RCC Structure – One Way Slab

Case Example:
A roof slab 3.5 x 8 meters, 160 mm thick is resting on a 250 mm thick wall all around. Consider Concrete grade M20, Steel grade Fe415, clear cover 15 mm. Short span 10 mm steel bar @ 150 mm c/c, Long span 8 mm steel bar @ 260 mm c/c. Add 1 kN/m^2 finish dead load, assume live load 4 kN/m^2. Analyze the design.

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

A. Slab Factored Load:

(i) DL = 0.16 x 25 = 4.0 kN/m^2
(ii) Finish load = 1kN/m^2
(iii) Total Dead load = 5 kN/m^2
(iv) Live load = 4 kN/m^2
(v) Factored load = (DL + LL)*load factor = 13.5 kN/m^2

B. Effective depth (d):
Slab thickness (160 mm) – clear cover (15 mm) – bar diameter (10mm)/2 = 140mm

C. Effective span:

(i) Short span + wall thickness = 3.5 + 0.25 = 3.75 m
(ii) Short span + effective depth = 3.5 + 0.14 = 3.64 m
(iii) Clause 22.2 minimum of the above = 3.64 m

D. Moment and Shear Force Calculation (1m x 1m slab)

(i) Total load = factored load x Effective span = 49.14 kN
(ii) Applied Moment (Mu) = (Total load * Eff. Span) /8 = (49.14*3.64)/8 = 22.35 kNm
(iii) Applied shear force (Vu)= Total load*eff.span/2 = 49.14/2 = 24.57 kN
(iv) Moment capacity = 0.138 f_{ck}*b*d^2 = 0.138*20.0e3*1.0*0.14^2 = 54.1 kNm (greater than applied moment)
(v) Shear force capacity = τ_c **b*** d = 0.27e3 * 1.0*0.14 = 37.8 kN (Refer table 19 IS 456:2000 for τ_c)
(vi) Above moment and shear force capacity is for concrete failure. Moment and shear force applied should be less than respective capacities.

E. Steel Area - primary:

(i) Calculate x/d = 1.2 – sqrt(1.2^2 – 6.6 Mu/f_{ck}.b.d^2) = 1.2 - √(1.44 – (6.6*22.35*10^6/(20*1000*140^2)) = 0.1655
(ii) Lever arm Z = d*(1- 0.416*x/d) = 130.2

(iii) Steel area Ast = Mu/(0.87*fy*Z) = $22.35*10^6$/(0.87*415*130.2) = 475 mm^2.
(iv) Steel area provided 10 mm bar @ 150 mm c/c = 523.33 mm^2

F. Steel area secondary (distribution) Clause 26.3.3
(i) Spacing 3d or 300 mm which ever is minimum
(ii) Not greater than 5d or 450 mm which ever is greater
(iii) Minimum percent steel on either direction = 0.12*b*D/100.0 = 192 mm^2
(iv) Steel provided 8 mm bar @ 260 mm c/c = 193 mm^2

G. Control of Deflection: (Clause 23.2)
(i) Span to effective depth (l/d) = 3.5*1000/140.0 = 26.0
(ii) Percent steel Pst = 523*100/(140*1000) = 0.373 %
(iii) Find modification factor from Figure 4.0 IS 456 for the given percent steel and fs = 0.58*fy*Steel area required/Steel area provided = 0.58*415*475/523 = 218.0
(iv) Modification factor from the graph found to be ≈ 1.5
(v) L/D Permissible for simply support = 20x modification factor = 30.0
(vi) Design L/D value is less than permissible hence design is safe.

H. Material Estimates
(i) Concrete volume: 3.5*8.0*0.160(span area) + 6*0.160 (wall area) = 5.44 m^3
(ii) Cement quantity: M20 Volume of cement 1:5.5 = 5.44*1440/5.5 = 1424 kg
(iii) Steel quantity: ϕ-10 mm x 186m length; ϕ 8 mm x 108 m length ≅ 159 kg
Add necessary allowances for wastage, shrinkage etc. to the above estimates.