APPENDIX 3

DESIGN OF BEAM (FOR M20 CONCRETE)
(SERIES A)

Span of beam = 480.0 mm
Overall depth of beam = 100.0 mm
Breadth of beam = 100.0 mm
Clear cover = 25.0 mm
Main bar diameter (TOR) = 8.2 mm (2 nos)
Hanger bar diameter (MS) = 6.0 mm (2 nos)
Stirrup bar diameter (MS) = 4.0 mm (5 nos)
Effective cover at top (d') = 25 + 6/2 = 28 mm
Area of main steel (A_t) = 105.62 mm²
Area of hanger bar (A_c) = 56.55 mm²
Area of stirrup (A_v) = 25.14 mm²
Effective depth of beam (d) = 100 - (25+4.1) = 71 mm (approx.)

Modulus of Elasticity of steel (E_s) = 2 x 10⁶ N/mm²
Characteristic compressive strength of concrete (M20) (f_k) = 23.42 N/mm²
Characteristic strength of steel in tension (f_t) = 450.00 N/mm²
Characteristic strength of steel in compression (f_c) = 275.00 N/mm²
Characteristic strength of stirrup steel (f_v) = 230.00 N/mm²
Spacing of stirrups (sv) = 125 mm
Size of Beams = 100 x 100 x 600 mm
Span = 480 mm
Loading = Two point load at 1/3 span on Simply supported beam

To find the position of neutral axis of the beam.
Equating the strength of compression and tensile zone

\[ \frac{0.36 \times f_{ik} \times b \times x_u + 0.0035(x_u-d') \times E_s \times A_{sc}}{x_u} = 0.87 \times f_{st} \times A_{st} \]

\[ \frac{0.36 \times 23.42 \times 100 \times x_u + 0.0035(x_u-28) \times 2 \times 10^5 \times 56.55}{x_u} = 0.87 \times 450 \times 105.62 \]

\[ 843 \times x_u + 39,585 (x_u - 28)/x_u = 41,350.23 \]

Solving the above equation

\[ x_u = 37.32 \text{ mm} \]

Flexural capacity of the beam

Compressive force in concrete (C_c) = 0.36 \times f_{ik} \times b \times x_u
= 0.36 \times 23.42 \times 100 = 37.32
= 31,465 N

Compressive force in compression steel (C_{st}) = 0.0035(x_u-d')/x_u \times E_s \times A_{sc}
= 39585 (37.32-28)/37.32
= 9,885 N
CALCULATION OF MOMENT CAPACITY

Taking moment of compressive forces about the centre of tension zone:

Moment due to concrete compressive force \( M_{cl} \) = \( C_c \times (d - 0.42 \times x_j) \)
\[ = 31,465 \times (71 - 0.42 \times 37.32) \]
\[ = 17,40,832 \text{ N mm} \]

Moment due to compressive force in steel \( M_{c2} \) = \( C_s \times (d - d') \)
\[ = 9,885 \times (71 - 28) \]
\[ = 4,25,082 \text{ N mm} \]

Total moment \( M = (M_{cl} + M_{c2}) \)
\[ = 21,65,915 \text{ N mm} \]

Moment due to applied load (2\( W_u \)) \( M \) = \( W_u \times 160 \)

Maximum load that can be applied on beam (\( W_u \))
\[ = \frac{21,65,915}{160 \times 1000} \]

Capacity of load due to Flexure = 27.07 kN

SHEAR CALCULATION

As per the IS : 456 -1978

The ratio of steel vs area of beam gives
\[ \frac{A_s \times 100}{b \times d} = \frac{(105.62 \times 100)}{100 \times 71} = 1.487 \]

The design shear strength \( \tau_s \) (Table 13, I.S.code 456 : 1978)
given as \( \tau_s = 0.718 \text{ N/mm}^2 \)
Shear capacity of concrete \( = 0.7182 \times b \times d \)
\[ = 0.7182 \times 100 \times 71 \text{ N} \]
\[ = 5097.8 \text{ N} \]
Shear capacity of stirrups (without external stirrups) = \( \frac{(0.87 \times f_{ys} \times A_{sv} \times d)}{s_v} \)

Total shear = \( \frac{0.87 \times 230 \times 25.14 \times 71}{125} \) = 2857.3 N

Total load capacity on the beam due to shear = 5,097.8 + 2,857.3 = 7,955 N

Total load capacity on the beam due to shear = \( 7,955 \times 2 / 1000 = 15.910 \) kN

DESIGN OF BEAM (FOR M_{15} CONCRETE)

Beam Detail

Span of beam = 480.0 mm
Overall depth of beam = 100.0 mm
Breadth of beam = 100.0 mm
Clear cover = 25.0 mm
Main bar diameter (TOR) = 8.2 mm (2 nos)
Hanger bar diameter (MS) = 6.0 mm (2 nos)
Stirrup bar diameter (MS) = 4.0 mm (5 nos)
Effective cover at top (d') = \( 25 + \frac{6}{2} = 28 \) mm
Area of main steel (A_{m}) = 105.62 mm²
Area of hanger bar (A_{m'}) = 56.55 mm²
Area of stirrup (A_{sv}) = 25.14 mm²
Effective depth of beam (d) = \( 100 - (25 + 4.1) = 71 \) mm (approx.)
Modulus of elasticity (E_p) = \( 2 \times 10^5 \) N/mm²
Characteristic compressive strength of concrete (M_{15}) (f_{ck}) = 18.87 N/mm²
Characteristic strength of steel in tension (f_{ut}) = 450.00 N/mm²
Characteristic strength of steel in compression (f_{ct}) = 275.00 N/mm²
Characteristic strength of stirrup steel (f_{sv}) = 230.00 N/mm²
Spacing of stirrups (sv) = 125 mm  
Size of Beams = 100 x 100 x 600 mm  
Span = 480 mm  
Loading = Two point load at 1/3 span on Simply supported beam

To find the position of neutral axis.
Equating the strength of compression and tensile zone

\[
0.36 \times f_{ck} \times b \times x_u + 0.0035(x_u - d') \times E_s \times A_{sc} \quad = \quad 0.87 \times f_{ct} \times A_{st} \\
\]

\[
0.36 \times 18.87 \times 100 \times x_u + 0.0035(x_u - 28) \times 2\times 10^5 \times 56.55 \\
\]

\[
X_u = 679 \times x_u + 39,585 (x_u - 28)/x_u \\
\]

\[
679 \times x_u + 39,585 (x_u - 28)/x_u = 41,350.23 \\
\]

Solving the above equation

\[x_u = 41.71 \text{ mm} \]

Flexural capacity of the beam

Compressive force in concrete (C_c) = \[0.36 \times f_{ck} \times b \times x_u \]
\[= 0.36 \times 18.87 \times 100 \times 41.71 \]
\[= 28,334 \text{ N} \]

Compressive force in compression steel (C_{st}) = \[0.0035(x_u - d')/x_u \times E_s \times A_{sc} \]
\[= 39585 (41.71-28)/41.71 \]
\[= 13,011 \text{ N} \]
CALCULATION OF MOMENT CAPACITY

Taking moment of forces about the centre of tension zone:

Moment due to concrete compressive force

\[ M_{c1} = C_C \times (d - 0.42 \times x_j) \]

\[ = 28,334 \times (71 - 0.42 \times 41.71) \]

\[ = 15,15,376 \text{ N mm} \]

Moment due to compressive steel force

\[ M_{c2} = C_S \times (d - d') \]

\[ = 13,011 \times (71 - 28) \]

\[ = 5,59,494 \text{ N mm} \]

Total moment

\[ M = (M_{c1} + M_{c2}) \]

\[ = 20,74,871 \text{ N mm} \]

Moment due to applied load (2Wu)

\[ M = W \times 160 \]

Maximum load that can be applied on beam (2Wu)

\[ = \frac{20,74,871}{160 \times 1000} \times 2 \]

Capacity of load due to flexure

\[ = 25.936 \text{ kN} \]

SHEAR CALCULATION

As per the I.S. code 456 : 1978

The ratio of steel vs area of beam gives

\[ \frac{A_s}{b \times d} \times 100 = \frac{(105.62 \times 100)}{100 \times 71} = 1.487 \]

The design shear strength \( \tau_c \) (Table 13, I.S.code 456 : 1978)

\[ \tau_c = 0.678 \text{ N/mm}^2 \]
Shear capacity of concrete  
\[ = 0.678 \times b \times d \]
\[ = 0.678 \times 100 \times 71 \text{ N} \]
\[ = 4,813.8 \text{ N} \]

Shear capacity of stirrups  
\[ = \frac{(0.87 \times f_{sy} \times A_{sv} \times d)}{s_r} \]
\[ = \frac{(0.87 \times 230 \times 25.14 \times 71)}{125} \]
\[ = 2,857.3 \text{ N} \]

Total shear  
\[ = 4,813.8 + 2,857.3 = 7,671.1 \text{ N} \]

Total load capacity on the beam due to shear  
\[ = 7,671.1 \times 2 / 1000 = 15.342 \text{ kN} \]
\[ = 15.342 \text{ kN} \]
\[ < 25.936 \text{ kN} \]

Shear capacity of the beam with external stirrups adopted between the support and the extreme load points.

Diameter of external stirrup  
\[ = 10 \text{ mm} \]

Tensile force taken by external stirrup  
\[ = \frac{0.87 \times 250 \times 100 \times \pi \times 2}{4} \]
\[ = 34,164.82 \text{ N} \]

Shear capacity of beam before providing external stirrups  
\[ = 7,671 \text{ N} \]

Total shear capacity after providing external stirrups (M_{15})  
\[ = (34,164.82 + 7,671) \times 2 \]
\[ = 41,835.82 \times 2 \]
\[ = 83,671.64 \text{ N} \]

Total external load if the beam have to fail in shear for (M_{15})  
\[ = 83,671.64 \text{ N} \]

Total external load if the beam have to fail in shear for (M_{20})  
\[ = 84,239.64 \text{ N} \]