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Review on Seismic Design of Multistoreyed RC Building using various Codes

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Abstract—Seismic design deals with the yielding and inelastic behaviour of structural element which are detailed to exhibit such behaviour during earthquake. The structure is designed with sufficient strength to behave elastically during earthquake. Seismic design of multistoreyed RC building is to withstand the ground motion caused during the earthquake. Inorder to design an earthquake resistant structure an Engineer must have a well knowledge about various seismic design codes. In this paper literatures of various researches were studied. Those papers give more information about the static and dynamic analysis done on various types of structures. The use of softwares in seismic analysis will reduce the time consumption and errors in analysis and design of the structure. The researchers used various countries codes to evaluate the seismic performance of the structure. The parameters such as displacement, base shear, storey drift, time period, axial and shear force bending moment were studied. From these researches, an interest arises to do seismic design of multistoryed building using various codes to understand which codal provision gives very effective design to perform good during earthquake.

1. **Keywords**—Base shear, Displacement, Seismic analysis , Storey drift, stiffness.

1. Introduction

Earthquake resistant structures are capable of resisting lateral and vertical forces acting on the structures. But no structures can entirely survive during earthquake without any damages. According to codes, earthquake resistant structures are designed to withstand expected earthquake atleast to occur once during the design life of the structure.

Reinforced concrete buildings are analysed and designed to meet the requirements of relevant codes of practice. Such buildings designed as per codal provision will survive during earthquake with minor damages of structural elements.

Many of the countries have their own codes of practice for Earthquake Resistant structures. The buildings are designed and detailed as per codes. This paper gives the review on performance of buildings towards seismic load for various designs. The review explains the need of improvement in codes, thus improve the performance of structures better during earthquake

2 LITERATURE REVIEW AND METHODS

Jaya Prakash Kadali et al[1](2015) conducted study on static analysis of multistoreyed RC buildings by using pushover methodology. The frames with various configuration are designed and detailed as Special Moment Resisting Frames(SMRF) and Ordinary Moment Resisting Frames(OMRF) as per IS 1893 (2002). A total of 10 frames are selected with various number of storeys, number of bays, infill wall configurations, and design methodology. The designs for SMRF buildings are done using IS13920 (2002). The buildings are modelled and Pushover Analysis is performed in SAP2000. Pushover analysis is a static nonlinear procedure to analyse a building with the increase in the magnitude of loads, the weak links and failure modes of the building are found. Special Moment Resisting Frames (SMRF) is used as seismic force resisting systems in buildings to resist earthquakes. SMRF resist strong earthquake shaking without loss of stiffness or strength. The buildings designed as SMRF perform much better compared to the SMRF building. Ductility and base shear of SMRF is more compared to OMRF.

Mr.K.Lova Raju et al[2] (2015) studied the effective location of shear wall on performance of building frame subjected to earthquake load. In this paper, four types of structures with G+7 are considered inwhich one of the frame without shear wall and three frames with shear wall in various positions. The Non Linear Static analysis is done using ETABS v9.7.2 software. The structure is designed for Seismic zone II, III, IV and V. In pushover analysis the lateral force increases with increase in height of building. The behaviour of structure is determined including ultimate load and maximum deflection. The pushover curve is generated by plotting base shear and roof displacement. Frame with shear wall performs better and the base shear increased when compared to the frame without shear wall. Shear wall performs better to lateral displacement and it reduces when compared to the frame without shear wall.

Md. Rashedul Kabir et al[3](2015) has determined response of multi-storey regular and irregular buildings of identical weight under static and dynamic loading in context of Bangladesh. In this paper, a 15 storeyed regular shaped and irregular shaped buildings have been modelled using program ETABS 9.6 for Dhaka (seismic zone 2), Bangladesh. The effect of static load, dynamic load and wind load is analysed. The mass of the each buildings were considered to be same. Displacement due to wind load is maximum in all type of buildings. Static and dynamic analysis gives less variation in displacement. The displacement obtained from static analysis is more when compared to dynamic analysis. The displacement increases with storey height. C shaped and L shaped structure has higher displacement. Rectangular and irregular shaped structure show almost similar displacement against wind load as the total mass is constant.

Akshay V. Raut et al[4] ***(2014)*** has performed pushover analysis of G+3 reinforced concrete building with soft storey. They have created the basic computer model of four storey building frame structure and define properties and acceptance criteria for the pushover hinges .The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. The curves show the behavior of the frame in terms of its stiffness and ductility. For bare frame maximum base shear from pushover analysis is 951.78 KN and maximum displacement of 240.65mm in X direction. The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates. The performance point is obtained at a base shear level of 550KN and displacement of 45mm in the X direction. Hinges have developed in the beams and columns showing the three stages immediate occupancy, Life safety, Collapse prevention. The column hinges have limited the damage.

Lakshmi K.O et al[5] (2014) determined effect of shear wall location in buildings subjected to seismic loads. Analysis software ETABS 9.5 is used to create the 3D model and run the linear static and dynamic analysis. Pushover analysis is done in SAP2000 V.14.1. Eight different models were considered. Sixteen storey (G+15) residential building having ground storey height and floor height of 3m is analysed for the soil type medium. Loads are taken from IS:875(Part 2). The load combinations considered for the analysis and design is as per IS:1893-2002. The seismic weight is calculated using full DL+ 25% of LL. Fixed supports are provided at base. Medium high rise buildings with shear wall are found to be effective in improving the overall seismic capacity of the structure. Drift value is reduced when shear wall is provided at the corner. The reinforcement requirement in column is affected by the location and orientation of adjacent shear walls and columns. Push over analysis results provides a detail about the performance of structures in post elastic range.

Nitin Choudhary et al[6](2014) performed pushover analysis of RC frame building with shear wall. In this project, a four storied reinforced concrete frame building situated in Zone IV, is taken for the purpose of study. Euro codes EC2 and EC8 are also based on performance based design philosophy, but Indian codes are still silent over this method. FEMA-273, FEMA-356 and ATC-40 gives the detailed procedure of non-linear pushover analysis. 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.

Riza Ainul Hakim et al[7] (2014) performed a seismic assessment of an RC building using pushover analysis. In this paper, a 6-story reinforced concrete structure located in Saudi Arabia with a story height of 4.0 m was used in the static pushover analysis. The type of soil is soft rock or site class C is selected according to the Saudi Building Code 301. The FEMA 356 rule, which is built in SAP 2000 with the IO(Immediate Occupancy), LS(Life Safety) and CP(collapse prevention) limit states for hinge rotation have been used for the acceptance criteria. Pushover analysis produces a pushover curve or capacity curve that presents the relationship between the base shear (V) and roof displacement (Δ). The Pushover curve depends on the strength and deformation capacities of the structure and explains the behaviour of the structure beyond the elastic limit. The structural system was designed using design based only on the gravity load and design of intermediate resisting frame (IMRF) according to SBC 301. The comparison of the pushover curve shows that the stiffness of frame is larger in IMRF (SBC301) compared to the gravity load design. SBC design has a greater capability to resist lateral load (seismic load) than the gravity load design. The performance point location is at IO (Immediate Occupancy) level which means the structure experience light damage. The design satisfies pushover analysis according to ATC 40.

Praveen Rathod et al[8] (2014) performed Non-Linear Static analysis of G+6 storeyed RC buildings with openings in infill walls. In this paper a two-dimensional seven storeyed reinforced concrete (RC) building models are considered with of 5%, 25%, and 35% openings. Bare frame and soft storey buildings are modeled considering special moment resisting frame (SMRF) for medium soil profile and zone III. Pushover analysis as per FEMA 440 is done using SAP2000. The moment-curvature values for beam column and load deformation curve values for strut are substituted instead of default hinge values in SAP2000. Base force and displacement along longitudinal direction for all building models are obtained. The percentage of openings increases the base force at performance point decreases for both default and user defined hinges. The default-hinge model is preferred due to simplicity. The user-defined hinge models are more successful in capturing the hinging mechanism compared to the default hinge models.

A. Cinitha et al[9] (2012) performed Nonlinear Static analysis to assess seismic performance and vulnerability of code - conforming RC buildings. In this paper, non linear analysis described in National Earthquake Hazards Reduction Program (NEHRP) guidelines is used for the seismic rehabilitation of buildings. Analysis is done using SAP2000. 4 and 6 storey buildings are designed according to the code IS456:2000 and IS1893:2002. The data used for analysis are gravity load design ground acceleration - 0.36g and seismic load design ground acceleration- 0.16g with medium soil. The buildings are designed for two cases, such as ordinary moment resisting frame (OMRF) and special moment resisting frame (SMRF). A 100% dead load

+ 50% live load is applied to the lateral load on the structure. Inelastic beam and column members are modelled as elastic elements with plastic hinges at their ends. The analysis results observed for displacement shows that the modern codes for framed structure are within collapse prevention level.

C. Bhatt et al*[10] *(2012) performed a comparison between American and European codes on the Non Linear Static analysis of RC buildings. In this paper they explained about non linear Static Procedure (NSP), which is a performance based seismic design which behaves sensible in seismic force than a strength designed in force based philosophy. They evaluate deformation in Global and Component level. N2 and Capacity spectrum method in FEMA 440, ATC 40 and EURO 8 is used. Static pushover analysis is done on 5 storey RC building which survived without damage in earthquake (1997). The building is designed properly for shear and collapse. The building is modelled using Fibre element model in SeismoStruct software. Hysteric damping is predefined in the model while non hysteric damping is 5% of tangent stiffness proportional damping. The displacement is calculated using N2 method. The torsional effect is calculated using torsional correction factor by amplifying the displacement results. In pushover analysis, N2 method is performed by appling Mass proportional force and Modal proportional force. But the CSM method is done by appling modal-proportional load patterns. Top displacements, lateral displacement profiles and interstorey drifts were determined using both methods. The CSM-FEMA440 was usually closer to the time-history.CSM-FEMA440 gives accurate procedure to calculate the target displacement. N2 method is the only method which gives the correct torsional motion of the building.

3 Conclusion

The above research papers give following conclusions;

The building designed using Eurocode performs better comparing to Indian standard (IS1893:2002) and American (ATC40 and FEMA440) codes. Hence Indian and American code needs improvement in performance based design.

Frame with shear wall performs better and the base shear increased by 9.82% when compared to the frame without shear wall. Shear wall performs better to lateral displacement and it reduces by 26.7% when compared to the frame without shear wall.

The ductility of SMRF buildings is more than the OMRF buildings, the reason being the heavy confinement of concrete due to splicing and usage of more number of stirrups as ductile reinforcement. The base shear capacity of OMRF buildings is 7 to 28% more than that of SMRF buildings. So it is necessary to increase strength and stiffness of building to withstand seismic loads.

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