Comparative Study on is 456:2000 and Eurocode 2: En 1992-1-1 for Analysis and Design of R.C.C. Beam

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Abstract

The reinforced concrete structures must be analyzed and designed according to the provisions of relative design standards. Design codes are the documents which are established for the design of a respective structure. Most of the countries have established their own design codes according to their local geographical, topographical and climatic conditions. However, such multiplicity in design criteria may lead towards the misperception of the structural engineers who are working on a global platform. Even though Indian Standards provides adequate guidelines for construction of buildings in India, there are some International standards which covers supplementary parameters that are not included in IS codes. Thus, the efforts are made to provide a comparative study on analysis and design parameters of R.C.C. beam according to the Indian code (IS456:2000) and European code (Eurocode 2 EN 1992-1-1). Such comparison will ensure the effectiveness in economical structural design worldwide.

Keyword- IS 456, Eurocode 2, Comparison, Effectiveness, Beam Design

I. INTRODUCTION

Several countries have framed out their own design specification for the construction of various types of structures. Such specifications are framed in engineering manners to formulate a design for various structural members such as beam, column, slab and footing. The primary purpose of these codes is to ensure structural stability by specifying minimum and maximum design requirements. Moreover, they also ensure a uniformity in procedures adopted by the various structural engineers in the country. Assessment of these codes will help them to customize the structural design in most effective way.

A. Scope of Work

The core objective of this study is to interpret the design procedure of R.C.C. beam followed by two design codes, Indian code (IS456:2000) and European code Eurocode 2 EN 1992-1-1. Moreover, sample example is solved to differentiate reinforcement requirement under identical loading pattern & intensity.

II. COMPARISON OF ANALYSIS & DESIGN PARAMETERS FOR BEAM

A. Design of Reinforced Concrete Beams

Reinforced concrete beam design consists primarily of producing member's details which will adequately resist the ultimate bending moments, shear forces and torsional moments. At the same time serviceability requirements must be considered to ensure that the member will behave satisfactorily under working loads.

The comparison of the two codes IS456 and EC2 will be made in tabular form for easy comprehension.

Consider a beam having a rectangular shape, the beam will hold the calculations of a rectangular section. The beam is simply supported.

Parameters	*IS 456*	*EC 2*
Effective span	*Centre to center distance between supports or clear span + effective depth.*	*Clear distance between the supports + 1/3 of the overall depth.*
Depth	*D = L/10 to L/16*	*h = d + Cover + t*
Breadth	$b \leq breadth\ of\ wall$	*1/3 to 1/2 of the effective depth*
Effective depth	*d = D – d'*	*d = h – (cover + t)*
L/d ratio	*20*	*18*
Minimum and Maximum longitudinal reinforcement	*<u>Tension reinforcement</u>* $\frac{A_s}{bd} = \frac{0.85}{f_y}$	*<u>Tension reinforcement</u>*

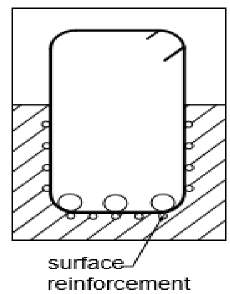
	Compression reinforcement *The maximum area of compression reinforcement shall not exceed 0.04bD.*	$A_{s,min} = 0.26\frac{f_{ctm}}{f_{yk}}b_t d \geq 0.0013 b_t d$ *Compression reinforcement* *The cross-sectional area of compression reinforcement should not exceed* $A_{s,max}$. $A_{s,max} = 0.04Ac$
Minimum shear reinforcement	$\frac{A_{sv}}{bs_v} \geq \frac{0.4}{0.87 f_y}$	$\rho_w = \frac{A_{sw}}{s \cdot b_{ws} sin\alpha} \geq \rho_{min}$ $\rho_{min} = (0.08\sqrt{f_{ck}})/f_{yk}$
Maximum spacing of shear reinforcement	*0.75d* $\leq 300mm$	*0.75d* $\leq 600mm$
Side reinforcement	*Where the depth of the web in a beam exceeds 750mm, side reinforcement shall be provided along the two faces.*	*In beams over 1m deep additional reinforcement must be provided in the side faces.*
Surface reinforcement	*The IS456 does not give any provisions for the surface reinforcement.*	*Surface reinforcement must be provided where it is necessary to control spalling of the concrete due to fire or where bundled bars or bars greater than 32mm diameter are used as main reinforcement.*  *Fig.1-Surface reinforcement*

Table 1: Comparative table of beam parameters for IS456 and Eurocode 2

III. SOLVED EXAMPLE ACCORDING TO IS 456:2000

Design a simply supported R.C. beam, having its size 250mm x 400mm, to resist a characteristic load of 30 KN/m (DL= 20 KN/m and LL= 10KN/m), spaced at a clear distance of 6m. Use M25 and Fe 415 steel.

- Design Data
  size = 250 mm x 400 mm
  l = 6 m
  w = 30 KN/m
  f_{ck}= 25 N/mm^2
  f_y= 415 N/mm^2
- Computation of Design Constants and Limiting Depth of NA
  For Fe 415 steel f_y =415 N/mm^2

$$\frac{x_{u,max}}{d} = \frac{700}{1100 + 0.87 \times 415} = 0.48$$

  For M25 concrete f_{ck}= 25 N/mm
  M = 0.138f_{ck}bd^2
  Consider 50 mm cover.
  d = 400 – 50 = 350 mm
  M = 0.138 x 25 x 250 x 350^2 = 105.656 x 10^6 Nmm
  $x_{u,max}$= 0.48d = 0.48 x 350 = 168 mm
- Design for Bending Moment
  L = 6000 + 350 = 6350 mm
  Available L/d =$\frac{6350}{350} = 18.14 < 20$
  Characteristic load = 30 KN
  Ultimate load w_u= 1.5 x 30 = 45 KN/m

$$M_u = \frac{w_u \times l^2}{8} = \frac{45 \times 6^2}{8} = 202.5 \times 10^6 \text{Nmm}$$

  since $M_u > M_{ulim}$ a doubly reinforced section will be required.

- Tensile Reinforcement

$$P_{t,lim} = 0.414\frac{f_{ck}}{f_y}\frac{x_{u,max}}{d} = 0.414 \times \frac{25}{415} \times 0.48 = 0.012$$
$$A_{st1} = P_{t,lim} \times bd = 0.012 \times 250 \times 350 = 1050 \text{ mm}^2$$
$$A_{st2} = \frac{M_u - M_{ulim}}{0.87f_y(d-d')} = \frac{(202.5 - 105.656) \times 10^6}{0.87 \times 415(350-50)} = 894.09 \text{ mm}^2$$

Total $A_{st} = A_{st1} + A_{st2} = 1050 + 894.09 = 1944.09$ mm^2
Provide 4 bars of 25 mm dia.

- Compressive Reinforcement

$$A_{sc} = \frac{M_u - M_{ulim}}{(f_{sc} - 0.446f_{ck})(d-d')}$$

$\frac{d'}{d} = \frac{50}{350} = 0.14$, take $f_{sc} = 353$ N/mm^2

$$A_{sc} = \frac{(202.5 - 105.656) \times 10^6}{(353 - 0.446 \times 25)(350-50)} = 944.31\text{mm}^2$$

Provide 3 bars of 20 mm dia.

- Shear Reinforcement

$$V_u = w_u \times \frac{L}{2} = 45 \times \frac{6.35}{2} = 142.875 \text{ KN}$$
$$\tau_v = \frac{V_u}{bd} = \frac{142875}{250 \times 350} = 1.63 \text{ N/mm}^2$$
$$\frac{100A_s}{bd} = \frac{100 \times 2 \times {}^{\pi}/_{4} \times 25^2}{250 \times 350} = 1.12$$
$$\therefore \tau_c = 0.66$$

Provide 8 mm dia. 2 lgd stirrups, having $A_{sv} = 100.5$ mm^2

$$S_v = \frac{0.87f_yA_{sv}}{(\tau_v - \tau_c)b} = \frac{0.87 \times 415 \times 100.5}{(1.63 - 0.66) \times 250} = 149.63\text{mmm}$$

Spacing based on effective depth of beam

$$S_v = 0.75d = 0.75 \times 350 = 262.5\text{mm}$$

Provide 8 mm dia. bar 2 legged stirrups at 200mm c/c near support and 300mm c/c towards end.

A. Solved Example According to Eurocode 2

Design a simply supported R.C. beam, having its size 250mm x 400mm, to resist a characteristic load of 30 KN/m (DL= 20 KN/m and LL= 10KN/m), spaced at a clear distance of 6m. Use M25 and Fe 460 steel.

- Design data
  size = 250 mm x 400 mm
  l = 6 m
  w = 30 KN/m
  f_{ck}= 25 N/mm^2
  f_{yk}= 460 N/mm^2
- Ultimate load
  $w_u = 1.35g_k + 1.5q_k$

$$w_u = 1.35 \times 20 + 1.5 \times 10 = 42\text{KN}$$
$$M = \frac{w_u \times l^2}{8} = \frac{42 \times 6^2}{8} = 189 \text{ KNm}$$
$$\frac{M}{bd^2f_{ck}} = \frac{189 \times 10^6}{250 \times 350^2 \times 25} = 0.246 > K_{bal} = 0.167$$

Hence, compression steel is required

$$x = 0.45d = 0.45 \times 350 = 157.5\text{mm}$$
$$\frac{d'}{x} = \frac{50}{157.5} = 0.317 < 0.43$$

- Compressive Reinforcement

$$A'_s = \frac{M - 0.167f_{ck}d^2}{0.87f_{yk}(d-d')} = \frac{189 \times 10^6 - 0.167 \times 25 \times 250 \times 350^2}{0.87 \times 460(350-50)} = 509.25\text{mm}^2$$

Provide 3 bars of 16mm dia.
Tensile reinforcement

$$A_s = \frac{0.167 f_{ck} b d^2}{0.87 f_{yk} z} + A'_s$$

$z = 0.82d = 0.82 * 350 = 287$

$$A_s = \frac{0.167 \times 25 \times 250 \times 350^2}{0.87 \times 460 \times 287} + 509.25 = 1622.45\text{mm}^2$$

Provide 4 bars of 25mm dia.

– Span-Effective Depth Ratio

$$\frac{\text{Actual span}}{d} = \frac{6000}{350} = 17.14 < 18$$

– Shear Reinforcement
  Check for minimum shear

$F = w_u \times \text{span} = 42 \times 6 = 252$ KN

At face of support

$V_{sf} = {}^{F}/_{2} - w_u \times {}^{b}/_{2} = {}^{252}/_{2} - 42 \times {}^{0.25}/_{2} = 120.75$KN

Maximum design shear resistance

$V_{Rd2} = 0.3 v f_{ck} b_w d$

$v = 0.7 - {}^{f_{ck}}/_{200} = 0.7 - {}^{25}/_{200} = 0.575$

$V_{Rd2} = 0.3 \times 0.575 \times 25 \times 250 \times \frac{350}{10^3} = 377.34\text{KN} > V_{sf} = 120.75$ KN

Shear links

$\frac{A_{sw}}{s} = \frac{1.28(V_{sd} - V_{Rd1})}{d f_{yk}}$

At a distance d from the support, shear V_{sd}, is

$$V_{sd} = V_{sf} - w_u d = 120.75 - (42 \times 0.35) = 106.05 \text{ KN}$$

Shear resistance of concrete VRd1 , is

$$V_{Rd1} = \tau_{rd} k (1.2 + 40\rho_1) b_w d$$
$$\tau_{rd} = 0.3$$
$$k = 1.6 - d = 1.6 - 0.35 = 1.25$$

Only four bars of 25mm extent a distance d past the critical section. Therefore

$\rho_1 = \frac{A_s}{b_w d} = \frac{4 \times {}^{\pi}/_{4} (25^2)}{250 \times 350} = 0.022$

Hence,

$$V_{Rd1} = 0.3 \times 1.25(1.2 + 40 \times 0.022) 250 \times 350 \times 10^{-3} = 68.25 \text{ KN}$$

So,

$\frac{A_{sw}}{s} = \frac{1.28(V_{sd} - V_{Rd1})}{d f_{yk}} = \frac{1.28(106.5 - 68.25) \times 10^3}{350 \times 460} = 0.3$

Provide 10mm links at 180mm c/c.

IV. CONCLUSION

Based on the study made in this research, it was concluded that the IS456 and Eurocode 2 are mainly equivalent and the differences between the codes are about minimal, although the Eurocode 2 is slightly more conservative than the IS 456.
For a combination of dead load and live load considered in this study, the IS 456 required about 6.66% more of the ultimate design loads than of the Eurocode 2.
The tensile and compressive reinforcement required is more in IS 456, which could be assumed that the Eurocode 2 provides a more economical design.

NOTATIONS AND ABBREVIATIONS

A_{sc} cross-sectional area of compression reinforcement
A'_s area of compression reinforcement
A_{st} cross-sectional area of tension reinforcement
A_s cross-sectional area of tension reinforcement
A_{sw} cross-sectional area of shear reinforcement in the form of links or bent-up bars
DL dead load
LL live load

F	load action
M	moment or bending moment
V	shear force
z	lever arm
b	breadth or width
b_w	minimum width of section
d	effective depth of a cross-section
f_{ck}	characteristic compressive cylinder and cube strength of concrete
f_{yk}	characteristic yield strength of reinforcement
f_y	characteristic strength of steel
g_k	characteristic permanent load per unit area
q_k	characteristic permanent load per unit area
k	constant coefficient or factor
l	length or span
s	spacing of shear reinforcement or depth of stress block
x	neutral axis depth
ρ_1	reinforcement ratio for longitudinal reinforcement
τ_c	shear stress in concrete
τ_v	nominal shear stress

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