RCC Structure – T-Beam

Case Example 2:
Analyze a T-beam 600 mm x 450 mm with web width 250mm and flange depth 125 mm. Beam span is 3.5 m with c/c slab width of 3.5 meter.
Assume concrete grade M30, Steel grade Fe415, Clear cover 25 mm.
Tensile reinforcement bars 20 mm 5 No, compressive reinforcement bars 20 mm 2 No. Provide 8 mm Two legged Stirrup bars.

Analysis:
Data:
Characteristic strength of concrete f_{ck} = 20 N/mm^2 = 20e3 kN/m^2
Yield strength of steel = 415 N/mm^2 = 415e3 kN/m^2
Tensile steel area Ast = 0.25π*25^2*4 = 1963 mm^2
Web width bw = 250 mm
Flange depth Df = 125 mm
Flange width fb = 600 mm

A. Beam Factored Load per meter length:
(i) DL = 0.125 x 25*3.5 = 10.94 kN/m
(ii) Finish load = 0.06 kN/m
(iii) Web self weight = 0.325*0.250*25.0 = 2.03 kN/m
(iv) Total Dead Load = 10.94+0.06+1.05*2.03 = 13.13 kN/m
(v) Live load = 4*3.5 = 14 kN/m
(vi) Factored load = (DL + LL)*load factor = 40.7 kN/m

B. Effective depth (d):
Overall depth (450 mm) – clear cover (25 mm) – bar diameter (25mm)/2 = 412.5 mm

C. Beam span and flange width:
(i) Effective span (given) = 3.5 m
(ii) Given flange width bf = 0.6 m
(iii) Effective flange width (Clause 23.31.2): 3500/6.0 + 250 + 6*125 = 1583

D. Moment and Shear
(i) Total load = factored load x Effective span = 142.4 kN
(ii) Applied Moment (Mu) = (Total load * Eff. Span) /8 = (140.7*3.5)/8 = 62.3 kNm
(iii) Applied shear force (Vu)= Total load/2 = 140.7/2 = 71.2 kN
(iv) Nominal shear stress τ = Vu/(b*d) = 71.2e3/(250*412.5)= 0.69 N/mm^2
(v) Concrete shear τ_c = 0.77 N/mm^2 (Refer table 19 IS 456:2000 for τ_c for given value of percent steel pt = Ast*100/(bw*d) =1963*100/(250*412.5) = 1.9%.
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E. Moment capacity

(i) Assume steel yields 0.87fy*Ast = 0.36 f_{ck}.bf*x Hence x = (0.87fy*Ast)/(0.36 f_{ck}.bf) = (0.87*415*1963)/(0.36*20*600) = 164 mm > flange depth

(ii) Neutral axis is below the flange; x/d = 0.398 ; Df/d = 0.30 Since Df/d is > 0.2 Flange is non-uniformly stressed.

(iii) X_{max} = D/2 = 225 mm hence approximate position of NA x_a = (164+225)/2 = 194.5 mm (One can determine this iteratively from recalculating the moment and x/d until assumed value of x agrees with the result. However, one can use this approximate value as upper limit of the moment capacity.)

(iv) Flange yf = 0.15x_a – 0.65Df = 110.4 mm

(v) Moment capacity Web Mu_{c1} = 0.36*. f_{ck}.bf*x_a*(d-0.416x_a) = 115.9 kNm

(vi) Moment capacity Flange Mu_{c2} = 0.45fck*(bf – bw)*yf(d-0.416yf) = 124 kNm

(vii) ∴ Moment capacity due to concrete failure = Mu_{c1} + Mu_{c2} = 240 kNm (upper limit)

(viii) Moment capacity due to steel yielding Mu_t = 0.87fy*Ast*(d-Df/2) = 248 kNm (upper limit)

F. Beam Design

(i) Applied moment 61.56 kNm

(ii) Moment Capacity 240 kNm

G. Stirrup spacing

(i) Since Concrete shear τ_c = 0.77 > Nominal shear τ = 0.69 provide nominal stirrups.

(ii) Clause 26.3.3-c Not greater than 300 mm

(iii) ∴ Provide stirrup spacing at 300 mm.

H. Material Estimates (web part only)

(i) Concrete volume (web part): 0.25*0.325*3.5 = 0284 m^3

(ii) Cement quantity: M20 Volume of cement 1:5.5 = 0.284*1440/3.5 = 74 kg

(iii) Steel quantity: ϕ-25 mm x 21m length ≈ 86 kg

Flange is integral part of the slab. Add necessary allowances for wastage, shrinkage etc. to the above estimates.