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Review on Comparative Study of Design of Structural Member of RC Building on Code for Different Countries

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ABSTRACT: Construction is a vital part of every developing country in this era. Every country has specific building design codes which provide the standards to engineers for the design of various structural components like beam, column and slab. RC building design of every country is based on their geographical location. In today world of globalization, an engineer must be efficient to understand and handle codes of various countries. Considering this the main focus of this research work is to bring out differences and similarities between different RC design codes and to use it to develop a common platform. In this research RC design code of USA, EUROPE, INDIA, JAPAN AND IRAN are considered. The main focus is the relative gains and shortcomings of various buildings design codes under certain criteria like loading analysis, design analysis, ease of use and economical point of view. Several parameters for different cross-section and different building material on basis of strength are considered. Comparison work has worked out on the basis of loading comparison like live load, dead load, wind load and different parameters for various elements of the building such as beam, column and slab. Load factor and load combination are also compared. This comparison investigates the design capacities for various building design codes.

KEYWORDS: Building codes, Structural Design, Loading Case, Beam, Column, Slab.

I. INTRODUCTION

Structural design is an art and science of understanding the behaviour of structural member subjected forces and loads and designing them with economy and elegance to give a safe, serviceable and durable. The structural design of buildings of any country is based on certain codes of practices which provide the essential data and standards in analysing and designing the structure from strength point of view and economical point of view. These codes are carried out by highly experienced structural engineers, academicians and other eminent fellows of respective areas. This paper concerned the comparison of nominal loads, load combination, load factor, design parameters like beam, column and beam and their suitability from various building codes. The use of different design methods and codes provide different results in structural analysis and design that leads to variability in behaviour, costs and durability of structures. Such study provides lots of information related to structural design that at what extent one country code is differ from another country code in terms of level of accuracy, safety, complexity and details. So, it is the responsibility of structural engineer to provide accurate standards that lead to optimum performance and economy by regarding the most appropriate design method. Such creative ability and imagination is totally based on experience of structural engineers. The structural design process involves structural planning, action of forces and loads, member analysis, member design, comparison among different buildings codes and their detailing. It reviewed that those countries where more than one code is adopted for structural design so it is helpful in determining that which code has higher factor of safety and degree of accuracy than another.

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II. LITERATURE REVIEWS

The building code provides guidelines for the professional and practitioners on design, analysis and construction of concrete structure, quality control of reinforced and pre-stressed concrete building and structure where the concrete is made with normal weight aggregates. It covers the requirements for strength, serviceability, durability and fire resistance. In this regard few developments on codal provisions and their implications in research are addressed here.

C. U. Nwoji and A. I. UGWU (2017)[1]:-Compare the BS 8110 and Eurocode2 in the design of structures to find out the relatives gains and shear loading of Eurocode2 and BS8110 under following's criteria like loading analysis , ease of use and technological advancement. They investigate that for beam Eurocode2 gave higher internal supports moments. For the case of maximum span moments and shear force values, the Eurocode2 values logged behind. Column load and moments value are generally lower for Eurocode2.with respect to maximum span moments, the Eurocode2 moments are lower than the BS 8110 values while for support moments in the continuous beam, the Eurocode2 moments supersede the BS 8110 moments. Euro code is more flexible, safer and more economical given the number of load conditions taken to get the moments and shear force envelopes. With respect to foundation load (service) the EC2 moments are higher than the BS 8110 values and hence larger bad area areas while for ultimate load, the EC2 moments are lower than BS 8110 values. At last they found the Eurocode2 is easier to use will provide more economical section and is technologically more advanced than BS 8110.

Mourad M and Bakhoum et al. (2015)[2]:-Considered the building design codes from USA, ACI, EUROPE, and Egypt are considered. Comparison is carried out for different parameters like action (loads) and for the resistance (strength) of section in flexural and compressive axial loading. The comparison is made for both from concrete and steel structures. Differences not only are observed in the safety factor used in calculating the resistance of different section, but they also impose actions in different design codes. Large different in live load intensities were noticed after comparing the values stipulated in different codes. They investigate that Egyptian code stipulates values that are some are the European code except for office building. The Egyptian standards generally yield the largest section dimensions with the heaviest values of steel reinforcement. For steel flexure components; the Egyptian standards yield the largest ultimate load combination and the lower sectional capacity. For steel columns, the axial capacity calculated by EC3 is larger than AISC-360-10 and ECP203-2007 by percentage between 1.6% and 45%.

Labani nandi, Priyabrata guha (2014)[3]:- used three different famous structural building codes like IS, BS and EC to compare the design of reinforced concrete structure from economical point of view. Although the principles contained in the considered the grade of concrete is same for three codes differ in grade of steel. They found area of steel for slab is maximum as per IS code than BS and EC, area of steel for beam is maximum as per EC code than IS and BS, area of steel for column is maximum as per BS code than IS and EC and area of steel for foundation is minimum as per IS than BS and EC.

A. C. Nwofer (2015)[4]:- Compare BS8110-97 and Eurocode2 for the design of reinforced concrete beam with a particular interest on the area of tension and shear reinforcement required from economical point of view. For the analysis and design, a six- span continuous beam from the roof of a three story shopping complex with the help of programmed excel spread sheet. The self-weight of the beam was taken as the dead load while the live load was assumed to be unity. They found that Eurocode2 require less amount of tension reinforcement at span as well as support as. The average percentage of both cases is 3.08% and -2.83% respectively. The percentage of shear reinforcement for BS 8110 is more than Eurocode2. For the combination of dead load and impose load are considered, average percentage difference for the span moments of the BS8110 exceed that of the Eurocode2 is more conservative in terms of the partial factor of safety for loading. For a combination of live and dead load considered in this study, the BS8110 required about 1.3% more of the ultimate design loads than that of the Eurocode2 .thus Eurocode2 is more economical design with the required margin of safety.

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Satya Prakash Mishra (2012)[5]:- presented a comparison of mix design procedures of IS method, BS method and ACI method. It was observed that water-cement ratio is highest for BS method and lowest for IS method and water-cement content in BS method is less as compared to other two methods. The highest amount of cement is used in IS method whereas lowest in BS method. The total aggregate content and the aggregate cement ratio in BS method is much high as compared to other two methods. The percentage of fine aggregate content in ACI method appears to be more consistent and it also contributed to the increased strength. The mixes designed by BS method failed to achieve the target mean strength. The main reason of failure appears to be due the use of high water-cement ratio, less amount of water content, less amount of cement content and higher amount of aggregate content. The mixes designed by IS method and ACI method achieved the target mean strength, which indicate that these methods are more consistent.

C. M. Chan, M. F. Huang (2010)[6]:- reviewed that taller and irregularly shaped buildings are potentially more sensitive to wind excitation. Performance-based-design (PBD) is a modern approach to design of building structure. This paper comprises a computer based technique for optimal wind resistant performance-based-design of tall building under various levels of wind hazard. A rigorously derived optimality criteria (OC) method is to be developed to solve the optimal structural solution satisfying the strength (life-safety), drift (damage) and acceleration (occupant comfort) design performance constraints. This paper also conclude an integrated wind-induced dynamic analysis and automatic performance-based design optimization technique for minimizing the structural cost of tall building subjected to multiple wind-resistant serviceability performance design criteria.

Alica E. Diaz De Leon (2010)[7]:- Showed that building codes is the primary source for guidance in the design and construction of building structures for many decades .A sound knowledge and proper application of building design and construction is very essential while performing a forensic investigation. This paper reviews the organizational structure of both codes and will present a comparative example using the structural design provisional of both codes. It is also covers the load combination case for both IBC and NBCI. The main difference between two codes is that IBC allows seismic design criteria to be established much earlier in the design process but in NBCI, seismic load are calculated through the map of zoning map. In summary, IBC's seismic provisional are more performance based whereas NBCI's seismic provision are based more on empirical data.

Ali S. Alnuaimi et al. (2013)[8]:- compare the amount of required reinforcement American Concrete Institute (ACI) and British Standard Institute (BSI) for the design of rectangular beam section subjected to combined loads of bending, shear and torsion, and punching shear in slab-column connection. It also includes the desired factor of safety for design loads. It was found that ACI required less reinforcement than BSI. The punching shear strength of flat slab-column connection was found more than BSI for same geometry, material and loading cases. The minimum area of flexural reinforcement as per ACI was found greater than BSI while maximum for shear reinforcement than BSI. BS curve is constant for all grade of concrete but ACI curve is constant for concrete grade of 30-40 N/mm² then reduces linearly for grades larger than 40N/mm². For different design loads, it was found that both the longitudinal and transverse reinforcements is lower for ACI method than BSI method. So, the ACI method is more preferred than BSI method from economical point of view.

Weizi Zhang and Bahram M. Sharooz (1999)[9]: -Used experimental data and analytical results with the help of two design codes ACI and AISC to find out the capacity of concrete filled steel tubular column (CFTs). The data was collected with the help of past studies and then testing of specimen of short and slender CFTs made with normal and high steel strength concrete. Residual stresses appear to nominally influence the response of CFT fibre analysis techniques is used for computation of capacities and iteration algorithm for analysing member with significant length. The reported study clarifies the difference between ACI and AISC is that the capacities from ACI and detailed analytical results are generally closer. The capacity also was calculated by reasonably detailed analytical techniques involving cross-section fibre analysis and numerical integration of the moment- curvature relationship along the length.

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Richard Fenwick, Gregory MacRae (2009)[10]:- describes the changes in the required design strengths, stiffness levels and capacity design provisions for the building in which reinforced concrete resisting moment frames provide lateral force resistance. The present data was compared with the corresponding 2009 design requirement for regular buildings in which lateral force is provided by the moment resisting frames. This paper provides lot of information related to seismic retrofitting of existing building to the engineers to show the different factors which should be considered in assessing existing structures against current design criteria. The comparison indicate that New Zealand codes in general required lower strength and stiffness levels for ductile moment resisting frame structures than the overseas code of practice.

Swajit Gaud et al. (2016)[11]:- present a comprehensive literature review on the design strength of materials, stress-strain curve for concrete, steel and confined concrete, partial safety factor and limitations of grade of concrete and grade of steel reinforcement as per Indian Standards, American Standards, European Standards, New Zealand Standards and Japanese Standards. The effect of high grade concrete on material properties and stress block parameters is not mentioned in IS code. With respect to time, the material properties which affects the strength of concrete, curing temperature in respect to strength of concrete and tensile strength of concrete is not properly mentioned. Only New Zealand has minimum and maximum value of concrete strength in seismic environment which is 20N/mm^2 and 70N/mm^2 respectively. The provisions of IS code are more close to New Zealand standards. From the above standards it was found that the recommended concrete strength lie between 20MPa to 50MPa and for steel it lies between 420MPa to 500MPa. The use of high strength concrete and steel in building construction has many advantages such as, increased strength of structures, reduced strength of cross-sections, more durable material and therefore substantial savings.

S. Karthiga et al. (2015)[12]:- present the analysis and design of G+10 for seismic forces using four international building standards IS1893, Euro Code 8, ASCE7-10 and British Code using STAAD.PRO.V8i. After the design of building a pushover analysis was done in SAP2000 to check the seismic performance of building. After the analysis it was found that maximum shear is obtained from IS code and it undergo minimum displacement than other standards.

Nadhir Al- Ansari et al. (2014)[13]:- reviewed the importance of code for short history, load correction factors, geo-technical requirements and materials used in concrete using some national building code of Egyptian, Syrian and Saudi Arabian. Most country codes are based on ACI and British code and a comparison was done between ACI and EC through a case study of foundation design, located at different location, which was designed and analysed by STAAD.PRO and SAFE software. Iraq has no national code to provide flexibility in building construction so generally ACI and EC standards are followed. The first code was Hammurabi code for safe building construction. Saudi Arabian code was the best code for middle-East because it includes all the requirements parameters for the buildings. From the case study it was found that bearing pressure is lower as per ACI code.

Rajmahendra Manikaro Sawant et al. (2015)[14]:- assess the effectiveness of steel fibre along with shear reinforcement in the formation of high grade fibre reinforced concrete. Direct shear test using push off specimens is used to find out the shear strength of concrete. Shear stress (strength) is calculated as the ratio of shear load per unit area of shear plane. The study was carried out on M60 grade of concrete to find out the workability, density and shear strength with different volume of concrete. The shear strength increased up to 29.42% and 28.76% at 7 and 28 days respectively over normal concrete at 1.5% fibre content. Fibre content reduces the deformation at all load levels, reduced spalling, maintain the ductility and overall integrity of the structure.

Shodolapo Oluyemi Franklin (2011)[15]:- used two famous international buildings code EC2 and BS8110 to analyse and design of beam element of four story building with the help of PROKON 32 programme. Using both codes, the emphasis was on examining bending moment diagram for the critical continuous beam span before the redistribution and after the 10%, 20% and 30% redistributions. It was found that the negative bending moment at internal support is lower for BS8110 than EC2 about 0 to 8.5% at all levels of moment redistribution but in case of maximum span

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moment the EC2 values is lowered than BS8110 about 4.5% to 9% for moment distribution up to 20%. In case of upper limit of shear force at supports the BS8110 exceeded the EC2 by 2.4% to 5.4% in general but for lower limit of shear force the BS8110's dominance was generally less than 2.5%.

Ibnu Rusydy, Muksin Umar and Lubna Alam (2018)[16]:- reviewed earthquake damage prediction in respect to magnitude and time through GIS model analysis for the UPLB's campus of Philippines. The study was done to produce an intensity map and earthquake model for the UPLB's campus to determine the damage ratio of building, to calculate the casualty in the UPLB's community and validate of earthquake model with historical earthquake in Philippines. A shallow crustal shaking attenuation was used to produce an intensity map on the bedrock and the surface after site coefficient correction. Fragility curve of buildings of Philippines was used to find out the damage ratio for different building. The obtained result shows that UPLB's building are subjected to intensity range of MMI (Modified Mercalli Intensity) 6.8-8.2 due to 6.1-7.7 Mw earthquakes coming from different sources. The validation results show that the mean square error between the calculated intensity and the actual intensity in Philippines is 0.35.

Jaime Landingin et al. (2013)[17]:- present a comparison of seismic provisions using three seismic codes of Philippines, Eurocode8 and American code for common residential frames of standard occupancy. A four storey regular and irregular building frame was analysed and compared with different country code. The response spectrum and the seismic parameters of NSCP 2010 were considered for the horizontal load action with load combinations. Response spectrum analysis and equivalent lateral force analysis were obtained with the help of SAP2000 software. Five representative columns for each RC frame structure were analysed. Column axial-load bending moment interaction diagrams result shows that EC8 was found to be conservative when compared to NSCP 2010 and 2009 IBC. The conclusion of analysis and design shows that EC8 provisions were considered to be safer.

Marjan Faizian, Yuji Ishiyama (2004)[18]:- compare the three building code for seismic provision as per 1981 Japan (BSLJ), 2000 USA (IBC), 1999 Iran (ICS) with their similarities and differences to find out the fundamental natural period of structure, base shear and distribution of lateral force along with structure height. For calculation of seismic load it is necessary to find out base shear coefficient, seismic zoning, spectral content, fundamental period, structural behaviour coefficient, and importance factor, effect of soil profile and foundation and weight of building. Torsion and overturning moment reduction are also discussed. Present study shows that ICS is quite similar to IBC, but there is a difference between these two and Japanese BSLJ. The importance of building is considered in ICS and IBC but not in BSLJ. In BSLJ, the fundamental period is calculated with the help of dynamic analysis using linear and non-linear time history analysis, in IBC through response spectral analysis, linear time history analysis and non-linear time history analysis but in ICS the building which height is more than 50 metre is analysed with the help of pseudo-dynamic analysis.

Muhammad Mostafijur Rahman et al. (2018)[19]:- compare the seismic design procedure for Bangladesh (BNBC-1993), India (1893) and US (ASCE 7-10) to analyse, design and seismic performance of reinforced concrete buildings on the basis of the type of allowable analysis procedure, zoning system, site classification, fundamental vibration period of structure, response reduction factor, importance factor, minimum design lateral force, allowed story drift and design response spectra. Three dimensional non-linear dynamic analysis of designed structure were conducted. The structural performance of each building was compared in terms of roof displacement, inter storey drifts, and load carrying capacity of beam and columns and overall energy dissipation characteristics. The result shows that the Indian code performed better than when subjected to the ground motion that it is intended to represent the Indian design response spectrum.

T. C. Becker et al. (2010)[20]:- Compares the codes and practise for designing seismically isolated building in the U.S and JAPAN. For both the country the building which is situated in comparable seismic region, a design spectra was developed. The ground motion demands through per review and isolation device were considered. A main focus on the displacement d for isolation device was considered. A comparison of the displacement for a three story building is

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made. The result was found that Japanese design for isolated building is faster and less expensive than U.S.A. design for many reasons including but not limited to standardization ground motion, 1D non-linear analysis, stream lined peer-review and pre-approved isolation devices.

Angelo Masi et al. (2008)[21]:- Reviewed a parametric study on reinforced concrete frames of European building to introduce the European code for the assessment retrofitting of existing building. Only for vertical load are considered .structural types having different number of story are considered. The seismic response is evaluated by means of the linear and non-linear static analysis. Different seismic actions, levels, behaviour factors, concrete strength are compared to understand the coherence of the analysis methods provided in the code that is if they lead to equivalent results in respect of the limit states verification taking also into account the different computing and accuracy of the adopted method.

III. CONCLUSION

The use and application of building codes has been instrumental in safeguarding the health, safety and welfare of the people. The “building code requirements for structural concrete” provides minimum requirements for the materials, design and detailing for the structural concrete building. Such code conclude following parameters like design and construction for strength, serviceability and durability, load combinations, load factors and strength reduction factor, deflection criteria, structural analysis method, splicing and development of reinforcement, constructions related to documentation’s information, quality and testing of materials, field inspection and testing and the methods of evaluation of strength of existing structure of various element like beam, column and slab.

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