Catalog

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Design of RC members for combined Bending, Shear and Torsion

Problem: Design a reinforced concrete beam of rectangular cross-section for the following data

b = 300mm **d = 800mm**
D = 850mm **f_{ck}= 15 N/mm^2**
f_y= 250N/mm^2 **M_u= 200 kNm**
V = 100 kN **T_u=50kN.m**

Step1: Equivalent shear

Since tensile reinforcement is not known at the outset, therefore the minimum % of tension steel is

Hence both the longitudinal and transverse reinforcement shall be provided

= 312.75kNm

Since M_u>M_t, *no* longitudinal reinforcement will be required on compression flange.

Longitudinal Reinforcement

$$M_{e1} = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}}\right)$$

$$312.75 \times 10^6 = 0.87 \times 250 \times A_{st} \times 800 \left(1 - \frac{A_{st} \times 250}{300 \times 800 \times 15}\right)$$

$$12.08 A_{st}^2 - 174000 A_{st} + 312.75 \times 10^6 = 0$$

$$b_1 = 300 - 30 - 30 - \frac{28}{2} - \frac{28}{2} = 212\text{mm}$$

$$d_1 = 800 - 30 - \frac{10}{2} = 765\text{mm}$$

Assuming ϕ 8 two-legged stirrups

$$A_{sv} = 2 \times \frac{\pi}{4} \times 8^2 = 100.53 \text{ mm}^2$$

Substituting these values in the above equation

$$100.53 = \frac{50 \times 10^6 s_\upsilon}{212 \times 765 \times (0.87 \times 250)} + \frac{100 \times 1000 s_\upsilon}{2.5 \times 765 \times (0.87 \times 250)}$$

$$s_\upsilon = 60.64 \text{ mm}$$

Provided 2 ϕ 10 on each face.

The arrangement of reinforcements is shown in Figure

UNIT -II
DESIGN OF BEAMS

2.1 Analysis and design of Flanged beams

In actual practice, T-sections and L-sections are more common than the rectangular section since part of the RC slab, monolithic with the beam and participate with the structural behavior of the beam. For the same load and span T-beam and L- beam carries more moment of resistance than rectangular beam. When a concrete slab is cast monolithically with and, connected to rectangular beams, a portion of the slab above the beam behaves structurally as a part of the beam in compression. The slab portions are called the flange and beam the web. If the flange projections are on either side of the rectangular web or rib, the resulting cross section resembles the T shape and hence is called a T-beam section. On the other hand, if the flange projects on one side, the resulting cross- section resembles an inverted L and hence is termed as L-beam.

Advantages of T-beam are

1. Beam and slab are casted monolithically hence; casting can be done at a time.
2. Slab and beam combined together to carry more bending moment.

For same section, T-beams have more M.R (flexural strength) than that ofrectangular beam.

EFFECTIVE WIDTH OF FLANGE:

It is that portion of slab which acts integrally with the beam and extends on either side of the beam forming the compression zone. The effective width of flange depends upon the span of the beam, thickness of slab and breadth of the web. It also depends upon the type of loads and support conditions.

As per code (clause 32.1.2 of IS: 456-2000)

Effective flange width for T and L beams are calculated as follows:

a) For T-beams: $b_f = l_0/6 + b_w + 6D_f$

b) For L-beams: $b_f = l_0/12 + b_w + 3D_f$

c) For isolated beams:

   i) For T-beams: $b_f = l_0/[(l_0/b)+4] + b_w$

   ii) For L-beams: $b_f = 0.5l_0/[(l_0/b)+4] + b_w$

Where,

b_f = effective width of the flange.

b_w = breadth of the web

D_f = thickness of the flange,

I = distance between point of zero moment (forcontinuous beam,

I = 0.7x (effective span of beam).

- First segment will be like a rectangular section and steel area A_{st1}.
- Second segment will be like a beam section having concrete section of area $[(b_f - b_w)D_f]$ and steel area of A_{st2}.
- Our consideration in design and analysis for depth of neutral axis $x_u > D_f$ will be ascertain the compressive force taken up by concrete in second segment and its line of action.
- If $x_u \leq D_f$, the beam can be thought of as a rectangular section of width b_f.

  The stress distribution for various values of x_u

STEPS FOR CALCULATING DEPTH OF NEUTRAL AXIS AND MOMENT OF RESISTANCE:

Given: b_f, d, A_{st}, D_f, grade of steel and grade of concrete, span for load calculation.

Required: Factored moment or moment of resistance and load.

Case I: Neutral axis lies within the flange

Steps:1 Calculate depth of neutral axis assuming neutral axis lies within the flange

$X_u/d = (0.87.f_y.A_{st})/(0.36.f_{ck}.b.d)$

Calculate x_u

If $x_u \leq D_f$ (Assumption is correct)

Where, D_f = depth of flange or slab

2. Note down the value of $x_{u,max}$ /d from IS:456-2000Calculate $x_{u,max}$

If $x_u < x_{u,max}$ section is under reinforced, calculate the moment of resistance bythe following expression

$$M_u = 0.87.\ f_y.\ A_{st}.d.\ [1-((\ f_y.\ A_{st})/(\ f_{ck}.b.d))]$$

3. If $x_u > x_{u,max}$ section is over reinforced, calculate the moment of resistance bythe following expression

$$M_{u.lim} = 0.36.\ f_{ck}.b_f.x_{u,max}.(\ d-0.42.x_{u,max})$$

Case II: Neutral axis lies below the flangeSteps:

Calculate neutral axis assuming neutral axis (NA) lies within flange. If $x_u > D_f$,assumption is wrong. NA lies below the flange.

Recalculate the value of x_u by using following relation $C_1+C_2=T$Where, C_1 = $0.36.f_{ck}.x_u.b_w$

$C_2 = 0.45.f_{ck}.(b_f - b_w).D_f$ $T = 0.87.\ f_y.\ A_{st}$

$0.36.f_{ck}.x_u.b_w + 0.45.f_{ck}.(b_f - b_w).D_f = 0.87.\ f_y.\ A_{st}$ (assume $(D_f / x_u) < 0.43$) andfind x_u

If $x_u > D_f$, assumption is correct, follow step 3.

If $x_u < D_f$, assumption is that $(D_f / x_u) > 0.43$

Then recalculate x_u by using relation $C_1 + C_2$ = TWhere, $C_1 = 0.36.f_{ck}.x_u.b_w$

$C_2 = 0.45.f_{ck}.(b_f - b_w).y_f$

$T = 0.87.\ f_y.\ A_{st}$

$y_f = (0.15\ x_u + 0.65D_f$

If $x_u \geq x_{u,max}$ section is over reinforced or balanced.

$D_f / d \leq 0.2$ use equation G.2.2 page No.96, IS:456-2000 for $M_u$calculation

$$M_{u.lim} = 0.36.\ f_{ck}.b_w.d^2.(x_{u,max}/d).(\ 1-0.42.(x_{u,max}/d)) + 0.45.f_{ck}.(b_f - b_w).D_f.(d-(D_f/2))$$

$D_f / d > 0.2$ use equation G.2.2.1 page No.97, IS:456-2000 for $M_u$calculation

$$M_{u.lim} = 0.36.\ f_{ck}.b_w.\ d^2.(\ (x_{u,max}/d).(\ 1-0.42.(x_{u,max}/d)) + 0.45.f_{ck}.(b_f - b_w).y_f.(d-(y_f/2))$$

Where, $y_f = (0.15\ x_u + 0.65D_f)$, but should not be greater than D_f.

If $x_u < x_{u,max}$ section is under reinforced.

1. $D_f / x_u \leq 0.43$ use equation G.2.2 page No.96, IS:456-2000 for $M_u$calculation

$$M_u = 0.36. f_{ck}.b_w. d^2.((x_u/d).(1-0.42.(x_u/d)) + 0.45.f_{ck}.(b_f - b_w).D_f.(d-(D_f/2))$$

2. $D_f / x_u > 0.43$ use equation G.2.2.1 page No.97, IS:456-2000 for $M_u$calculation

$$M_u = 0.36. f_{ck}.b_w. d^2.((x_u/d).(1-0.42.(x_u/d)) + 0.45.f_{ck}.(b_f - b_w).y_f.(d-(y_f/2))$$

Where, $y_f = (0.15\, x_u + 0.65D_f)$, but should not be greater than D_f.

UNIT -II
DESIGN OF BEAMS

2.2 Design of Flanged beams

Problem 1.Find the flange width of the following simply supported T-beam. Effectivespan = 6m, C/C distance of adjacent panels = 3.0m, Breadth of the web =350mm, Thickness of slab = l00mm.

Solutions:

Given: l = 6m,

b_f = 300,

D_f = l00mm.

Since the beam is simply supported, the distance between the points of zero momentsl0 = l = 6m

Clear span of the slab to the left or right of the beam

= C/C distance of adjacent panels — b_w

=3000 — 350 = 2650mm

Effective width of the flange is the least of the following:

i) b_f = l_0 /6 + b_w +6D_f

= 6000 + 350 + 6 x100= l950mm

ii) b_f = b_w + Half of the clear distance to the adjacent beams on either side

= 350 + 2650/2 + 2650/2 = 3000mm

Therefore, b_f = **1950**mm.

Problem 2.A T-beam of depth of 450 mm has a flange width of 1000 mm and depth of 120 mm. It is reinforced with 6- 20mmϕ bars on tension side with a cover of 30 mm. If M-20 concrete and Fe415 steel are used. Calculate MR of beam. Take b_w= 300mm.

Solution:

Given : b_w = 300mm,

b_f = l000mm,

D_f = 120mm,

Clear Cover = 30mm,

D = 450mmEffective cover= 30 + 20/2 = 40mm

d = 450 - 40 = 4l0mm

M20, f_{ck} = 20 N/mm^2

Fe415, f_y = 415 N/mm^2

Assuming Actual Neutral Axis (x_u) lies within the flange (i.e, $x_u \leq D_f$)

$X_u/d = (0.87.f_y.A_{st})/ (0.36.f_{ck}.b.d)$

= 0.87x415x1885 / (0.36x1000x20)

= 94.52mm < D_f(120mm)

Assumption is correct

The value of $x_{u,max}$ /d from IS:456-2000 for Fe415

0.48.$x_{u,max}$ = 0.48d = 0.48x410 = 196.8mm

$x_u < x_{u,max}$, section is under reinforced, calculate the moment of resistance by the following expression

$M_u = 0.87. f_y. A_{st}.d. [1-((f_y. A_{st})/(f_{ck}.b.d))]$

= 0.87x415x1885x410x(1-((1885x415)/(1000x410x20)))

= 252.41x10^6 N-mm

M_u= **252.41x10^6** N-mm.

Problem 3.Calculate the Ultimate moment of resistance of a tee-beam having the following section properties. Use M20 and Fe 415 HYSD bars. Width of flange = l300mm, Thickness of flange = l00mm, Width of rib = 325mm, Effective depth = 600mm, Area of steel = 4000mm^2

Solution:

Given: b_w = 325mm,

b_f = l300mm,

D_f = l00mm,

d = 600mm,

f_{ck} = 20N /mm^2,

f_y =415N/mm^2,

A_{st} = 4000mm2.

Assuming Actual Neutral Axis (x_u) lies within the flange (i.e, $x_u \leq D_f$)

$X_u/d = (0.87.f_y.A_{st})/ (0.36.f_{ck}.b.d)$

= 0.87x415x4000 / (0.36x1300x20)

= 154.3mm > D_f(100mm)

Assumption is wrong, neutral axis lies below the flange.

D_f / d = 100 / 600 = 0.166 < 0.2

The value of x_u by using relation $C_1+C_2=T$

C_1 = $0.36.f_{ck}.x_u.b_w$ = 0.36x20x325x x_u = 2340 x_u

C_2 = $0.45.f_{ck}.(b_f - b_w).D_f$

= 0.45x20x100x(1300-325)

= 877500 NT = $0.87. f_y. A_{st}$

= 0.87x415x4000 = 1444200 N

2340 x_u + 877500 = 1444200

x_u = 242.18mm

$x_{u,max}$ = 0.48d = 0.48x600 =

288mm $x_u < x_{u,max}$, section is under

reinforced.D_f / x_u = 100 / 242.18 = 0.413

< 0.43.

Hence use equation for M_u calculation

$M_u = 0.36. f_{ck}.b_w.d^2.(x_u/d).(1-0.42.(x_u/d)) + 0.45.f_{ck}.(b_f - b_w).D_f.(d-(D_f/2))$

M_u= 0.36x (242.18/600)x(1-0.42x(242.18/600))x325x600^{2}x20 +

0.45x20x(1300-325)x100x(600-(100/2))

= 282557218 + 482625000

= 765.18x10^6 N-mm

= **765.15** kN-m.

Design of Shear Reinforcement

When τ_v exceeds τ_c given in Table 19, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,

b) Bent-up bars along with stirrups, and

c) Inclined stirrups.

Behaviour of rectangular RC beams in shear and torsion

$V_e = V_u + 1.6(T_u/b)$

where V_e = equivalent shear,

V_u = actual shear,

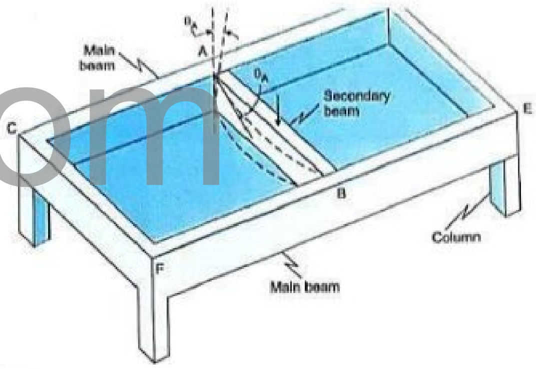
T_u = actual torsional moment,

b = breadth of beam.

(b) The equivalent nominal shear stress τ_{ve} is determined from:

$\tau_{ve} = (V_e / bd)$

, τ_{ve} shall not exceed τ_{cmax} given in Table 20 of IS 456



The longitudinal flexural tension reinforcement shall be determined to resist an equivalent bending moment M_{e1} as given below:

$$M_{e1} = M_u + M_t$$

where M_u = bending moment at the cross-section, and

$M_t = (T_u/1.7)\{1 + (D/b)\}$

where T_u = torsional moment,

D = overall depth of the beam, and

b = breadth of the beam.

Design Problem – T beam

An isolated T-beam has a flange of 1200x100mm, width of rib is 250mm and effective depth is 600mm. Tension steel is 3500mm2. Grade of concrete is M20 and steel grade is Fe415. Compute the ultimate moment of resistance. Span of SS beam = 8m. Also calculate the safe superimposed load the T-beam can carry, if effective cover = 50mm.

Solution:

Given: bw = 250mm,

bf = l200mm,

Df = l00mm,

d = 600mm,

fck = 20N /mm^2,

fy = 415N/mm^2,

Ast = 3500mm^2,

l = 8m,

D = 600 + 50 = 650mm.

For Isolated T-beam Effective flange width is the least of the following:

1. bf = I /[(I/b)+4] + bw

   = 8000/((8000/1200)+4)+250 = 1000mm

2. bf = actual width of the flange = 1200 mm

Therefore, bf = 1000 mm.

Assuming Actual Neutral Axis (xu) lies within the flange (i.e, xu ≤ Df)

Xu/d = (0.87.fy.Ast)/ (0.36.fck.b.d) = 0.87x415x3500 / (0.36x1000x20) = 175.51mm > Df (100mm)

Assumption is wrong, neutral axis lies below the flange.

Df / d = 100 / 600 = 0.166 < 0.2

The value of xu by using relation C1+C2=T

C1 = 0.36.fck.xu.bw = 0.36x20x250x xu = 1800 xu

C2 = 0.45.fck.(bf – bw).Df = 0.45x20x100x(1000-250) = 675000 N T = 0.87. fy.

Ast = 0.87x415x3500 = 1263675 N

1800 xu+ 675000 = 1263675

xu = 327.04mm

$x_{u,max}$ = 0.48d = 0.48x600

= 288mm xu> xu,max,

section is over reinforced.

Df / xu = 100 / 327.04 = 0.305 < 0.43.

Hence use equation for Mu calculation

Mu= 0.36. fck.bw.d2.($x_{u,max}$/d).(1-0.42.($x_{u,max}$ /d)) + 0.45.fck.(bf – bw).Df.(d-(Df/2))

Mu= 0.36x 0.48x(1-(0.42x0.48))x250x6002x20 + 0.45x20x(1000-250)x100x(600- (100/2))

= 248334336 + 371250000

=

=

Design Problem – T beam

An isolated T-beam has a flange of 1200x100mm, width of rib is 250mm and effective depth is 600mm. Tension steel is 3500mm2. Grade of concrete is M20 and steel grade is Fe415. Compute the ultimate moment of resistance. Span of SS beam = 8m. Also calculate the safe superimposed load the T-beam can carry, if effective cover = 50mm.

Solution:

Given: bw = 250mm,

bf = l200mm,

Df = l00mm,

d = 600mm,

fck = 20N /mm^2,

fy = 415N/mm^2,

Ast = 3500mm^2,

l = 8m,

D = 600 + 50 = 650mm.

For Isolated T-beam Effective flange width is the least of the following:

1. bf = I /[(I/b)+4] + bw

   = 8000/((8000/1200)+4)+250 = 1000mm

2. bf = actual width of the flange = 1200 mm

Therefore, bf = 1000 mm.

Assuming Actual Neutral Axis (xu) lies within the flange (i.e, xu ≤ Df)

Xu/d = (0.87.fy.Ast)/ (0.36.fck.b.d) = 0.87x415x3500 / (0.36x1000x20) = 175.51mm > Df (100mm)

Assumption is wrong, neutral axis lies below the flange.

Df / d = 100 / 600 = 0.166 < 0.2

The value of xu by using relation C1+C2=T

C1 = 0.36.fck.xu.bw = 0.36x20x250x xu = 1800 xu

C2 = 0.45.fck.(bf – bw).Df = 0.45x20x100x(1000-250) = 675000 N T = 0.87. fy.

Ast = 0.87x415x3500 = 1263675 N

1800 xu+ 675000 = 1263675

xu = 327.04mm

$x_{u,max} = 0.48d = 0.48x600$

= 288mm xu> xu,max,

section is over reinforced.

Df / xu = 100 / 327.04 = 0.305 < 0.43.

Hence use equation for Mu calculation

Mu= 0.36. fck.bw.d2.($_{xu,max}$/d).(1-0.42.(x $_{xu,max}$ /d)) + 0.45.fck.(bf – bw).Df.(d-(Df/2))

Mu= 0.36x 0.48x(1-(0.42x0.48))x250x6002x20 + 0.45x20x(1000-250)x100x(600- (100/2))

= 248334336 + 371250000

=

=