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A Review on Comparison of Seismic Behavior of RC Structures Using Various Codes

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ABSTRACT

The seismic design of building is made to withstand the earthquake effect without the loss of life and property. The design of structures according to provision of seismic code provides adequate safety against the seismic forces due to earthquake. Seismic codes are unique to particular region. The comparisons of the static and dynamic analysis on various types of structures using various codes are performed. It figures out the variations that occurs in parameters such as displacement, base shear, storey drift, axial and shear force, bending moments while using different codes. This paper presents a review on seismic behavior of various structures using various codal provisions as given in Indian Code, American code, European code, New Zealand code for earthquake analysis.

Highlights

- The seismic behavior of various structures was compared using various codes namely-Indian Code, American code, European code, New Zealand code for earthquake analysis.
- The building designed by considering Euro code was conservative than the buildings designed using other codes.

Keywords: Base Shear, Storey Drift, Displacement, Axial Force, Seismic Analysis.

In general, all structures are primarily designed for force to carry the gravity loads. During the earthquake, the ground shakes in all three directions- along the two horizontal directions and the vertical direction. The building resting on the ground will experience the motion. The vertical acceleration induced by ground motion either adds to or subtracts from the acceleration due to gravity. In the design of structures, use of factor of safety to the gravity load provides adequate resistance against vertical ground motion. The structures designed to carry gravity loads are able to resist vertical motion, may not be able to resist the horizontal motion. Therefore, it is necessary to build earthquake resistant structures for adequate safety of the structures against horizontal ground motion.

The seismic design of structures is to withstand the forces and deformations generated due to ground motion caused by earthquake. To make earthquake resistant structure, structures must be analyzed and designed to meet the requirement of seismic code. The structures designed as per seismic code will be capable to resist horizontal and vertical motion. The earthquake resistant structures will survive during earthquake with minor damage of structural components. Therefore, an engineer must have knowledge of seismic codes. Countries throughout the world have their own code of practice for earthquake resistant structures. The building are analyzed, designed and detailed as per that seismic code.

Structures designed according to seismic code are intended to withstand the largest expected earthquake at least once occurring at that location during the design period of structures. Seismic codes are varying with different location so these are unique to particular region or country and the factors such as local seismology, accepted level of seismic risk, building typologies, materials and methods used in construction are considered. Seismic codes are representative of development of any country, made in the field of earthquake engineering. Seismic codes have progressed significantly over the year due to the contribution of practicing engineers, as well as academic and governmental researchers. The progress depends on the improvement of the representation of ground motion, soil type and structure.

To sustain operations of important structures, to protect the lives and to limit the damage from worst conditions occurred during earthquake, seismic code provides the provisions for designing and constructing the buildings in the seismic area. Seismic provisions have several parameters which can be used to improve the performance of the structures during earthquake. The various seismic codes are significantly different in specifying the limits on various control parameters. If a building is designed for a given seismic region, using different seismic design codes, it is expected that the seismic performance of a building will vary significantly. Due to this reason, there is a need to conduct comparative studies that may lead to the harmonization of different international seismic design codes and added up the crucial step in the process of evolution of the next generation of design codes.

The earthquake resistant structures will survive during earthquake with minor damage of structural components. To make earthquake resistant structure, there are requirement of an engineer who have sound knowledge of various seismic codes. Many academic and governmental researchers have worked and contributed their efforts for the evaluation of the various seismic codes. The analysis and design of various structures using the various codes was done by researchers. The evaluation of seismic performance was done by limiting the parameters according to the provision of various codes. This paper gives an overview of some paper published in international journals around the world and gives summary about the articles and papers found in the literature, about the comparison of various international and national codal provisions.

Review of literature Waris *et al.* (2017) compared the recently developed Oman seismic code (OSC), Uniform Building Code 1997 (UBC) and International Building Code 2006 (IBC). In the present paper, the base shear has been compared with lateral force distribution obtained from the three seismic codes using equivalent static load method. Three types of buildings were used for comparison- 4 storey building having height 17m, 10 storey building having height 41m and 14 storey building having height 57 m. OSC provided much smaller value of base shear for both seismic zones and all building heights as compared to UBC and IBC. For high seismic zone, base shear using UBC and IBC were 3.2 - 7.6 times and 2.6 - 6.3 times higher than OSC, respectively. For low seismic zone, UBC provided base shear 3.3 - 7.8 times that of OSC, while IBC provided 2.4 – 5.8 times of OSC. It also observed that base shear reduced with building height for both international codes, while UBC gave relatively higher ratio for low seismic zone and IBC showed larger ratios for high seismic zone. The lateral force distribution followed the same pattern as shear force but in case of UBC, there was slight difference for the top storey. It can be concluded that the both UBC and IBC provided highly conservative seismic loads on buildings compared with OSC. Therefore, it was need of implementation of the national seismic code to make the seismic design more realistic and economical.

Indumathi and Saravanan (2016) evaluated the performance of G+9 reinforced concrete frame structure subjected to earthquake forces in severe condition. The reinforced concrete structure was designed as per IS1893: 2002 and then analyzed for seismic lateral loading as per IS 1893:2002, ASCE 7-10, NZS 1170-2004 and EUROCODE 8-2004 using ETABS 2013 v 13.1.1. Maximum storey displacement in 3D frame structure in descending order in Bare frame model, stiffen columned in soft first storey and Infill wall at corners of soft first storey respectively for Indian, American, New- Zealand and European Standards loading. Similarly in 2D frame maximum storey displacement and maximum storey drift gave the same results. Hence use of infill walls at corners of soft first storey gives good resistant to lateral force. Further, on comparing ETABS results of Indian, American, New- Zealand and European Standards, Base Shear values were in descending order of European > New Zealand

> American > Indian standards. Base shear value as per Eurocode was about 9 times greater than Indian Standard. Factors like Seismic zone factor, Importance factor, Response reduction factor, Fundamental period and total mass of the structure varied from Standard to Standard. So, the base shear values were also different. Therefore, it also affected the deformation of building.

Khan and Prasad (2016) compared the seismic behavior of multistorey RC building using provisions made in Indian code i.e. IS 1893 2002, American i.e. IBC 2006 and Australian code i.e. AS 1170 2007 by considering residential building G+ 5 storey as reference. This study describes the variations in the results obtained using three codes, particularly in design base shear, lateral loads, drifts and area of steel for structural members of RC buildings. The ordinary moment resisting frame was modeled and equivalent static method analysis was performed using STAAD Pro software. It inferred that design base shear as per IBC code was more than IS 1893 and AS 1170. Its value for IBC code was approximately double of IS 1893 and value for AS 1170 was 70% of IS 1893. The Column moments for IBC code were nearly 150% for below plinth and Ground Floor, 130% for second floor and110% for top floor than that of IS 1893 and for AS 1170 its values were nearly 80 - 85% of IS 1893. The axial loads on column for IBC code and AS 1170 was less than IS 1893. The beam moments and beam shear forces for IBC code were approximately120% of IS 1893 and for AS 1170 were approximately 80% of IS 1893. The lateral displacement and storey drift values was more in IBC code. It also depicted that building design using IBC code would be more conservative than IS 1893 and AS 1170 codes because the area of steel required for the RCC members for IBC code would be more than IS 1893 and AS 1170 codes.

Dhanvijay *et al.* (2015) considered the standards of Eurocode, IBC (American Society of civil Engineers) and Indian code i.e. IS 1893:2002 for analyzing the poor performance of building during earthquake. The structure modeled in STAAD Pro. V8i software was G+10 Special RC moment-resting frame and Lateral seismic forces were calculated manually as per different codes. A comparative analysis was performed in terms of base shear, displacement, axial load, and moments in Y and Z direction for columns and also for displacement, shear Y, torsion and moment Z of beams on each floor. Conclusion was drawn that base shear in X direction was 5.53% less and 38.52% more according to IBC and Eurocode respectively than Indian code and in Z direction, IBC showed 5.7 % less base shear and Eurocode showed 30.47 % more base shear than Indian code. The displacement, axial force and moment in Y and Z direction for columns were more in Indian code as compared to others code. Also, the displacement, moment-Z, shear-Y and torsion for beams as per Indian code were more compared to other codes.

Karthiga *et al.* (2015) analyzed and designed a residential building (G+10) for seismic forces using four international building standards- IS1893, Euro code 8, ASCE7-10 and the British Codes. The analysis of the building was done using STAAD. Pro.V8i. then designed as per the specified codes. The seismic performance of the building was investigated by pushover analysis in SAP2000. The base shear as per Indian code was optimum. As compared to Indian standards, Euro standards had 3.05%, American standards had 11.10% and British standards had 12.25% less base shear. The displacement occurred as per Indian standards was less than as per others code. This study can inferred that the Euro standards served to be the most economical design and the Indian Standards were the least economical because building designed according to the Indian standards was more rigid and thus it attracted more seismic forces.

Bari and Das (2014) performed a comparison between Bangladesh National Building Code (BNBC), National Building Code of India 2005 (NBC-India 2005) and American Society of Civil Engineering 7-05 (ASCE 7-05). This study gives information about safety required against earthquake. The various parameters were studied in BNBC 2010 and compared with that of BNBC 1993, NBC-India 2005 and ASCE 7-05. From exploration, it was enumerated that BNBC 1993 had the least base shear among all the codes. The base shear as per BNBC 2010 was found to have increased significantly than that of BNBC 1993 for low rise buildings. But BNBC 2010 had less base shear value as compared to ASCE 7 05 for low storied buildings and are relatively closer to NBC-India 2005. Therefore, the higher factor of safety against the earthquake given by BNBC 2010 code due to higher values of base shear was appreciable. But higher reinforcement required in ground floor column of low storied buildings than BNBC 1993.

Landingin *et al.* (2012) compared the seismic provisions of three seismic design code that are the Philippine code (National Structural Code of the Philippines or NSCP2010), the European code (Eurocode 8 or EC8), and American code (2009 International Building Code or 2009 IBC). Two regular and irregular reinforced concrete (RC) frames were analyzed and compared. The structural models of RC frames were created and response spectrum analysis was performed using SAP2000 software package. Using the NSCP 2010 response spectrum function, maximum base shear, story shear, axial loads and bending moments were obtained as compared to other codes. The results obtained by using EC8 revealed that columns required an additional 20% to 40% reinforcement as compared with NSCP 2010 and 2009 IBC. However, overall increment in the reinforcement ratio was observed due to the irregularity in the frames. In EC8, in the load combination cases, earthquake action effects were considered in both directions and this was not considered in the NSCP 2010 and 2009 IBC. Therefore, it concluded that the RC buildings designed using the EC8 can be considered conservative than the buildings designed using the NSCP 2010 and 2009 IBC.

Imashi and Massumi (2011) analyzed the seismic forces calculated by the static analysis method according to both International Building Code (IBC 2003) and in the Iranian Seismic Code (IS 2800-05). The design base shear of a building with combined system (special moment steel frames + eccentric bracings) in four different soil types and vertical distribution of base shear at story level was determined according to both codes. The results proved that there was significant difference between the two codes. Shear force values were more in IS 2800-05 as compared to the IBC 2003 for all type of soil profiles and seismically active areas. Lateral force distribution in the building height showed that distribution pattern was different among the two codes. In IS 2800-05, force distribution in the height was linear for all structures and all periods but an additional force was applied to the top floor of long period buildings. In IBC 2003, there was no additional force considered and vertical force distribution for all structures with period greater than 0.5s was parabolic. The IBC 2003 recommended the story drift limitation according to structural system type and importance factor value. In IS 2800-05, the story drift limitation was dependent only on fundamental period of the structure. So, there are need to review the IS 2800-05 and develop more appropriate relations onwards achieving economic and functional objective.

CONCLUSION

The comparative study was carried out between the different design codes as reported by different researchers. The seismic performance of building was analyzed by them and designed using various codes. The seismic forces by the different method such as response spectrum method, pushover analysis, equivalent static analysis etc with various codes gave different results. This comparative study helps to check the code which serves as economical and reliable for seismic design and analysis of building.

A comparative analysis was performed by earlier researchersin terms of base shear, displacement, axial load, and moments in Y and Z direction for columns and also for displacement, shear Y, torsion and moment Z of beams on each floor using the various code. The building designed by considering Euro code c was conservative than the buildings designed using other codes. Euro code used for designing was served to be the most economical as compared to others codes.

REFERENCES

Bari, M.S. and Das, T. 2014. A comparative study on seismic analysis of Bangladesh national building code (BNBC) with other building codes. *J. Inst. Eng. India Ser. A.*, **94**: 131–137.

Dhanvijay, V., Telang, D. and Nair, V. 2015. Comparative study of different codes in seismic assessment. *Int. Res. J. Eng. Technol.*, **2**: 1371-81.

Imashi, N. and Massumi, A. 2011 A comparative study of the seismic provisions of Iranian seismic code (standard no. 2800) and International building code 2003. *Asian J. Civil Eng.*, **12**: 579-96.

Indumathi, K. and Saravanan, G. 2016. Comparative analysis of soft storey mechanism using different codal standards. *Int. J. Scientific Res. Dev.*, **4**: 778-83.

Karthiga, S., Titus, H.E., Hazarika, R.R. and Harrish, M. 2015. Design and comparison of a residential building (G+10) for seismic forces using the codes: IS1893, Euro code 8, ASCE 7-10 and British code. *Int. J. Res. Eng. Technol.*, **5**: 205-09.

Khan, S.A. and Prasad, R.V.R.K. 2016. A comparative study of seismic behaviour on multistoreyed RC buildings by the provisions made in Indian and other International building codes. *Int. J. Eng. Dev. Res.*, **4**: 1967-73.

Landingin, J., Rodrigues, H., Varum, H., Arêde, A. and Costa, A. 2012. Comparative analysis of RC irregular buildings designed according to different seismic design codes, *15th International Conference on Experimental Mechanics.*

Waris, M.B., Jabri, K.S.A. and Hussain, I.E. 2017. Comparison of oman seismic code for buildings with international Counterparts, *16th World Conference on Earthquake.*