**THE DESIGN AND ANALYSIS OF A REINFORCED CONCRETE CONTINUOUS BEAM USING THE** **BS CODE**

**BY**

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**SUBMITTED IN PARTIAL FULFILMENT**

**OF THE REQUIREMENT FOR THE AWARD OF THE**

**BACHELOR OF ENGINEEERING (B.ENG) DEGREE IN CIVIL ENGINEERING**

**TO**

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**SOLUTION**

**Assumptions**

* Dead load, $G\_{k}=25{kN}/{m}$
* Live load, $Q\_{k}=5{kN}/{m}$

Design load, DL $=1.4G\_{k}+1.6Q\_{k}$

 $=1.4\left(25\right)+1.6\left(5\right)=43{kN}/{m}$

| **S/N** | **CALCULATIONS** | **REMARKS** |
| --- | --- | --- |
| **1** | **USING HARDY CROSS METHOD OF MOMENT DISTRIBUTION**Stiffness, k = $^{1}/\_{l}$ (k = $^{3}/\_{4}×^{1}/\_{l}$ for the end spans)Distribution factor, DF = $\frac{k}{\sum\_{}^{}k}$Fixed end moment, FEM = $\pm \frac{wl^{2}}{12}$Out of balance moment, OBM = $∑$ moments at a jointBalance moment, BM = $-1×$ OBMDistributed moment, DM = BM $×$ DFTransferred moment, TM = $^{1}/\_{2}×$ DMFinal moment, M = FEM $+$ DM $+$ TM |  |
|  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **MEMBERS** | **AB BA** | **BC CB** | **CD DC** | **DE ED** |  |
| **k** | 0.1667 | 0.2381 | 0.1818 | 0.1974 |  |
| **DF** 0 | 1 0.4118 | 0.5882 0.567 | 0.433 0.4794 | 0.5206 1 | 0 |
| **FEM** | **-72.56 72.56** | **-63.21 63.21** | **-108.4 108.4** | **-51.74 51.74** |  |
| **OBM**  -72.56 9.35 -45.19 56.66 51.74  |
| **BM**  72.56 -9.35 45.19 -56.66 -51.74  |
| **DM 0** | **72.56 -3.85** | **-5.5 25.62** | **19.57 -27.16** | **-29.5 -51.74** | **0** |
| **TM** | **-1.93 36.28** | **12.81 -2.75** | **-13.58 9.79** | **-25.87 -14.75** |  |
| **OBM**  -1.93 49.09 -16.33 -16.08 -14.75  |
| **BM**  1.93 -49.09 16.33 16.08 14.75  |
| **DM 0** | **1.93 -20.22** | **-28.87 9.26** | **7.07 7.71** | **8.37 14.75** | **0** |
| **TM** | **-10.11 0.97** | **4.63 -14.44** | **3.86 3.54** | **7.38 4.19** |  |
| **OBM**  -10.11 5.6 -10.58 10.92 4.19  |
| **BM**  10.11 -5.6 10.58 -10.92 -4.19  |
| **DM 0** | **10.11 -2.31** | **-3.29 6.00** | **4.58 -5.24** | **-5.68 -4.19** | **0** |
| **TM** | **-1.16 5.06** | **3.00 -1.65** | **-2.62 2.29** | **-2.10 -2.84** |  |
| **OBM**  -1.16 8.06 -4.27 0.19 -2.84  |
| **BM**  1.16 -8.06 4.27 -0.19 2.84  |
| **DM 0** | **1.16 -3.32** | **-4.74 2.42** | **1.85 -0.09** | **-0.10 2.84** | **0** |
| **M 0** | **0 85.17** | **-85.17 87.67** | **-87.67 99.24** | **-99.24 0** | **0** |

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|  | **Support Moments**$M\_{A}=0$ $M\_{B}=85.17 kNM$ $M\_{C}=87.67 kNM$ $M\_{D}=99.24 kNM$ $M\_{E}=0$ **Free Moments** $\left(M^{f}=\frac{wl^{2}}{8}\right)$$M^{f}\_{AB}=\frac{43×4.5^{2}}{8}=108.84 kNm$ $M^{f}\_{BC}=\frac{43×4.2^{2}}{8}=94.82 kNm$ $M^{f}\_{CD}=\frac{43×5.5^{2}}{8}=162.59 kNm$ $M^{f}\_{DE}=\frac{43×3.8^{2}}{8}=77.62 kNm$ **Span Moments** $\left(M^{s}\_{AB}=M^{f}\_{AB}-\left(\frac{M\_{A}+M\_{B}}{2}\right)\right)$$M^{s}\_{AB}=108.84-\left(\frac{0+85.17}{2}\right)=66.26 kNm$ $M^{s}\_{BC}=94.82-\left(\frac{85.17+87.67}{2}\right)=8.4 kNm$ $M^{s}\_{CD}=162.59-\left(\frac{87.67+99.24}{2}\right)=69.14 kNm$ $M^{s}\_{DE}=77.62-\left(\frac{99.24+0}{2}\right)=28 kNm$ **Shear Force** $\left(V\_{AB}=\left(\frac{wl}{2}\right)+\left(\frac{M\_{A}-M\_{B}}{L\_{AB}}\right)\right)$$V\_{AB}=\left(\frac{43×4.5}{2}\right)+\left(\frac{0-85.17}{4.5}\right)=77.82 kN$ $V\_{BA}=\left(\frac{43×4.5}{2}\right)+\left(\frac{85.17-0}{4.5}\right)=115.68 kN$ $V\_{BC}=\left(\frac{43×4.2}{2}\right)+\left(\frac{85.17-87.67}{4.2}\right)=89.7 kN$ $V\_{CB}=\left(\frac{43×4.2}{2}\right)+\left(\frac{87.67-85.17}{4.2}\right)=90.9 kN$ $V\_{CD}=\left(\frac{43×5.5}{2}\right)+\left(\frac{87.67-99.24}{5.5}\right)=116.15 kN$ $V\_{DC}=\left(\frac{43×5.5}{2}\right)+\left(\frac{99.24-87.67}{5.5}\right)=120.35 kN$ $V\_{DE}=\left(\frac{43×3.8}{2}\right)+\left(\frac{99.24-0}{3.8}\right)=107.82 kN$ $V\_{ED}=\left(\frac{43×3.8}{2}\right)+\left(\frac{0-99.24}{3.8}\right)=55.58 kN$ **DESIGN**Beam size = 230 \* 600 mm Beam span = 18 mCharacteristic strength of concrete, $f\_{cu}=25{N}/{mm^{2}}$Characteristic strength of steel, $f\_{y}=410{N}/{mm^{2}}$Diameter of bar, $θ\_{bar}=16 mm$Diameter of stirrup, $θ\_{stirrup}=10 mm$Cover = 20 mmEffective depth, $d=h-cover-^{1}/\_{2}θ\_{bar}-θ\_{stirrup}$$d=600-20-8-10=562 mm$ **Supports**$M\_{max}=99.24 kNm$ Ultimate moment of resistance, $M\_{u}=0.156f\_{cu}bd^{2}$$M\_{u}=\frac{0.156×25×230×562^{2}}{1000×1000}=283.31 kNm$ $k=\frac{M\_{max}}{bd^{2}f\_{cu}}=\frac{99.24×10^{6}}{230×562^{2}×25}=0.0546$ Lever arm factor, $la=0.5+\sqrt{0.25-\frac{k}{0.9}}$$la=0.5+\sqrt{0.25-\frac{0.0546}{0.9}}$ $la=0.935<0.95$ Lever arm, $z=lad=0.935×562=525.47 mm$Area of steel in tension, $As=\frac{M\_{max}}{0.95f\_{y}z}$$As=\frac{99.24×10^{6}}{0.95×410×525.47}=484.88 mm^{2}$ Provide 3Y16 bars TOP $\left(As=603 mm^{2}\right)$**Check;**$0.15\leq \frac{100As}{bd}\leq 4$ $0.15\leq \frac{100×603}{230×562}\leq 4$ $0.15<0.47<4$ **Spans**$M^{s}\_{max}=69.14 kNm$ $k=\frac{M^{s}\_{max}}{bd^{2}f\_{cu}}=\frac{69.14×10^{6}}{230×562^{2}×25}=0.0381$ Lever arm factor, $la=0.5+\sqrt{0.25-\frac{k}{0.9}}$$la=0.5+\sqrt{0.25-\frac{0.0381}{0.9}}$ $la=0.955>0.95$ Lever arm, $z=lad=0.95×562=533.9 mm$Area of steel, $As=\frac{M^{s}\_{max}}{0.95f\_{y}z}$$As=\frac{69.14×10^{6}}{0.95×410×533.9}=332.48 mm^{2}$ Provide 2Y16 bars BOTTOM $\left(As=402 mm^{2}\right)$**Deflection**Design service stress, $f\_{s}=\frac{2}{3}×f\_{y}×\frac{As\_{req}}{As\_{prov}}$$f\_{s}=\frac{2}{3}×410×\frac{332.48}{402}=226.0643$ Modification factor, $Mf=0.55+\frac{\left(477-f\_{s}\right)}{120\left(0.9+\frac{M^{s}\_{max}}{bd^{2}}\right)}\leq 2$$Mf=0.55+\frac{\left(477-226.0643\right)}{120\left(0.9+\frac{69.14×10^{6}}{230×562^{2}}\right)}\leq 2$ $Mf=1.68<2$ Deflection, $df=\frac{beam span}{26×Mf}$$df=\frac{18×10^{3}}{26×1.68}$ $df=412.09 mm$ **Shear**Shear force, $V\_{max}=120.35 kN$Shear stress, $v=\frac{V\_{max}}{bd}$$v=\frac{120.35×10^{3}}{230×562}=0.93{N}/{mm^{2}}$ Permissible shear stress, $v\_{c}=0.79×\frac{\left(\frac{100As}{bd}\right)^{\frac{1}{3}}×\left(\frac{400}{d}\right)^{\frac{1}{4}}}{λ\_{m}}$$λ\_{m}=1.25$ $v\_{c}=0.79×\frac{\left(\frac{100×402}{230×562}\right)^{\frac{1}{3}}×\left(\frac{400}{562}\right)^{\frac{1}{4}}}{1.25}=0.39{N}/{mm^{2}}$ The shear condition is (iii), that is, $\left(v\_{c}+0.4\right)<v<0.8\sqrt{f\_{cu}} OR 5$Hence, minimum stirrups are required throughout the beam spanSpacing, $s\_{v}=\frac{0.95As\_{v}f\_{y}}{b\left(v-v\_{c}\right)}$$As\_{v}=2×\frac{π×10^{2}}{4}=157 mm^{2}$ $s\_{v}=\frac{0.95×157×410}{230\left(0.93-0.39\right)}=492.36 mm$ But spacing is limited to 300 mmProvide 2 legs Y10 @ 300 mm c/c stirrups throughout(230 x 600) mm | $$M<M\_{u}$$**Only tension reinforcement is required****Use 0.935 as lever arm factor****All supports:****3Y16 TOP****Area of steel provided lies within the limit****Use 0.95 as lever arm factor****All spans:****2Y16 BOTTOM****Use 1.68 as modification factor**$$df<d$$**Deflection is satisfied****Stirrups:****2 legs Y10 @ 300 mm c/c** |
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