RCC Structure – Simple Beam Under Flexure

Case Example:
A simple beam 300 mm x 500 mm is subjected to 250 kNm moment 120 kN Vertical Shear. Concrete grade M20, Steel grade Fe415, Clear cover 25 mm. Tensile reinforcement bars 25 mm 5 No, compressive reinforcement bars 20 mm 3 No. Provided 8 mm Two legged Stirrup bars. Analyze the design.

Analysis:
Data:
Characteristic strength of concrete f_{ck} = 20 N/mm^2 = 20e3 kN/m^2
Yield strength of steel fy = 415 N/mm^2 = 415e3 kN/m^2

A. Beam Load:
(i) Moment = 250 kNm
(ii) Shear Force = 120 kN

B. Effective depth (d):
Depth (500 mm) – clear cover (25 mm) – bar diameter (25mm)/2 = 462.5 mm

C. Moment Capacity in doubly reinforced beam – Tensile zone
(i) Moment due to concrete failure $Mu_1 = 0.138\ f_{ck}*b*d^2$ = 0.138*20.0e3*0.3*0.462*0.462 = 176.7 kNm
(ii) Balanced steel expression 0.87fy*Ast1 = 0.36 $f_{ck}*b*x_u$ Rearranging we get $Ast_1*100/b*d$ = Pt = $(0.36/0.87)(f_{ck}/fy)*(x_u/d)*100$; use (x_u/d)= 0.48 for Fe415 steel and get Pt = 0.957%
(iii) Total tensile steel area Ast = $5*0.25\pi*25^2$ = 2454 mm^2
(iv) $Ast_2 = Ast-Ast_1$ = 2454 -1328 = 1126 mm^2
(v) $Mu_2 = Ast_2*0.87fy*(d-d')$ where d' = (clear cover + bar dia/2)= 35.0 ; Mu_2 =1126*0.87*415*(462.5 – 35.0) = 173 kNm
(vi) Moment capacity for tensile zone = Mu_1+Mu_2 = 177+173 = 350.0 kNm

E. Moment capacity in doubly reinforcement beam – compressive zone
(i) Strain in outermost compressive fiber is assumed to be 0.0035
(ii) Corresponding strain in compressive steel bar $\varepsilon_{sc} = (x_4 - d')*0.0035/x_u$; substitute value of x_u =0.48*d and d' =35 we get ε_{sc} = 0.002948.
(iii) From stress-strain curve for Fe415, stress fes ≈ 352 N/mm^2
(iv) $Mu_c = fes*Asc*(d-d') = 352.0*(3*0.25\pi*20^2)*(462.5-35.0)$
(v) Moment capacity for compressive zone = Mu_1+Mu_c = 177+142 = 319 kNm

F. Beam Design Capacity

(i) Less of Moment capacity of Tensile or compressive zone = 319 kNm

(ii) Concrete shear stress τ_c from table 19 for M20 = 0.75N/mm^2

(iii) Shear capacity Vu = τ_c*300*d /1e3+ 0.87fy*(2*0.25π*8^2)/1e3 = 141 kN

(iv) Design capacity of the beam is more than the given moment (250 kNm) and shear force (120kN).

G. Stirrup spacing

(i) Nominal shear = Shear force/(width*d) = 120e3/(300*462) = 0.87 N/mm^2

(ii) τ_{sv} = (Nominal shear – concrete shear) = 0.87 – 0.75 = 0.12 N/mm^2

(iii) Two legged stirrup area Asv = 2*0.25π*8^2 = 100.48 mm^2

(iv) Clause 26.5.1.6 Asv/sv = (0.4b/0.87fy) and sv = (Asv*0.87fy)/(0.4b) = (100.48*0.87*425)/(0.4*300)= 302.3 mm

(v) Clause 26.3.3-b 0.75*effective depth = 346.0 mm.

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

(vii) $\therefore$ Provide stirrup spacing at 300 mm.

H. Material Estimates /meter beam length

(i) Concrete volume: 0.300*0.5*1.0 = 0.15 m^3

(ii) Cement quantity: M20 Volume of cement 1:5.5 = 0.15*1440/5.5 = 39 kg

(iii) Steel quantity: ϕ-25 mm x 5m length; ϕ 20 mm x 3 m length $\approx$ 28 kg

Add necessary allowances for wastage, shrinkage etc. to the above estimates.