Yousuf Dinar[7], Md. Imam Hossain[7], Rajib Kumar Biswas[7], Md. Masud Rana[7] (2014), focused on the effects of variation of configuration of structure on the capacity of structure. Considering the seismic loads, non-linear analysis provides better results in comparison to linear seismic analysis. The parameters for consideration of seismic analysis were base shear, displacement of joints, drift of story and number of plastic hinges formed. The most basic joint in a RC structure is the rigid joint which restricts motion in all six directions (3D). In this nonlinear static analysis, the gravity loads are kept constant along with increasing the lateral loads until a collapse failure mechanism is developed in the structure.

The load distribution pattern is kept constant throughout the increment of the lateral loads. A pushover curve of shear force versus displacement is generated with the help of any analysis software such as ETABS or StaadPro. This analysis also helps in the retrofitting processes as they can easily simulate the weak elements of the structure. They recommended using shear walls at the periphery rather than using the parallel shear wall configuration. The performance of a structure changes highly with change in the shear wall configuration and the infill.

3. CONCLUSION

It can be inferred that earthquakes cannot be predicted nor can we deviate their direction as of now, but we have under our scope is to reduce the damage caused due to these earthquakes by constructing earthquake resistant structures. There are many methods involving use of both linear as well as nonlinear analysis considering static and dynamic loading patterns. The crux of all the papers was that the action of seismic load adds a horizontal or lateral component of force, which changes the loading pattern of the structure and hence the behavior of structural elements changes accordingly. Figure 1 shows how lateral forces affect by generating an eccentricity to the gravity loads resulting in increased values of bending moments. When we consider pushover analysis, seismic loads are gradually increased from Wsi to Wsf resulting in lateral displacement of Δ_o (initial) and Δ_f (final) respectively.

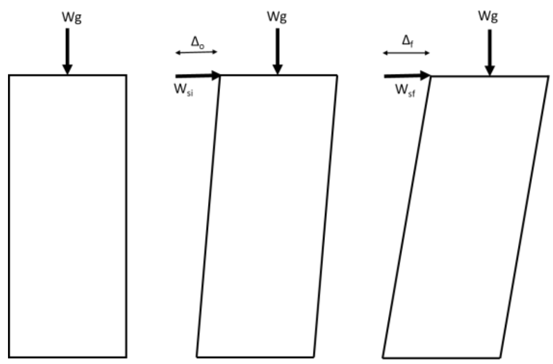

Figure 1

It should also be noted that when lateral loads of gravity or wind are considered, the factored load is reduced from the factor of 1.5 to 1.2 which results in significant reduction of longitudinal rebar. But this rebar percentage is to be increased with increase in the seismic zone from zone II to zone V. Also while considering the seismic analysis, it was observed that linear static analysis gives correct analysis for small structures but fails to provide precise analysis of high rise structures.

As loads increase with respect to time, the internal material properties change resulting in loss of stiffness of a joint. The study suggests use of time history analysis for places with adequate history of past earthquakes so as to approximate the impact of the next earthquake while use of pushover analysis for high rise structures is suggested. Among all the points, it should be noted that earthquakes are phenomenon with very low probability but requires uneconomical designs many time, so we suggest use of earthquake design in earthquake prone regions, Water storage structures like dams, tanks, retaining walls, places near water bodies and places of heavy population density with clustered settlements.

4. REFERENCES

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