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Review Article

A REVIEW PAPER ON COMPARISON OF DIFFERENT COUNTRIES REINFORCED CONCRETE BUILDINGS DESIGN CODES

Reena Dagar*., Tabish Izhar., Syed Abdur Rab and Mohammad Zakaria Siddiqui

Department of Civil Engineering, Integral University, Lucknow(U.P.), India

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ABSTRACT

A building code, is a set of rules that specify the minimum standards and laying down the guidelines for the design and construction of structures. Thus these Design codes are the most important and basic tools for structural design engineers. Diversity of codal provisions for countries worldwide leads to problem when engineers have to move from one country to other. Thus knowledge of main features commonalities and differences of various code of practice is necessary to form a common platform for structural design throughout the world. This paper reviews the efforts being made by various researchers worldwide to compaire the RC building design codes. The review study shows that work has been done by taking various countries. Comparison work has been done in terms of load comparison such as seismic load, wind load and strength parameters for various elements of the building such as beam, column, slab etc.

INTRODUCTION

Different countries have formulated their own codes for laying down the guidelines for the design and construction of structures. These codes came into picture after a collaborative effort of highly experienced structural engineers, construction engineers, academicians ant other eminent fellows of respective areas. These codes are revised periodically based on current research and trends (e.g.IS456:1978 and IS456:2000).Codes serves the following objectives/purposes:

They ensure structural stability/safety by specifying certain minimum design requirements. They make the task of a designer rather simple by making available results in the form of tables and charts. They ensure a consistency in procedures adopted by the various designers in the country. They protect the design against structural failures that are caused by improper site construction practices i.e. codes have legal sanctity and one can have a stand on the basis of these design codes

Various countries around the world follow different methodologies in building design thus there are many design codes that are build across the world. Comparison between these building codes will help to form a most effective and economical building design. Research work in this respect is being done all around the world to remove the barriers for design engineers to move and work in any country of the world.

LITERATURE REVIEWS

Present scenario reveals that technology and its application has no boundary or cannot be country specific. Because of this researchers and technocrat are trying to make the thing easy implementable and accessible irrespective of boundary and locations. In this regard few developments on codal provisions and their implications in research are addressed here.

Ali *et al*. (2012)[1] made a comparative study on the amount of reinforcements required in a rectangular beam subjected to combined loads using ACI code and BS code. The research reveals that amount of reinforcement required using BS code was less than ACI code when factor of safety was not included. Keeping safety criteria into consideration excess reinforcement may be uneconomical. The research was also extended to flat slab-columns and found out that the punching shear strength and flexural reinforcement is more using ACI code while shear reinforcement is more using BS. The paper concludes that BS code is preferred over ACI for lower reinforcement requirements.

Rao and Injaganeri (2013)[2] carried out an experimental study for the evaluation of minimum shear reinforcement in reinforced concrete beams using ACI 318, IS, BS, Canadian

Corresponding author:* **Reena Dagar
Department of Civil Engineering, Integral University, Lucknow(U.P.), India

code and American Association of State Highway and Transportation Officials (AASHTO). The study revealed that minimum shear reinforcement varies with the compressive strength of concrete as per ACI 318, Canadian code and American Association of State Highway and Transportation Officials(AASHTO)but as per IS and BS code it varies with the yield strength of shear reinforcement.

Ameli and Ronagh (2007)[3] reviewed the provisions of the current standards in relation to torsion of reinforced concrete beams and found that except for ACI all other standards such as EC2, Canadian code and Australian code had predicted the torsional capacities conservatively. The paper revealed that EC2 and Canadian code were more successful in predicting the ultimate torques compared to other standards. The paper concluded that Australian standard was the least deviated and its conservativeness can be trusted more confidently as compared to others.

Chee Khoon Ng *et al*. (2006)[4] compared BS 8110 and EC2 taking into account both concrete cube strength and cylinder strength for beams reinforced with mild steel or high yield steel and found similar values. The slight differences are due to steel reinforcement provisions and concluded that either of the codes can be used.

N.Karthiga Alias Shenbagam, N.Arunachalam(2017)[5]worked to find the cost design of RC tension with varying conditions using the Artificial Neural Network. Design constraints were used to cover all reliable design parameters, such as limiting cross sectional dimensions and; their reinforcement ratio and even the beahviour of optimally designed sections. The design of the RC tension members were made using Indian and European standard specifications which were discussed. The designed tension members according to both codes satisfy the strength and serviceability criteria. While no literature is available on the optimal design of RC tension members, the cross-sectional dimensions of the tension members for different grades of concrete and steel, and area of formwork are considered as the variables in the present optimum design model. A design example is explained and the results are presented. It is concluded that the proposed optimum design model yields rational, reliable, and practical designs.

N. Subramanian (2005)[6] In this paper, the existing recommendations in design codes for punching shear failure of slabs are reviewed. Though the Indian code formulae predict the punching shear resistance of high strength concrete slabs as compared to the experimental results, they do not consider the reinforcement ratio and size effects. Hence, a formula similar to that of CEB-FIP code formula is suggested. Out of the several methods to enhance the punching shear capacity, the stud shear reinforcement is found to increase the load carrying capacity, punching shear strength and ductility of flat slabs. Recent provisions in the American code allow 100 percent enhancement of shear capacity if shear stud reinforcements are used.

Jaime Landingin, Hugo Rodrigues, Humberto Varum, António Arêde and Aníbal Costa(2013)[7] This paper presents a comparison of seismic provisions of three seismic design codes, the Philippine code, Eurocode 8 and the American code, to the most common ordinary residential frames of standard occupancy. Regular and irregular reinforced concrete frames were analyzed and compared for four storey building types. The response spectrum and the seismic parameters of NSCP 2010 were considered for the horizontal load action with different load combinations. Response spectrum analysis and equivalent lateral force analysis were performed using SAP2000 software package. Five representative columns for each RC frame structure were analyzed. Based on the results of column axial load - bending moment interaction diagrams, EC8 was found to be conservative when compared to NSCP 2010 and 2009 IBC. The conclusion is that for the design and analysis of ordinary RC residential buildings with certain irregularity, EC8 provisions were considered to be safer.

Swajit Singh Goud, Chenna Rajaram & Ramancharla Pradeep Kumar(2016)[8] In the present paper a comprehensive literature review on the design strength of materials, stress stain curve for concrete, steel and confined concrete, partial safety factors and limitations/recommendations for usage of concrete grade and reinforcement steel grade in design provisions of Indian Standards, American Standards, European Standards, New Zealand Standards, Japanese Standards and from the latest available literature is done. Change in material properties with time for estimating the existing strength, effect of curing temperature on strength of concrete and tensile strength of concrete are some major points need be incorporated in design codes. The provisions of the above parameters in design codes such as American, European, New Zealand, Japanese and Indian Standards are studied in the present paper and also the importance of these parameters is discussed in detail.

Falak Parikh and Vimlesh Agarawal, (2013)[9] This paper presents critical review of recommendations of well established codes regarding design column depth and shear strength aspects of beam column joints. The codes of practice considered are Draft code IS13920-1993, NZS 3101: Part 1:1995 and the Euro code 8 of EN 1998-1:2003. Draft code 13920-1993 requires smaller column depth as compared to the other two codes for satisfying the anchorage conditions for interior and exterior joints. The effect of higher concrete grade in reducing the column depth has been included in EN 1998-1:2003 and NZS 3101:1995. The requirement on the depth of column in interior joint is more compared to that in exterior joint. The criteria for minimum flexural strength of columns required to avoid soft storey mechanism is very stringent as per NZS 3101:1995 while the other two codes recommendations are comparable.

C. U. Nwoji and A. I. Ugwu (2017)[10] This work was undertaken to compare the use of BS 8110 and Eurocode 2 in the design of structures and focused on outlining the relative gains and/or shortcomings of Eurocode 2 and BS 8110 under certain criteria which are loading, analysis, ease of use and technological advancement. To accomplish this, the analysis and design of the main structural elements in reinforced concrete building was undertaken using the two codes. A modest medium rise building was loaded using the two code and analyzed. Analysis was done using CSI start tedds to obtain the shear force and bending moment envelopes. For the beam, it was found that Eurocode 2 gave higher internal supports moments. For the case of maximum span moments and shear force values, the Euroode 2 values lagged behind. Column load and moments values were generally lower for Euroode 2. In summary, the comparative benefits of using

Euroode 2 are that it is logical and organized, less restrictive and more extensive than the BS 8110. The new Eurocodes are claimed to be the most technically advanced code in the world and therefore should be adopted by Nigerian engineers.

Entidhar Al-Taie, Nadhir Al-Ansari, Sven Knutsson(2014)[11] This paper reviews some national codes (Egyptian, Syrian and Arabia Saudi) were done as well as comparison between load's correction factors, geotechnical requirements and materials used in concrete. Most of the national codes were highly based on the ACI, British and Germany codes and standards. In addition, a review and comparison were presented for International codes (American (ACI) and European (EC)) through a case study. EC code is becoming more common for the world. Eurocode gives more flexibility to the user to employ their own standards (national annex). To find the best suitable foundation design to be used in Iraq and the differences when using the American and European codes, a building model was designed and analyzed using STAAD Pro., and SAFE softwares for three locations (Mosul, Baghdad and Basrah). The combination loads used in the two softwares were for ACI and EC codes. Results obtained were very similar.The type of foundation to be chosen for Mosul location is spread or continuous. For Baghdad location the suitable type is raft and for Basrah the choice is raft and piles. In view of the fact that Iraq has no national code, engineers and designers were depending on the ACI and British codes and standards. It is very important to have an Iraqi code because it will improve the quality and safety of the design and construction of buildings as well as its economic value.

S.S.Patil, Rupali Sigi (2014)[12]This paper consist of the analysis of flat slab executed by Direct Design Method (DDM) & Equivalent Frame Method (EFM) as directed by different standard, however the Finite element analysis & Equivalent frame analysis is carried out by using software SAFE (Slab Analysis by Finite element method and Equivalent frame method). The analysis & design is performed by Equivalent Frame Method with staggered column & without staggered column as prescribed in the different codes like IS 456-2000, ACI 318-08, BS 8110-1997, EC2 Part1 2004 are compared. In this process moments are distributed as column strip moments & middle strip moments. The methodology for analysis & design of slab is thoroughly explained in the paper. Equivalent frame analysis is also carried out for distribution of column strip moments & middle strip moments by using software SAFE. Excel worksheets for analysis and design of flat slab using equivalent frame method for all standard codes are also prepared.

Ankita Suman Mohanty and Aloke Kumar Datta (2015)[13] In this research, a comparative study on the amount of required flexural reinforcements was conducted using Indian Standard (IS), British Standards Institution (BS), European Standard (EC2), and American Concrete Institute (ACI). The comparison included design case of rectangular beam subjected to bending for different spans and loads on the beam. It was found that EC2 require less reinforcement as compared to the other codes. The study showed that the difference is due to the variation of load safety factors for different codes. . In addition the comparison included, combined action of shear and flexure for the reinforced concrete beams. With the increasing Mu/Vu ratio the difference increases up to 60% for shear reinforcement and 20% for flexure reinforcement proposing EC2 requires lesser area as compared to other codes.

Nikolai A. Popov,(2000)[14] In this paper the main features of Russian wind load code are shown in comparison with requirements of some national and international codes. All parameters of average and gust loads: the basic wind pressure, importance factor, territory coefficient and shape factor as well as a dynamic coeffcient, are discussed here. Besides, for four structures the ``theoretically'' exact dynamic coeffcient that was numerically found is compared with its value drawn from the considered codes. It is shown that, at least, for these structures, Eurocode underrates the gust response and, on the contrary, Russian code overstates the one in the most cases.

Karthik N, Varuna Koti(2017)[15]In this a comparative analysis of dynamic loads are carried out on these high-rise structures using various International Standard Codes (American, European and Indian), with the inclusive of recently developed IS 1893:2016 has been done.

Asmita Ravindra Wagh, P. J. Salunke, Prof. T. N. Narkhede (2016)[16] This study focuses on comparison of International standards. An Illustrative study of Seismic design and assessment of a High-Rise Structure using different International Codes is performed. The objective of this study is to investigate the differences caused by the use of different codes in the analysis of a High-Rise building. The parameters such as displacement, base shear, storey drift, time period, axial and shear forces, bending moments are studied to figure out the variations that occur while using different codes. An interest develops to carry out the seismic design of a high rise building using various codes to understand which codal provisions give effective designs to perform good during an earthquake crisis. This paper is intended to compare the design of High rise structure with different International codes. In R.C. buildings, frames are considered as main structural elements, which resist shear, moment and torsion effectively. These frames are subjected to variety of loads, where lateral loads are always predominant. The study of papers published so far helps in understanding the major contributing factors that lead to poor performance of Structures during an earthquake, so as to achieve their adequate safe behaviour under future earthquakes. A comparative analysis can be figured out in terms of Base shear, Displacement, Axial loads, Moments and Displacement.

N.P.K.V. Karunaratne, MR Niranga1 and H.P. Sooriyaarachchi, K.S Wanniarachchi(2012)[17]This paper presents various features of Recode, the learning tool developed to teach beginners how to do design under different standards and the experienced, how to adopt to changing scenarios to which their designs have to be confirmed.

N.Arunachalam, S.Ashmi (2012)[18] In this paper provisions of Indian (IS 456: 2000), European (EC2 - 1992) and American (ACI 318) codes of practice for the design of RC columns have been critically studied. As per the recommendations of Indian, European and American codes of practice, RC rectangular columns have been designed adopting limit state method for all designs. The total cost of columns has been calculated and is compared using bar chart. It is found that the total cost of the column is less when Indian code of practice is adopted.

Ali Abdul Hussein Jawad(2006)[19] This paper compare design requirements of the structural building codes from safety and economical point of view. Three different famous structural building codes have been adopted. These are the ACI 318M-02, BS8110:1985, and Euro Code2:1992. These codes have been compared in the strength design requirements of structural elements. The comparison include safety provisions, flexural design, shear design, and column design. Throughout this study elaborated design models and criteria of the considered codes have been exhibited. Although the principles contained in these codes are basically the same, they differ in details. The comparison between results has shown that EC2 is more liberal in partial safety factors and strength design than ACI Code. After following this study, design engineers will discover easily that the transition among codes is not a difficult process.

S.Karthiga, Hanna Elza Titus, Reetwiz Raj Hazarika, Mohamed Harrish(2015)[20]This paper presents with the analysis and design of a 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. The building was then designed as per the specified codes. Once the design was completed a pushover analysis was done in SAP2000 to check the seismic performance of the building. A comparative study between the design and the seismic performance of the building was done.

Labani Nandi(2014)[21]this paper is intended to compare the design of reinforced concrete structure with various International codes from economical point of view. Three different famous structural building codes have been adopted. These are the IS456:2000, BS8110:1985, and Euro Code2:1992. These codes have been compared in the strength design requirements of structural elements. The comparison include shear design. Throughout this study elaborated design models and criteria of the considered codes have been exhibited. Although the principles contained in these codes are basically the same, they differ in details.

Mourad M. Bakhoum, Sherif A. Mourad, Maha M. Hassan(2015)[22]In this paper building design codes from USA, Europe, and Egypt are considered. Comparisons of the provisions for actions (loads), and for the resistance (strength) of sections in flexural and compressive axial loading are carried out. Several parameters are considered including variable actions for occupancy and different material strengths. The comparison is made considering both concrete and steel structures. Issues and consequences of mixing actions from one code and resistance from another code are also discussed. Three building design codes and the corresponding codes for actions are considered. It was shown that comparing variable actions and ultimate resistance of sections separately is useful; however, including the combined effect of both actions and resistances as stipulated by different codes is crucial for better comparison. There are many similarities between design codes in concepts and design formulas.

CONCLUSION

Based on the literature review it is clear that numerous researcher have worked on various provision of codes. However the comparisons were limited to few provisions and codes. No study was found in the literature review which has the purpose of forming common platform for concrete codes worldwide so that barrier of working in any country for design engineers can be removed.

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