# DESIGN OF RC MEMBER USING DIFFERENT BUILDING CODE: A REVIEW

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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, and BRITISH 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.

**Key Words:** Building codes, Structural Design, Loading Case, Beam, Column, Slab**.**

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# INTRODUCTION

The structural design of the building is generally based on national and/or international codes of practices. Such code provides the guidelines to the engineers in the appraisal of the overall structural scheme, detailed analysis and designs. Codes of practice are basically aids drawn up by experienced engineers and allied professions and they provide a frame work for addressing issues of safety and serviceability in structural design.

The code is intended to cover all buildings of the usual types both large and small. A building code states only the minimum requirements necessary to provide for public health and safety. The code is based on this principle. For any structures the engineers may require the quality of materials and constructions to be higher than the minimum requirements necessary to protect the public and property as stated in the code. However lower standards are not permitted.

The comparative study of various structural standards like nominal loads, load combinations, load factors, resistance factor, structural design philosophies and material properties etc. of different countries code point out at what extent one country code is differ from another country code with regard to the level of accuracy, safety, complexity and details. Such comparison are very fruitful for those countries where more than one code is allowed for structural design because such study provides lots of information like which code has higher factor of safety than others. . 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.

The available literature includes many comparative studies for the provisions included in different designs codes. Introduction of new structural codes, design philosophies and materials is totally based on comparative studies between different buildings codes of different countries which provide more reliable data. Design methods are formulated based on philosophies, leading to design codes attendant to a particular design method. The study of different design methods and code will surely find out different results in structural analysis and design leading to variability in cost, nature and durability of structures.

This paper reviewed a quantitative comparison of different design building codes like India, America, British, and Europe. The considered code include IS 456:2000, IS 800:2007 and IS 1893:1993 from India, ASCE 7-10, ACI 318-14 and AISC 360-10 from USA, EN 1991-1;1996 (EC 1), EN 1992-2:2001 (EC 2), EN 1993-1-3:2001 (EC 3), and EN 1994-1-2004 (EC 4) from Europe and BS 8110:1995 part 1 and 2 from British.

It is always the duty of structural engineers to provide designs that would lead to optimum performance and economy by employing the most efficient design method in accordance with a relevant design code available, in order to satisfy the desirable requirements.

# USED MATERIALS

Reinforced concrete structure is a common composite materials used in construction. Reinforced concrete is a combination of two dissimilar but complimentary materials, namely concrete and steel. Concrete also known as artificial stone is produced by mixing sand, cement, aggregate and water. Fresh concrete can be customized into any shape depending on the mould in which it cast into. Steel on the other hand, is a metal alloy that is composed principally of iron and carbon. Concrete and steel combined as reinforced concrete (RC) is widely used in construction and other applications. The reinforcement is usually, though not necessarily; steel reinforcing bars and is usually embedded passive in the concrete before the concrete sets.

## STRUCTURAL DESIGN

The structural design is an art and science of understanding the behaviour of structural members subjected to loads and designing them with economy to give a safe, serviceable and durable. Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life.
The structural design of any structures first involves establishing the loading and other design conditions, which must be supported by the structures and therefore must be considered in its design. This is followed by the analysis and computation of internal gross forces (i.e. thrust, shear, bending moment and twisting moment) as well as stress intensities, stress-strain behaviour, deflection and reactions produced by loads, changes in temperature, shrinkage, creep and other design conditions.

### Stages of structural design

The stages of structural design are as follows

1. Structural planning
2. Action of forces and computation of loads
3. Member Analysis
4. Member Design
5. Comparison between various RCC design codes
6. Detailing, drawing and preparation of schedules.

### Structural Analysis

Structural analysis is done for predicting structural behaviours with an acceptable level of accuracy, static-actions for force-deformation relationship of the member, dynamic-action in case of ground-structure interaction, and fire design for the temperature evaluation within the structure as well as models for the mechanical behaviours of the structures at elevated temperatures. In order to achieve adequately durable structures, the following should be taken into account:

1. The intended and foreseeable use of the structures
2. The required design criteria
3. The expected environmental conditions
4. The compositions properties and performance of the materials and products
5. The properties of the soil

6. The choice of the structural system
7. The shape of members and the structural detailing
8. The quality of workmanship and the level of control
9. The particular protective measures
10. The intended maintenance during the design working life.

## DESIGN CODES

Many countries have their own structure design codes, codes of practices or technical documents which perform a similar function. It is necessary for a designer to become familiar with local requirements and recommendations in regard to correct practices. In this study generally some country codes are reviewed which are follows-

**1. IS code:-** This Indian standard(Fourth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement and Concrete and Concrete Sectional Committee had been approved by the Civil Engineering Division Council. This Standard was first published in 1953 under the little 'Code of plain and reinforced concrete for general building construction' and subsequently revised in 1957. The code was further revised in 1964 and published under title 'Code of plain and reinforced concrete', thus enlarging the scope of use of this code to structures other than general building construction also. The third revision was published in 1978, and it included limit state approach to design. This is the fourth revision of the standard. This revision was taken up with a view to keeping abreast with the rapid development in the field of concrete technology and to bring in further modification/improvement in the light of experience gained while using the earlier version f the standard.

**2. British code:-** This part of bs8110 has been prepared by subcommittee B/525/2. It is a revision of BS 8110-1:1985 which is withdrawn BS 8110-1:1997 incorporates all published amendments made to BS 8110-1:1985. Amendment No. 1 (AMD 5917) published on 31 May 1989; Amendment No.  (AMD 6276) published on 22 December 1989; amendment no 3 (AMD 7583) published on 15 march 1993; Amendment No. 4 (AMD 7373) published on 15 September 1993. It also includes changes made by incorporating Draft Amendments no's 5 & 6 issued for public comment during 1994 and 1995.Amendment No. 5 detailed the insertion of various reference to different cement used in concrete construction, covered by BS 5328 and the recommendations of BS 5328 for concrete as a material up to the point of placing, curing and finishing in the works. Amendment no. 6 dealt with the change of the partial safety factor for reinforcement beam, from 1.15 to 1.05. it has been assumed in the drafting of this British standard that the execution of provisions will be entrusted to appropriately qualified and experienced people.

**3. American Code:-** This Code addresses structural systems, members, and connections, including cast-in-place, precast, plain, non-prestressed, prestressed, and composite construction. Among the subjects covered are: design and construction for strength, serviceability, and durability; load combinations, load factors, and strength reduction factors; structural analysis methods; deflection limits; mechanical and adhesive anchoring to concrete; development and splicing of reinforcement; construction document information; field inspection and testing; and methods to evaluate the strength of existing structures. "Building Code Requirements for Concrete Thin Shells" (ACI 318.2) is adopted by reference

in this Code. The Code user will find that ACI 318-14 has been substantially reorganized and reformatted from previous editions. The principal objectives of this reorganization are to present all design and detailing requirements for structural systems or for individual members in chapters devoted to those individual subjects, and to arrange the chapters in a manner that generally follows the process and chronology of design and construction. Information and procedures that are common to the design of members are located in utility chapters.
The quality and testing of materials used in construction are covered by reference to the appropriate ASTM standard specifications. Welding of reinforcement is covered by reference to the appropriate American Welding Society (AWS) standard. Uses of the Code include adoption by reference in a general building code, and earlier editions have been widely used in this manner. The Code is written in a format that allows such reference without change to its language. Therefore, background details or suggestions for carrying out the requirements or intent of the Code provisions cannot be included within the Code itself. The Commentary is provided for this purpose.

**4. Euro code:-** European code is based on philosophy of limit state, including both criteria of serviceability and strength. They are called resistance and factors design. Moreover, the code includes the reduction factors of material strength. The uses of load factors are to increase the working loads. EN 1992-2 describes the principles and requirements for safety, serviceability and durability of concrete structures, together with specific provision for bridges. It is based on the limit state concept used in conjunction with a partial factor method. EN 1992-2 gives principles and application rules for the design of bridge in addition to those stated in 1992-1-1. All relevant clauses of EN 1992-1-1 are applicable to the design of bridge unless specially deleted or varied by EN 1992-2. It has appropriate to introduce in EN 1992-2 some material, in the form of new clauses or amplification of clauses in EN 1992-1-1. Which is not bridge specific and which strictly belongs to EN 1992-2 are deemed to comply with the principles of EN 1992-1-1. Clauses in EN 1992-2 that modify those in EN 1992-1-1 are numbered by adding ‘100’ to the corresponding clause number in these are numbered by adding ‘101’ to the last relevant clause or sub-clause in EN 1992-1-1. For the design of new structures, EN 1992-2 is intended to be used, for direct application, together with other parts of EN 1992, Euro codes EN 1990, 1991,1997 and 1998 also as a reference document for other CEN/TCS concerning structural matters. EN 1992-2 is intended for use by: committees drafting others standards for structural design and related product, testing and execution standards; clients (e.g. for the formulation of their specific requirements on reliability levels and durability); design and relevant authorities. Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability.

## LITERATURE REVIEW

**1. Mourad M Bakhoum et. Al (2015):-** compare the actions and resistance in different buildings design codes of USA, Europe and Egypt in flexural and compressive axial loading condition for occupancy and different material strengths. Table 1 summarised ultimate load acting on the beam calculated as per each of the considered codes and ultimate bending moment considering the simply supported statically system and Fig. No. 1 shows ultimate load effect and ultimate resistance for different considered codes.

Table 1 Summery of the results for studied structural element.

| Design Load | Dead Load (KN) | Ultimate Load (KN) | Mu (KN-m) | Ultimate Resistance (KN-m) |
|---|---|---|---|---|
| 1. Studied Concrete Beam | | | | |
| ACI 318-14 | 21.4 | 33.89 | 128.14 | 160.74 |
| EC 2 | 21.4 | 36.99 | 139.87 | 149.04 |
| ECP 203-2007 | 21.4 | 38.60 | 145.96 | 148.74 |
| 2. Studied Steel Beam | | | | |
| AISC-360-10 | 18.94 | 30.94 | 116.99 | 135.65 |
| EC 3 | 18.94 | 33.67 | 127.32 | 137.02 |
| ECP 205-2007 | 18.94 | 35.16 | 132.95 | 128.11 |
| 3. Studied Steel- Concrete Beam | | | | |
| AISC-360-10 | 18.94 | 34.73 | 247.51 | 315.4 |
| EC 4 | 18.94 | 33.67 | 269.38 | 350.5 |
| ECP 205-2007 | 18.94 | 35.16 | 281.2 | 281.2 |

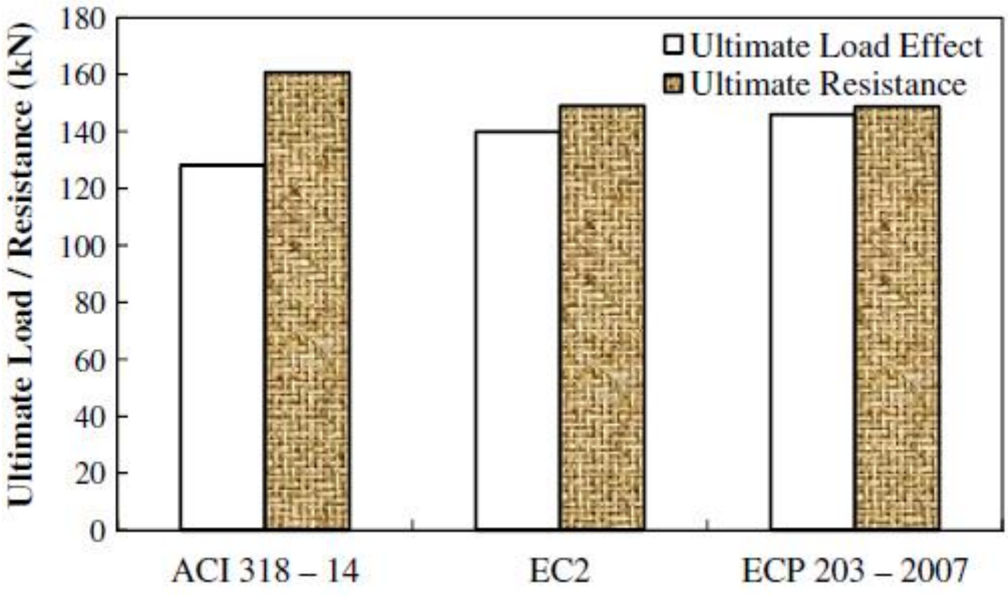


Figure 1 Ultimate load/resistance using different codes

Table 2 shows the comparison of combined effect of the actions and ultimate resistance of the studied singly reinforced concrete beam. It can be observed that ACI 318-14 generally require smaller sections that EC 2. This means that it is less conservative or more economic by 2% to 10% depending upon the reinforcement ratio and resistance of steel as well as ECP203-2007 requires larger section that that of EC2.

Table 2 Comparison of ultimate moment of resistance and combined effect of action and resistance of singly reinforced concrete sections.

| $f_{ck}$ (N/mm$^2$) | $F_{yk}$ (N/mm) | p(%) | $M_{ult\text{-}code}/M_{u\text{-}ec2}$ ACI318-14/EC2 | $M_{ult\text{-}code}/M_{u\text{-}ec2}$ ECP2033-2007/EC2 | EC2 value $M_u/bd^2$(N mm) |
|---|---|---|---|---|---|
| 25 | 360 | 0.5 | 1.05 | 1.00 | 1.48 |
| | | 1.0 | 1.06 | 1.00 | 2.78 |
| | | 1.5 | 1.08 | 1.00 | 3.92 |
| | | 2.0 | 1.10 | 1.00 | 4.87 |
| 25 | 500 | 0.5 | 1.05 | 1.00 | 2.01 |
| | | 1.0 | 1.08 | 1.00 | 2.78 |
| | | 1.5 | 1.11 | 1.00 | 3.92 |
| | | 2.0 | 1.14 | 1.00 | 4.87 |
| 40 | 360 | 0.5 | 1.04 | 1.00 | 2.01 |
| | | 1.0 | 1.05 | 1.00 | 3.68 |
| | | 1.5 | 1.06 | 1.00 | 5.02 |
| | | 2.0 | 1.07 | 1.00 | 6.02 |
| 40 | 500 | 0.5 | 1.05 | 1.00 | 1.51 |
| | | 1.0 | 1.06 | 1.00 | 2.91 |
| | | 1.5 | 1.08 | 1.00 | 4.21 |
| | | 2.0 | 1.09 | 1.00 | 5.40 |

Combined effect of ultimate action and ultimate moment of resistance

| Use | Materials (N/mm$^2$) | Permanent load (KN/m$^2$) | p(%) | ACI318-14/EC2 | ECP2033-2007/EC2 |
|---|---|---|---|---|---|
| Residential (Floors) | $f_{ck}$ =25 $f_{yk}$ =360 | 3 | 0.5 | 0.90 | 1.05 |
| | | 3 | 1.5 | 0.87 | 1.05 |
| | | 7 | 0.5 | 0.88 | 1.04 |
| | | 7 | 1.5 | 0.85 | 1.05 |
| | $f_{ck}$ = 25 $f_{yk}$= 500 | 3 | 0.5 | 0.89 | 1.05 |
| | | 3 | 1.5 | 0.85 | 1.05 |
| | | 7 | 0.5 | 0.87 | 1.04 |
| | | 7 | 1.5 | 0.83 | 1.05 |
| Office (Floors) | $f_{ck}$ =25 $f_{yk}$=360 | 3 | 0.5 | 0.83 | 0.96 |
| | | 3 | 1.5 | 0.83 | 0.96 |
| | | 7 | 0.5 | 0.84 | 0.99 |
| | | 7 | 1.5 | 0.81 | 0.99 |
| | $f_{ck}$ = 25 $f_{yk}$= 500 | 3 | 0.5 | 0.83 | 1.15 |
| | | 3 | 1.5 | 0.79 | 1.15 |
| | | 7 | 0.5 | 0.83 | 0.99 |
| | | 7 | 1.5 | 0.79 | 0.99 |

Concrete compressive strength, reinforcement yield strength and reinforcement ratio are shown by Table 5. The results shown that for the same section dimensions EC 2 yields the heights axial strength compared to ACI 318-14 and ECP 203-2007 by 30% and 23% respectively.

**2. Sami W. Tabsh (2013):-** approved reinforced concrete design of building structures based on the ACI 318 and BS 8110 codes. The main purpose of this study is to compare the structural design requirements of the ACI 318 code with the BS 8110 for flexural, shear and axial compression limit states as well as the load factors and load combinations in the two codes are also compared. To obtain the results a large number of cross-sections with different geometry, material properties and reinforcement ratios are analysed according to both specified standards.

Table 3 Comparison of ultimate strength of axially loaded short columns.

| $f_{ck}$ (N/mm$^2$) | $f_{yk}$ (N/mm) | ρ(%) | ACI318-14/EC2 | ECP2033-2007/EC2 | EC2 value $M_u/bd^2$(N mm) |
|---|---|---|---|---|---|
| 25 | 500 | 1.0 | 0.73 | 0.77 | 18.66 |
| 25 | 500 | 3.0 | 0.69 | 0.77 | 27.30 |
| 40 | 500 | 1.0 | 0.74 | 0.77 | 27.15 |
| 40 | 500 | 3.0 | 0.71 | 0.77 | 35.85 |

They found that the differences between the design capacities in the ACI 318 and BS8110 codes are minor for flexure, moderate for axial compression and major for shear. Figure 2 shows that design capacities ratios $M_{ACI}/M_{BS}$ slightly decrease with an increase in the tension reinforcement index.

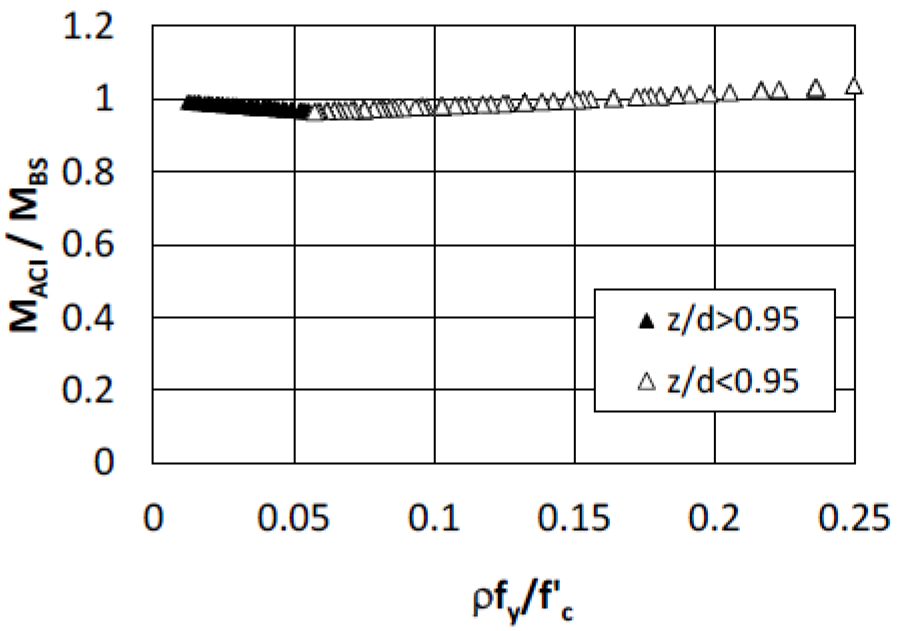


Figure 2 Flexural capacity ratio versus tension steel reinforcement index

Figure 3 shows that the discrepancies between the shear strength obtained by the ACI 318 and BS 8110 codes and indicate that ACI 318 code yields 10 to 30% lower shear strength than BS 8110 code.

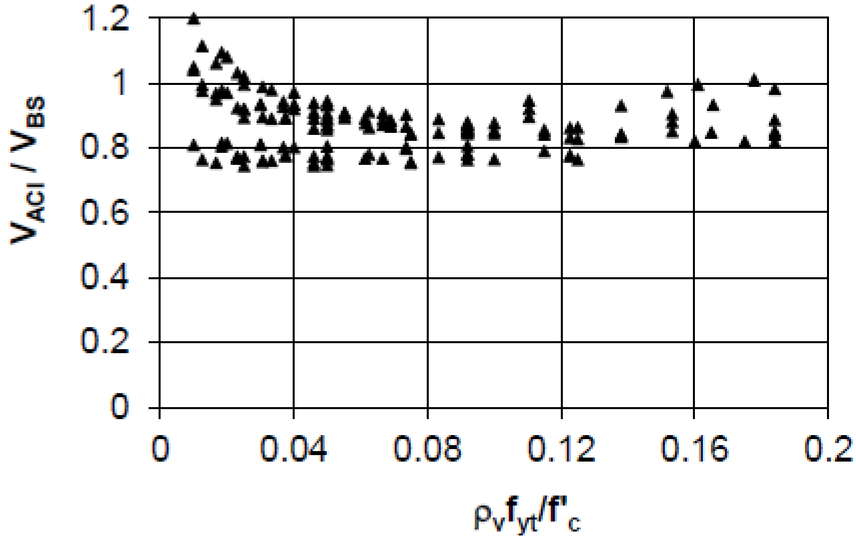


Figure 3   Shear capacity ration versus shear reinforcement index

Figure 4 indicates that with the increase in longitudinal steel reinforcement, the axial compressive strength of concentrically loaded cross-section according to ACI 318 is lower about 10 to 25% than BS 8110 code.

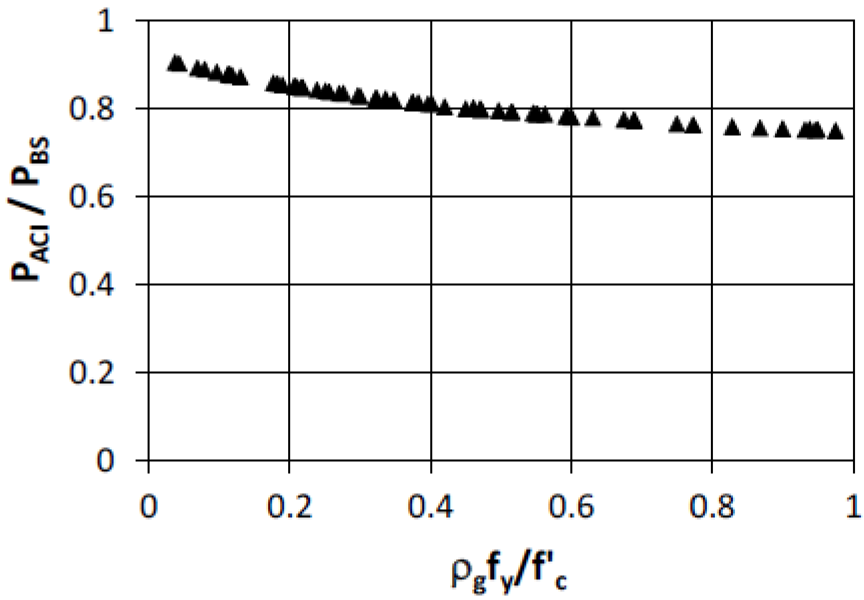


Figure 4   Axial compression capacity ratio versus gross steel reinforcement index

**3. Labani Nandi (2014):-** compare the design of reinforced concrete structures with various international codes like IS 456:2000, BS 8110:1985 and EC 2:1992 as well as compare strength design requirements of structural elements like slab, beam and column. The comparison includes shear design as well as the minimum and maximum area of steel requirements for elements of concrete structures. Table 4 shows partial factor of safety for the loadings and Table 5 shows the area of steel with respect to actual grade of concrete and steel.

Table 4 Basic loading combinations and Partial Factor safety at ultimate limit states

| Code | Dead load (DL) | Live load (LL) |
|---|---|---|
| IS 456:2000 | 1.5 | 1.5 |
| BS 8110:1985 | 1.4 | 1.6 |
| EC 2:1992 | 1.35 | 1.5 |

Table 5 Calculation of area of steel

| Code | Slab ($A_{st}$) | Beam ($A_{st}$) | Column ($A_{st}$) | Foundation ($A_{st}$) |
|---|---|---|---|---|
| IS 456:2000 [M30 & FE415] | 279 | 619.64 | 1240.37 | 1676.88 |
| BS 8110:1985 [M30 & FE460] | 203.41 | 583.88 | 1653.23 | 2080 |
| EC 2:1992 [M30 & FE500] | 269.57 | 743.17 | 1512 | 2080 |

The results shows that for slab area of steel is maximum as per IS code than BS and EC, for beam area of steel is maximum as per EC code than IS and BS code, for column area of steel is maximum as per BS code than IS and EC code and for foundation the area of steel is minimum as per IS code than BS and EC code.

**4. Temple Nwofer et. Al (2015):-** compare BS 8110and EC 2 for the design of a continuous reinforced concrete beam to find out the area of tension and shear reinforcement with the aim of determining which is most economic using Microsoft excel spreadsheet. In this study the self weight of the beam was taken as the dead load while the live load was assumed to be a unity. Table 6 shows the basic span/effective depth ratios for rectangular beams.

Table 6 BS8110 and EC 2 basic span/effective depth ratios for rectangular beams

| Support conditions | BS 8110:1997 | EC 2 |
|---|---|---|
| Cantilever | 7 | 7 |
| Simply Supported | 20 | 18 |
| Continuous | 26 | 25 |
| End spans of continuous beam | - | 23 |

Table 7 shows the input data used in generating bending moments and shear forces along the beam.

Table 7 Input data for both codes

| Parameter | EC 2 | BS 8110 |
|---|---|---|
| Concrete unit weight | 25 $kN/m^3$ | 24 $kN/m^3$ |
| Over all depth | 450 mm | 450 mm |
| Width | 300 mm | 300 mm |
| Live Load | 1 kN/m | 1 kN/m |
| Dead Load | 3.75kN/m | 3.24kN/m |

Table 8 Comparison of moment along the beam section

| | | Left support moment (kNm) | | | Maximum span moment (kNm) | | | Right support moment (kNm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Span | length | BS8110 | Eurocode2 | % difference | BS8110 | Eurocode2 | % difference | BS8110 | Eurocode2 | % difference |
| AB | 5.0 | 0 | 0 | 0.00 | -11.07 | -10.92 | -1.36 | 16.22 | 19.01 | -1.30 |
| BC | 5.0 | -16.22 | -16.01 | -1.30 | -5.16 | -5.10 | -1.16 | 11.81 | 11.65 | -1.35 |
| CD | 5.0 | -11.81 | -11.65 | -1.35 | -6.64 | -6.10 | -1.20 | 13.26 | 13.09 | -1.28 |
| DE | 5.0 | -13.26 | -13.06 | -1.28 | -6.64 | -6.50 | -1.20 | 11.81 | 11.65 | -1.35 |
| EF | 5.0 | -11.81 | -11.65 | -1.35 | -5.16 | -5.10 | -1.16 | 16.22 | 16.01 | -1.30 |
| EG | 5.0 | -16.22 | -16.01 | -1.30 | -11.07 | -10.92 | -1.36 | 0 | 0 | 0.00 |
| | | **Average** | | **-1.10** | | | **-1.24** | | | **-1.10** |

Table 9 Percentage difference in area of Tension steel required for maximum span moments

| Span | length | Maximum span moment (kNm) | As required ($mm^2$) | | %difference |
|---|---|---|---|---|---|
| | | | Euro code 2 | BS8110 | |
| AB | 5.0 | 221.40 | 154.91 | 1599.57 | -3.67 |
| BC | 5.0 | 103.20 | 646.56 | 661.31 | -2.20 |
| CD | 5.0 | 132.80 | 857.17 | 887.09 | -3.37 |
| DE | 5.0 | 132.80 | 857.17 | 887.09 | -3.37 |
| EF | 5.0 | 103.20 | 646.56 | 661.13 | -2.20 |
| FG | 5.0 | 221.40 | 1540.91 | 1599.57 | -3.67 |
| | | **Average** | | | **-3.08** |

Table 10 Percentage difference in area of Tension steel required for maximum support moments

| Support | Distance from first outer support (m) | Maximum span moment (kNm) | As required ($mm^2$) | | %difference |
|---|---|---|---|---|---|
| | | | Euro code2 | BS8110 | |
| B | 5.0 | 340.62 | 2315.12 | 2370.24 | -2.33 |
| C | 10.0 | 248.01 | 1713.72 | 1771.59 | -3.77 |
| D | 15.0 | 278.46 | 1911.46 | 1968.42 | -2.89 |
| E | 20.0 | 248.01 | 1713.72 | 1771.59 | -3.27 |
| F | 25.0 | 340.62 | 23.15.12 | 2370.24 | -2.33 |
| | | **Average** | | | **-2.83** |

Table 11 Percentage difference in shear links required between EC 2 and BS 8110

| Span | length | Maximum shear force (kN) | $A_{sv}/s_v$ | | %difference |
|---|---|---|---|---|---|
| | | | Euro code2 | BS8110 | |
| A | 0 | 181.50 | 0.463 | 1.064 | -56048 |
| B | 5.0 | 278.70 | 0.712 | 2.087 | -65.88 |
| C | 10.0 | 225.75 | 0.577 | 1.529 | -62.26 |
| D | 15.0 | 234.45 | 0.600 | 1.621 | -62.99 |
| | | **Average** | | | **-61.90** |

The results shows that BS 8110 moments exceeds that of the EC 2 by an average of about 1.24% at span and 1.10% at supports, the shear force at the support for BS 8110 exceeds EC 2 by an average of about 1.19% for both upper and lower limits of shear force and the BS 8110 exceeds EC 2 by an average of about 3.08% for the area of tension reinforcement for span and 2.83% for support. So, Euro code provides a more economical design than BS 8110.

**5. Ali Abdul Hussain Jawed (2006):-** compare ACI 318M-02, BS 8110:1985 and EC 2:1992 for design requirements of the structural building codes from safety and economical point of view. The comparison include safety provisions, flexural design, shear design and column design. Figure 5 shows the stress block adopted by ACI code and compared to those used by BS 8110 and EC 2.

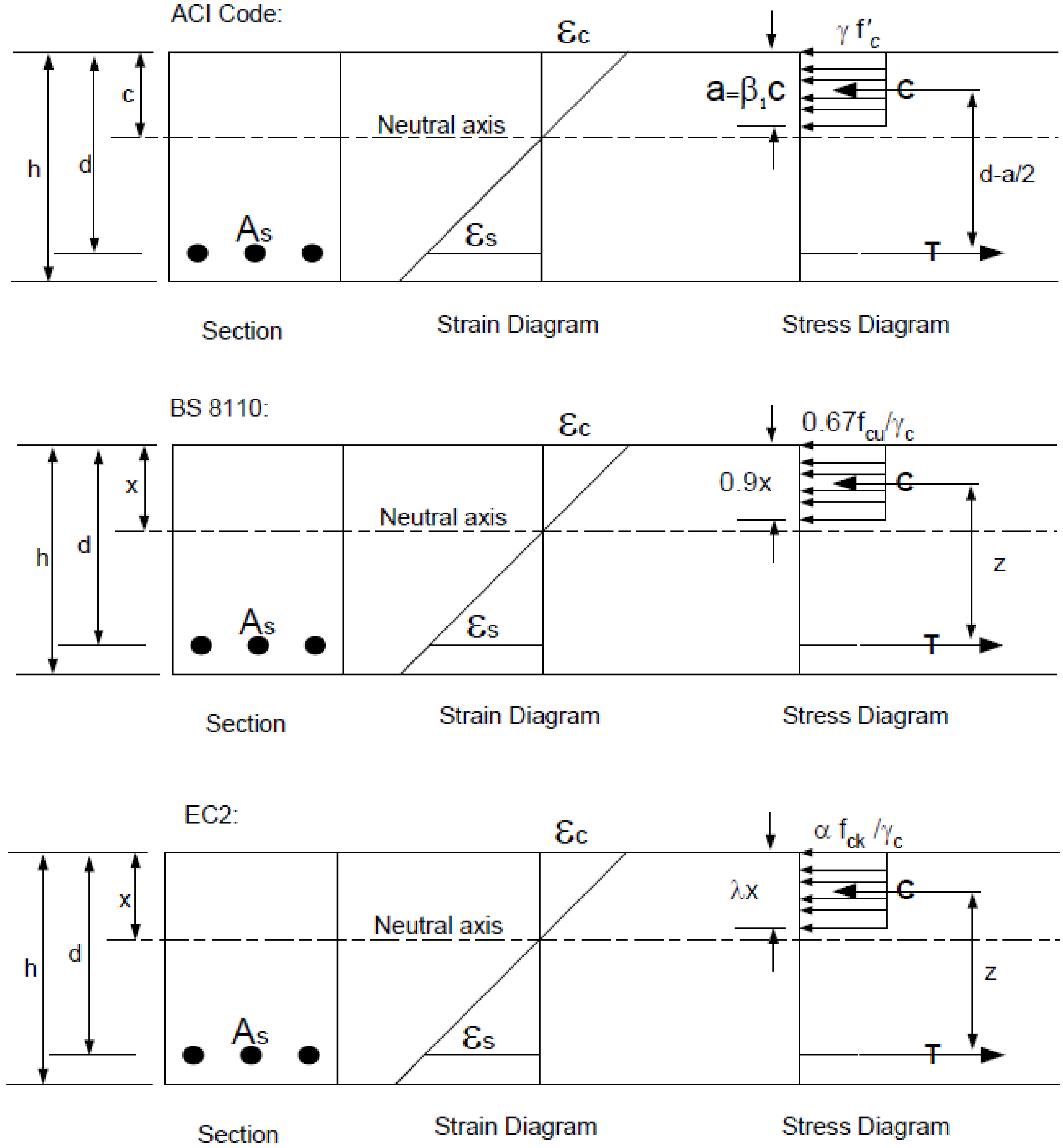


Figure 5 Strain distribution and stress block

Figure 6 shows that allowable shear stress of concrete in concrete increases the compressive strength of concrete.

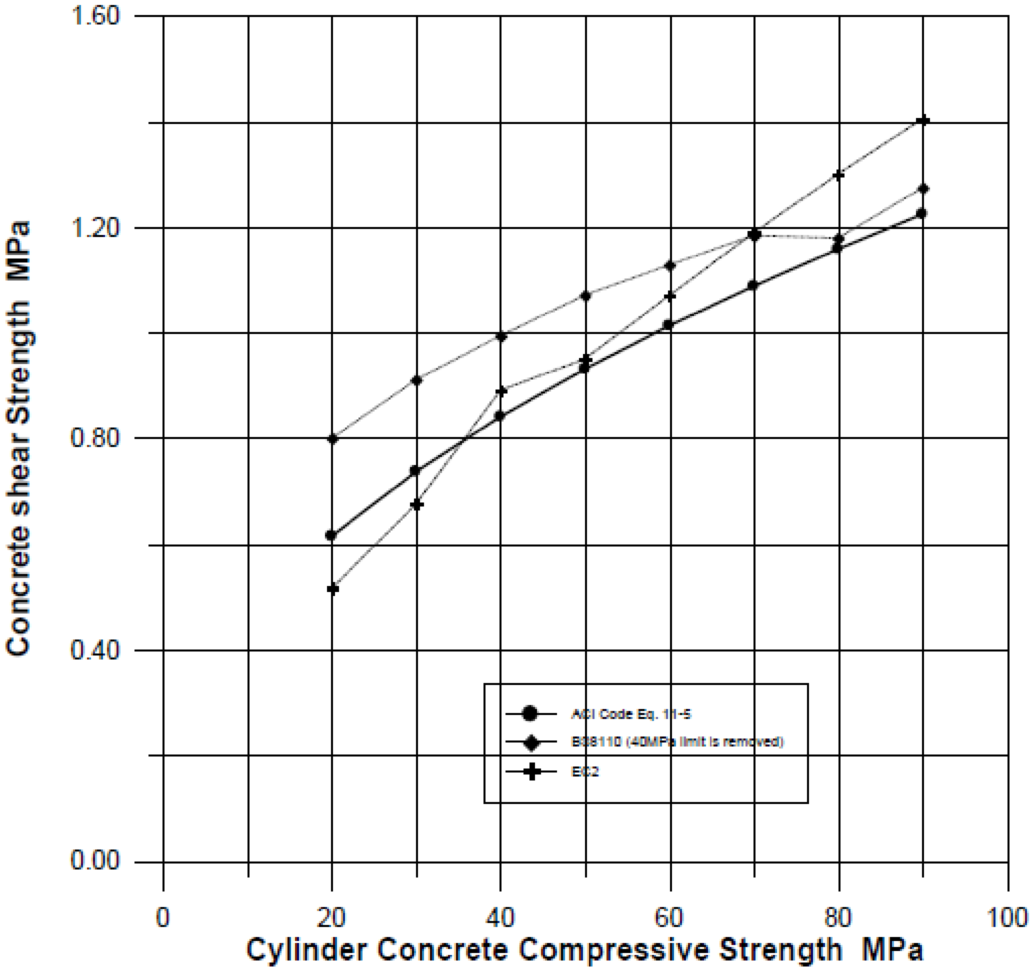


Figure 6 Concrete compressive strength versus concrete shear strength

The minimum or maximum amount of longitudinal reinforcement should not violate the limits stipulated by codes. Table 12 shows minimum and maximum steel ratio proposed by ACI code, BS 8110 and EC 2.

Table 12 Minimum and maximum column longitudinal steel ratio

| Code | Min. Steel Ratio | Max. Steel Ratio |
|---|---|---|
| ACI 318M-02 | 0.01 | 0.08 |
| BS 8110 | 0.004 | 0.06 |
| EC 2 | 0.003 | 0.08 |

The results show that EC code and ACI code are more extensive for design requirements point of view than BS 8110, BS 8110 exhibits large allowable design shear strength of concrete and all codes gives very close design moment capacity for steel ratios but EC 2 is more generous in doubly reinforced sections.

**6. C. U. Nwoji et. Al (2017):-** compare BS 8110 and Euro code (EC 2) to find outthe relatives gains and shortcomings of EC 2 and BS 8110 under loading analysis, ease of use and technical advancement. Loading summary for each span of the beam for the ultimate limit states and the serviceability limit states is summarised in Table 13 and 14 respectively.

Table 13 Loading Case for beam (BS 8110)

| span | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|
| | DL | IL | DL | IL | DL | IL |
| 7a-8 | 53.7 | 11.6 | 53.7 | 11.6 | 38.0 | 0.0 |
| 8-9 | 59.8 | 11.6 | 42.0 | 0.0 | 59.8 | 11.6 |
| 9-10 | 53.7 | 11.6 | 53.7 | 11.6 | 38.0 | 0.0 |
| 10-11 | 53.7 | 11.6 | 38.0 | 0.0 | 53.7 | 11.6 |
| 11-12 | 59.8 | 11.6 | 59.8 | 11.6 | 42.0 | 0.1 |
| 12-13 | 53.7 | 11.6 | 38.0 | 0.0 | 53.7 | 11.6 |

Table 14 Loading Case for beam (EC 2)

| span | Case 1 | | Case 2 | | Case 3 | | Case 4 | | Case 5 | | Case6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DL | IL | DL | IL | DL | IL | DL | IL | DL | IL | DL | IL |
| 7a-8 | 53.7 | 11.6 | 53.7 | 11.6 | 38.0 | 0.0 | 38.0 | 0.0 | 38.0 | 0.0 | 38.0 | 0.0 |
| 8-9 | 59.8 | 11.6 | 42.0 | 0.0 | 59.8 | 11.6 | 59.0 | 11.6 | 59.8 | 11.6 | 59.8 | 11.6 |
| 9-10 | 53.7 | 11.6 | 53.7 | 11.6 | 38.0 | 0.0 | 38.0 | 0.0 | 38.0 | 0.0 | 38.0 | 0.0 |
| 10-11 | 53.7 | 11.6 | 38.0 | 0.0 | 53.7 | 11.6 | 53.7 | 11.6 | 53.7 | 11.6 | 53.7 | 11.6 |
| 11-12 | 59.8 | 11.6 | 59.8 | 11.6 | 42.0 | 0.0 | 42.0 | 0.0 | 42.0 | 0.0 | 42.0 | 0.0 |
| 12-13 | 53.7 | 11.6 | 38.0 | 0.0 | 53.7 | 11.6 | 53.7 | 11.6 | 53.7 | 11.6 | 53.7 | 11.6 |

Table 15 Bending Moment and Column axial load for BS 8110 and EC 2

| Level | BS 8110 | EC 2 | % Difference |
|---|---|---|---|
| $2^{nd}$ Floor | M=790 KN-m | M=577 KN-m | -36.92 |
| | N=1565 KN | N=1335 KN | -7.22 |
| First Floor | M= 0 KN-m | M= 0 KN-m | 0 |
| | N=2294 KN | N=2173 KN | -5.52 |

The results shows that Euro code has lower span moment than BS 8110 but in case of continuous beam the EC 2 moments supersede the BS 8110 moments, for the upper and lower limits of shear force envelopes BS 8110 are generally higher than EC 2 by 3 to 10%, for column load and moments EC 2 values are lower than the BS 8110 values and in case of easement the EC 2 code are much more easy than BS 8110.

**8. Shodolapo Oluyemi Franklin et. Al (2011):-** compare EC 2 and BS 8110 for the analysis and design of the main structural elements in a four storey reinforced concrete building with the aid of the Prokon 32 suited of programmes. It comprises the bending moment diagram for the critical continuous beam span for both codes before moment redistribution and after 10%, 20% and 30% redistribution. The below Figure 8 shows the bending moment along different critical sections after 10% and 20% moment redistribution.

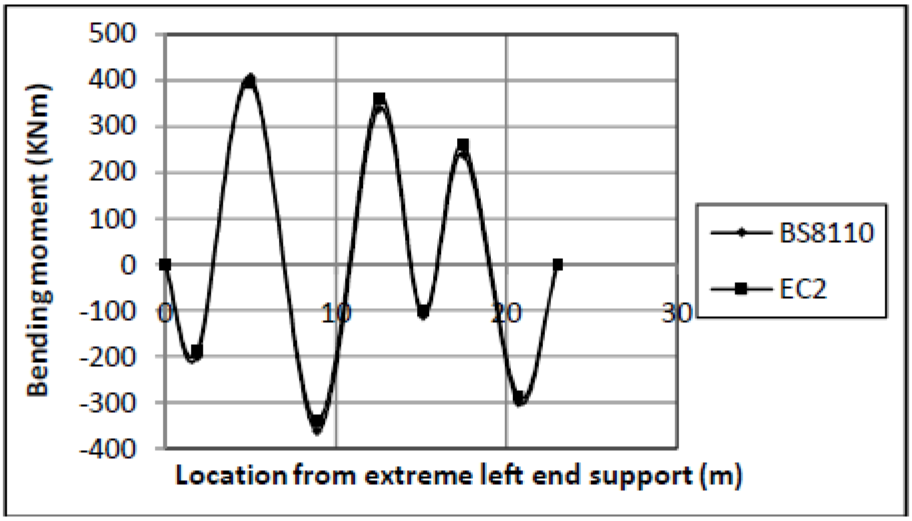


Figure 7 Comparison of B.M. along the building critical section at 10% moment redistribution

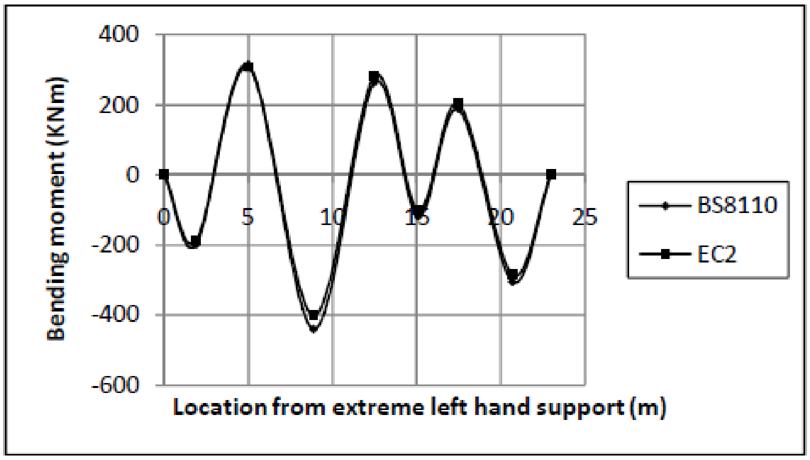


Figure 8 Comparison of B.M. along the building critical section at 10% moment redistribution

The results shows that EC moments values are lower than BS 8110 values about 4.5% to 9% in case of maximum span moments of continuous beam for 20% moment redistribution. However at 30% redistribution the lag is about 14.3% as well as in case of the upper and lower limits of the shear force envelops, BS 8110 estimates are generally higher by a range of 2.4% to 5.4%.

**9. Ali S. Alnuaimi et. Al (2013):-** compare ACI 318:08 and BS 8110:97 building codes for the design results of Rc member subjected to bending, shear and torsion of slab-column connection as well as the difference in the amount of reinforcement. It was found that BS code requires less reinforcement than ACI code for the same value of design load. Table 15 shows the parametric study to compare steel required for bending and shear with DL+LL combination using ACI and BS.

Table 16   Steel required for B.M. and shear with DL+LL

| BEAM NUMBER | RATIO DL/LL | Service UDL (KN/m) DEAD | LIVE | Ultimate UDL($W_u$) Design (KN/m) ACI (1.2D+1.6L) | BS (1.4D+1.6L) | DIFF. In $W_u$ (%) | Ultimate Moment Design At Mid Span Mu (KNm) ACI | BS | Ultimate Shear Design (KN) ACI | BS | Flexural As Reinforcement ($mm^2$) ACI | BS | DIFF. IN $A_S$ (%) | Shear Asv/S Reinforcement ($mm^2/mm$) ACI | BS | Diff. In $A_{SV}/S$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR4 | 4 | 20 | 5 | 32 | 36 | 12.5 | 144 | 162 | 76 | 86 | 588 | 646 | 9.9 | Min | 0.18 | - |
| BR5 | 5 | 25 | 5 | 38 | 43 | 13.2 | 171 | 194 | 90 | 102 | 706 | 789 | 11.8 | Min | 0.18 | - |
| BR6 | 6.5 | 33 | 5 | 47 | 56.5 | 13.8 | 212 | 241 | 112 | 127 | 891 | 1014 | 13.8 | 0.15 | 0.24 | 60.0 |
| BR7 | 7 | 35 | 5 | 50 | 57 | 14.0 | 225 | 257 | 119 | 135 | 951 | 1094 | 15.0 | 0.18 | 0.26 | 44.4 |
| BR8 | 8 | 40 | 5 | 56 | 64 | 14.3 | 252 | 288 | 133 | 152 | 1057 | 1257 | 16.5 | 0.24 | 0.31 | 29.2 |

Minimum area of flexural reinforcement required by ACI code is larger than BS code for RC rectangular beams. Fig. No.10 Shows that minimum area of flexural reinforcement at different characteristics strength of concrete.

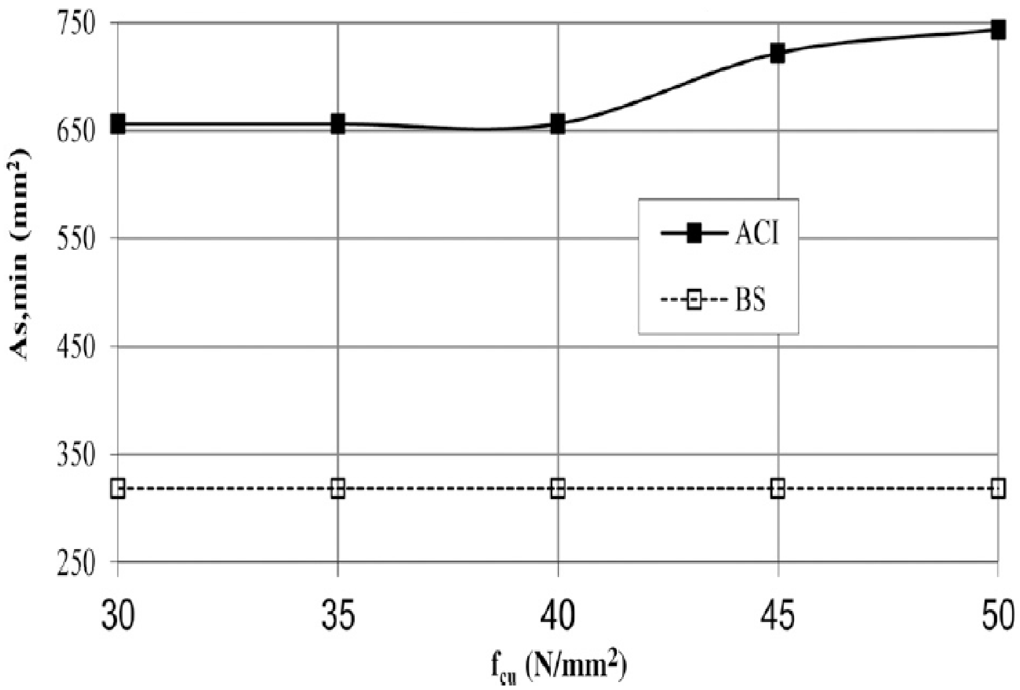


Figure 9   Minimum area of flexural reinforcement with different $f_{cu}$

Minimum area of shear reinforcement required by ACI code is smaller than BS code for RC rectangular beam. . Fig. No.11 Shows that minimum area of shear reinforcement at different characteristics strength of concrete

In ACI code, punching shear strength remains constant for different percentage of flexural reinforcement, whereas in the BS code, punching shear strength increases with increase of flexural reinforcement. Fig No.12 Shows that punching shear strength at different percentage of reinforcement as per ACI and BS code.

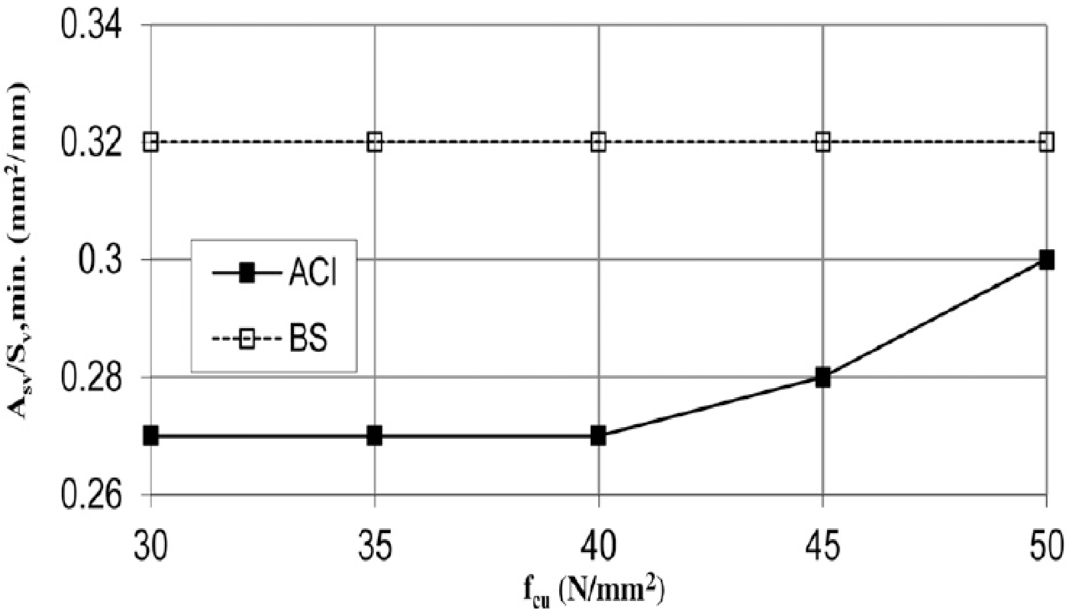


Figure 10 Minimum area of shear reinforcement with different $f_{cu}$

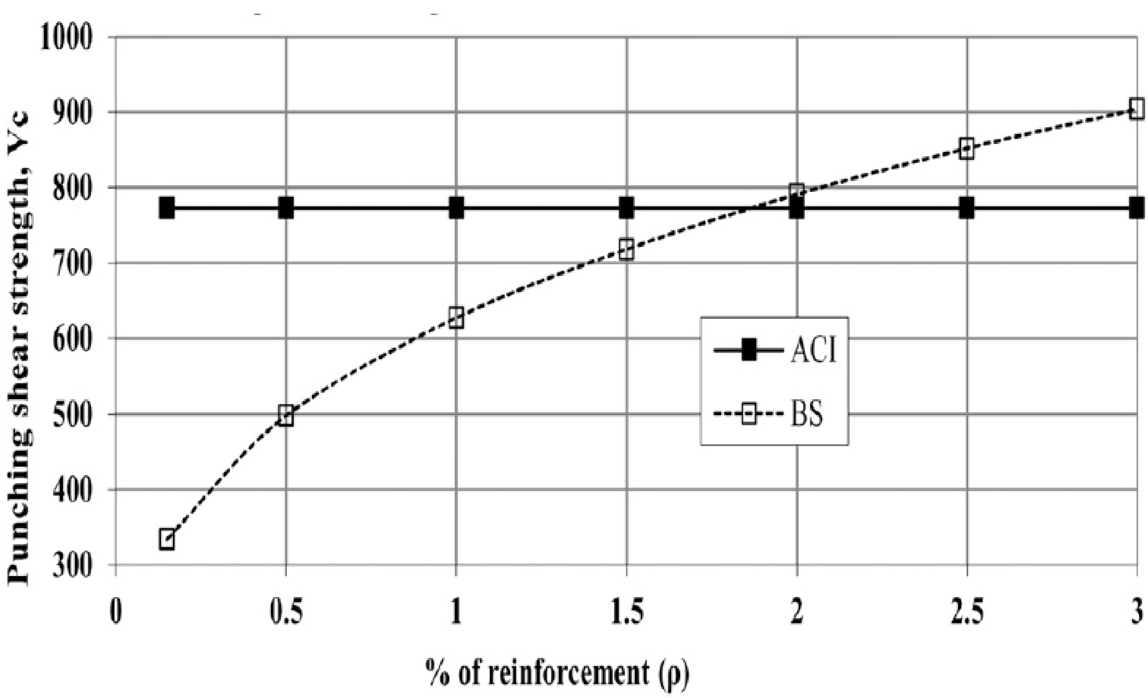


Figure 11 Punching shear strength versus percentage of reinforcement

**10. Tabish Izhar and Reena Dagar (2018):-** evaluate the comparison of reinforced concrete member like beam, column and slab with the help of various countries code like European code, American code, Indian code, British code and Canadian code. The comparison between these building code will help to form a most effective and economical building design provisions. The below Figure shows the various parameters as per such codes-

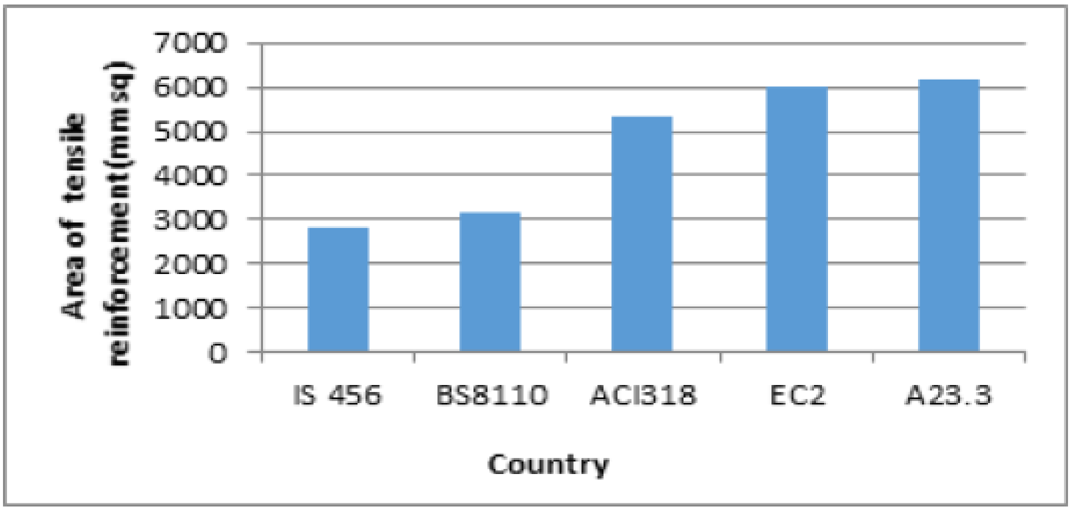


Figure 12 Variation of tensile reinforcement of beam

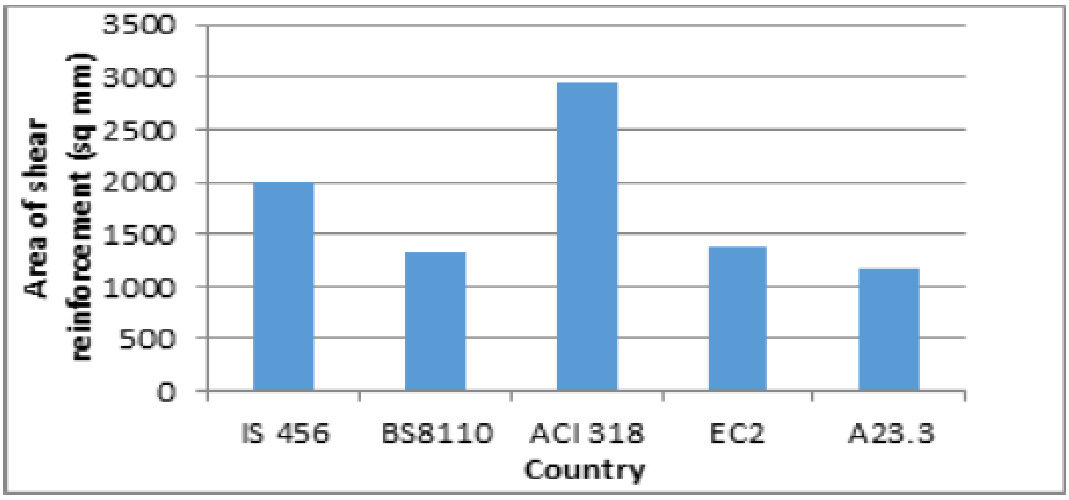


Figure 13 Variation of shear reinforcement of beam

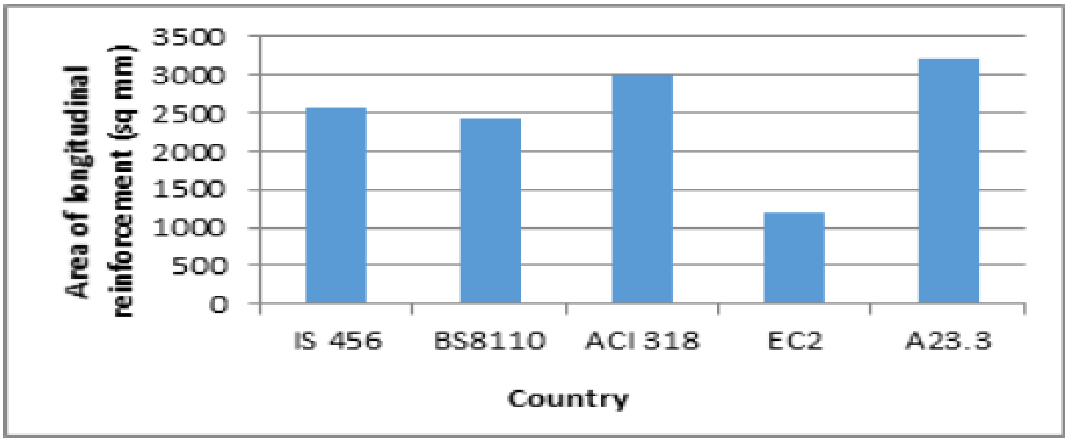


Figure 14 Variation of longitudinal reinforcement in column

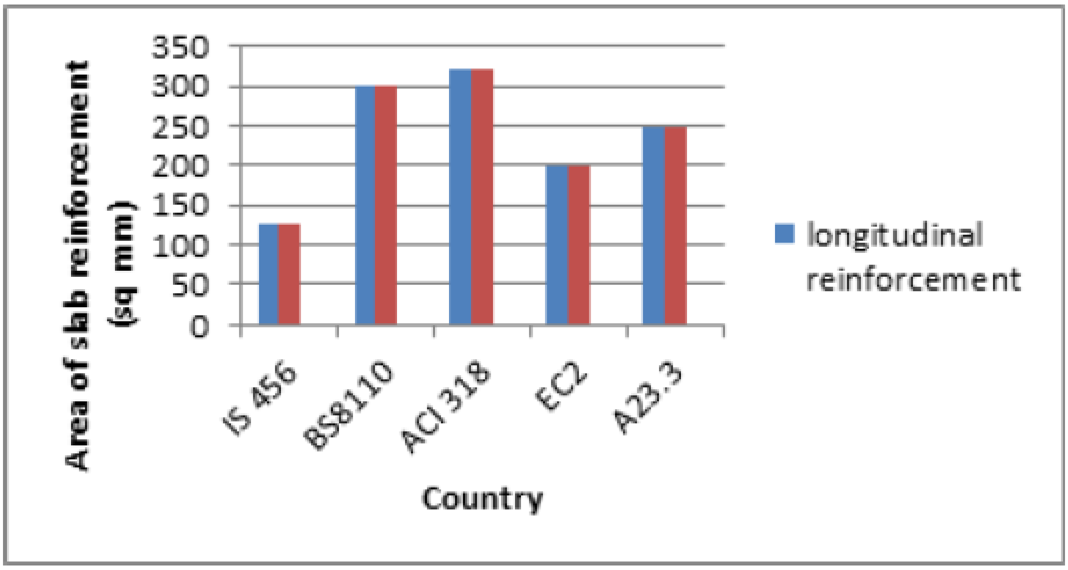


Figure.15 Variation of longitudinal and transverse reinforcement in slab

The results shows that flexural reinforcement is least from IS 456:2000 code and maximum for CSA A 23.3 by keeping the live load, dead load and wind load same for all code. Shear reinforcement for beam is least for IS456:2000 and maximum for Canadian code, longitudinal reinforcement for column is minimum for EC 2 and maximum for Canadian code and the last longitudinal and transverse reinforcement for slab is least for EC 2 and maximum for ACI 318.

## 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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