DESIGN OF RC DEEP BEAMS AS PER INDIAN, EUROPEAN AND AMERICAN CODES OF PRACTICE

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Abstract:

Provisions of Indian (IS 456: 2000), European (EC2 - 1992) and American (ACI - 318) codes of practice for the design of RC deep beams have been critically studied and reported. As per the recommendations of these codes, RC deep beams have been designed adopting limit state method. The quantities of concrete and steel and the total cost of deep beams for three different spans have been calculated and are compared using bar chart.

Keywords:*Limit state design, RC deep beam, limiting moment of resistance, side face reinforcement.*

"1. Introduction"

Design of a reinforced concrete structure is not easily reduced to a science, since it implies functional and aesthetic factors, as well as technical and economic ones. Design is a matter of talent, technical knowledge and imagination. As of today, a reinforced concrete structure should satisfy the requirements of safety or reliability, serviceability, durability, economy and aesthetics. Comparison of various building code requirements reveals significant differences between practices adopted by various countries. In this paper, RC deep beams have been designed as per the following three codes of practice and the relative quantities of steel are compared.

- **"*Indian Standard* Plain and Reinforced Concrete – Code of Practice IS: 456: 2000"**
- **"Manual for the design of reinforced concrete building structures to EC2 – 1992"**
- **"ACI 318: Building Code Requirements for Reinforced Concrete (ACI 318 - 95) and Commentary (ACI 318R – 95)"**

"2. Critical parameters for the design of RC deep beams as per the three codes of practice"

The Indian and European codes of practice follow SI units whereas the American code of practice followsFPS units. The following are the different parameters required for the design of RC beams;

Table 1: Critical parameters for the design of RC deep beams as per the three codes of practice

Parameters	IS 456:2000	EC2-1992	ACI-318
Unit weight of concrete	25 kN/m³	24 kN/m³	145 lb/ft³ = 22.78kN/m³
Load combination (DL+LL) for limit state design	1.5(DL+LL)	1.35DL+1.5LL	1.4DL+1.7LL
Effective Span/ Overall depth ratio permitted:			
i) Simply supported	< 2	<2	<1.25
ii) Continuous	<2.5	<2.5	<2.5
Lever Arm			
i) Simply supported	z = 0.2 (*l*+ 2D) when *l*≤ *l*/D ≤ 2 (or) z = 0.6 *l* when *l*/D < 1	z = 0.2 (*l*+ 2D) when *l*≤ *l*/D ≤ 2 (or) z = 0.6 *l* when *l*/D<1	z = 0.2 (*l*+ 2D) when *l*≤ *l*/D ≤ 2 (or) z = 0.6 *l* when *l*/D<1
ii) Continuous	z = 0.2(*1*+1.5D) when *1*≤ *l*/D ≤ 2.5 (or) z = 0.5*l*when *l*/D < 1	z = 0.2(*1*+1.5D) when *1*≤ *l*/D ≤ 2.5 (or) z = 0.5*l*when *l*/D < 1	z = 0.2(*1*+1.5D) when *1*≤ *l*/D ≤ 2.5 (or) z = 0.5*l*when *l*/D < 1

Effective span of the beam	i) c/c distance between supports ii) 1.15 x clear span whichever is smaller	Clear distance between the faces of supports + one-third of their width	i) c/c distance between supports ii) 1.15 x clear span whichever is smaller
Positive Reinforcement	$A_{st} = \frac{Mu * \gamma m}{fy * z}$	$A_{st} = \frac{Mu}{0.87\ fy * z}$	$A_{st} = \rho bD$ $\rho = 0.85ß(fc/fy)$ $(\frac{87000}{87000+fy})$
Zone of Depth	0.25D – 0.05l	0.25D – 0.05l	0.25D – 0.05l
Development length	$0.8\ (\frac{\emptyset\ \sigma_s}{4\ \tau_{bd}})$	$0.8\ (\frac{\emptyset\ \sigma_s}{4\ \tau_{bd}})$	$0.8\ (\frac{\emptyset\ \sigma_s}{4\ \tau_{bd}})$
Side face reinforcement			
Condition	D > 750mm	D > 1000mm	D > 36 in = 914.4mm
Area of vertical reinforcement	0.0012 gross area	$0.6b\ (0.83d - x) / \sigma_s$	0.012b (d – 30)
Area of horizontal reinforcement	0.002 gross area	0.002 gross area	$0.0025\ b\ S_2$ $S_2 = d/3$
Maximum spacing	i) 0.75d(in mm) ii) 300mm whichever is less	300mm	i) 3d (in inch) ii)18 inch whichever is less

By using the above parameters, the design of RC deep beams have been carried out and the results are given below.

"3. Results and discussions"

The results for the design of RC deep beams of span 3.5m, 4m and 4.5m to carry working live load of 300kN/m are tabulated.

Table 2: AS PER IS 456:2000

Clear span (m)	**3.5**			**4**			**4.5**		
Description	Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement	
		Horizontal	Vertical		Horizontal	Vertical		Horizontal	Vertical
Diameter (mm)	12	8	8	12	8	8	12	8	8
Numbers	12	18	14	14	18	16	17	18	18
Length (m)	3.45	3.45	2.95	3.95	3.95	2.95	4.45	4.45	2.95
Total length (m)	41.4	62.1	41.3	55.3	71.1	47.2	75.65	80.1	53.1
Weight of steel (kg/m)	0.878	0.39	0.39	0.878	0.39	0.39	0.878	0.39	0.39
Total weight of steel (kg)	36.35	24.22	16.1	48.55	27.73	18.4	66.42	31.24	20.7
Total weight of steel (N)	**751.97**			**928.53**			**1160.81**		
Volume of concrete (m^3)	**3.15**			**3.6**			**4.05**		

TABLE 3: AS PER EC2-1992

Clear span (m)	**3.5**			**4**			**4.5**		
Description	Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement	
		Horizontal	Vertical		Horizontal	Vertical		Horizontal	Vertical
Diameter (mm)	12	8	8	12	8	8	12	8	8
Numbers	16	18	20	18	18	20	20	18	20
Length (m)	3.45	3.45	2.95	3.95	3.95	2.95	4.45	4.45	2.95
Total length (m)	55.2	62.1	59	71.1	62.1	59	89	62.1	59
Weight of steel (kg/m)	0.878	0.39	0.39	0.878	0.39	0.39	0.878	0.39	0.39
Total weight of steel (kg)	48.46	24.22	23.1	62.42	24.22	23.1	78.14	24.22	23.1
Total weight of steel (N)	**938.39**			**1075.29**			**1229.45**		
Volume of concrete (m^3)	**3.15**			**3.6**			**4.05**		

TABLE 4: AS PER ACI-318

Clear span (m)	**3.5**			**4**			**4.5**		
Description	Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement		Main reinforcement	Side face reinforcement	
		Horizontal	Vertical		Horizontal	Vertical		Horizontal	Vertical
Diameter (mm)	12.7	9.525	9.525	12.7	9.525	9.525	12.7	9.525	9.525
Numbers	17	18	20	20	18	20	22	18	20
Length (m)	3.45	3.45	2.95	3.95	3.95	2.95	4.45	4.45	2.95
Total length (m)	58.65	62.1	59	79	62.1	59	97.9	62.1	59
Weight of steel (kg/m)	0.983	0.553	0.55	0.983	0.553	0.55	0.983	0.553	0.55
Total weight of steel (kg)	57.65	34.34	32.6	77.65	34.34	32.6	96.23	34.34	32.6
Total weight of steel (N)	**1222**			**1418.13**			**1600**		
Volume of concrete (m^3)	**3.15**			**3.6**			**4.05**		

The reinforcement details for design of deep beam of span 3.5m as per IS456:2000 is shown below.

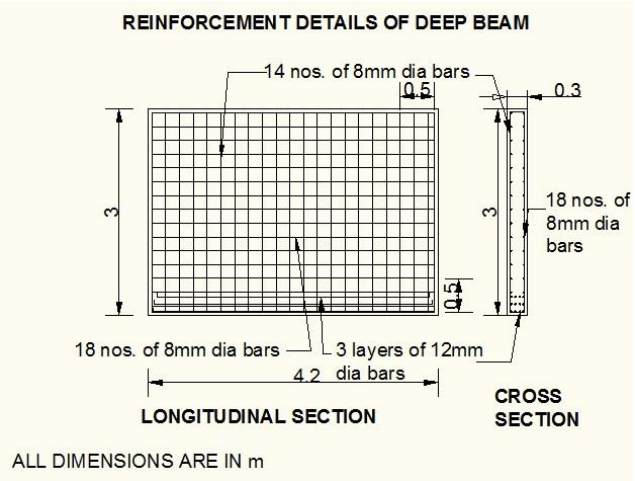
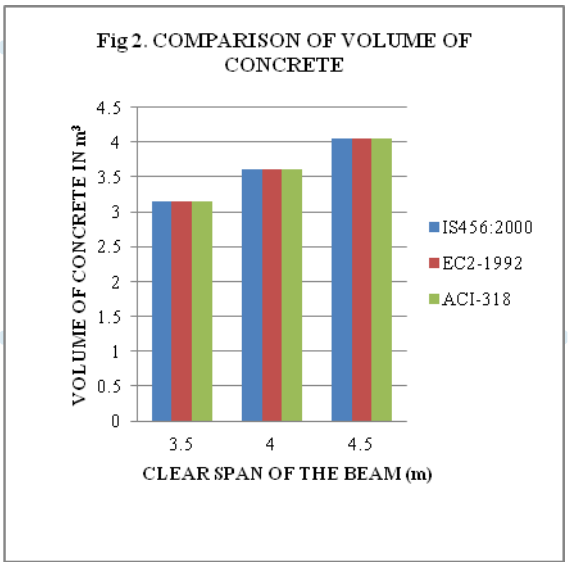
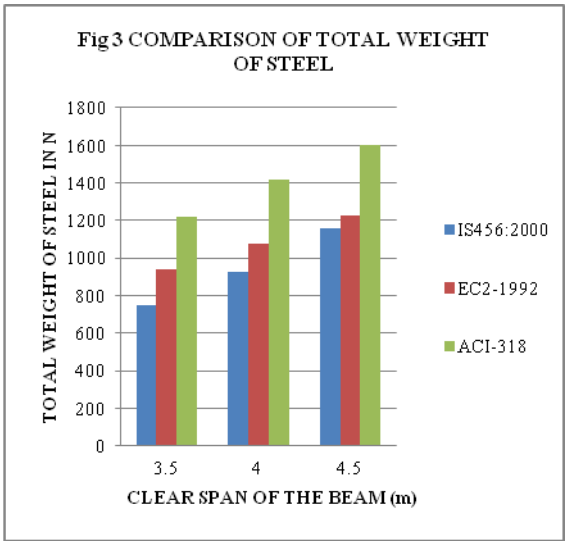


Fig. 1 Reinforcement details of Deep Beam of span 3.5m

The volume of concrete and total weight of steel for each span are compared using the following bar charts.





"4. CONCLUSIONS ON DESIGN OF DEEP BEAMS"

- The required volume of concrete increases due to the increase in span of the beam.
- The weight of steel required is the highest for all the beams when designed as per ACI code. This is mainly due to the number of bars and the spacing to be provided for main and side face reinforcement as per ACI code.
- Thus, the cost of the beam is less if designed as per Indian standards when compared to European and American Standards and is more if American code is adopted.

"5. LIST OF SYMBOLS"

A_{st}	-	Area of tension reinforcement
A_{sv}	-	Area of vertical stirrups
a	-	Stress block depth
B	-	Width of the beam
D	-	Overall depth of the beam
DL	-	Dead Load
D	-	Effective depth of the beam
d´	-	Clear cover of the beam
f_c	-	Characteristic compressive strength of concrete in N/mm²
f_c'	-	Specified compressive strength of concrete in psi
f_y	-	Characteristic compressive strength of steel in N/mm²
L	-	Clear span of the beam
Leff	-	Effective span of the beam
LL	-	Live Load

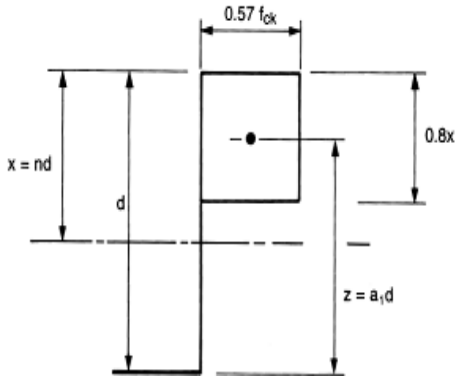


Fig. (4) Stress block diagram as per EC2-1992

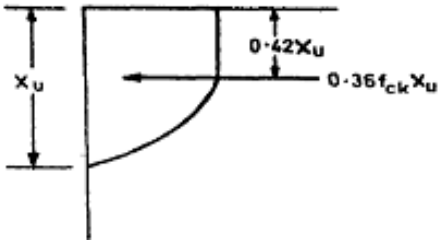


Fig. (5) Stress block diagram as per IS456:2000

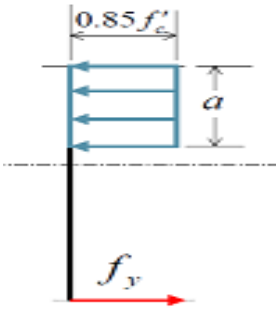


Fig. (6) Stress block diagram as per ACI- 318

"6. REFERENCES"

- "*Indian Standard* Plain and Reinforced Concrete – Code of Practice IS: 456: 2000"
- "Manual for the design of reinforced concrete building structures to EC2 – 1992"
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