1.0 INPUT

1.1 Dimensions

Breadth	b	= **300** mm	
Depth	h	= **600** mm	

1.2 Reinforcement Cover

Clear Cover for Bottom	C_{ob}	= **25** mm	
Clear Cover for Top	C_{ot}	= **25** mm	
Side Cover	C_{os}	= **25** mm	

1.3 Design Loads

Design Moment	M	= **140** kNm	
Design Shear Force	V	= **0** kN	
Service Moment	M_s	= **100** kNm	

1.4 Materials

Concrete Grade	f_{cu}	= **35** N/mm^2	
Main Reinforcement Grade	f_y	= **460** N/mm^2	
Shear Reinforcement Grade	f_{yv}	= **460** N/mm^2	
Modulus of Elasticity of Steel	E_s	= **200** kN/mm^2	
Aggregate Size	h_{agg}	= **20** mm	

1.4.1 Material Safety Factors

Concrete in Compression	γ_{mc}	= **1.5**	
Concrete in Shear	γ_{mcs}	= **1.25**	
Reinforcement	γ_{ms}	= **1.15**	

1.5 Crack Width

Check for Crack Width		**Yes**	
Maximum Allowable Crack Width	W_k	= **0.3** mm	

Figure (cross-section): 2 - D16 (top); 2 L - D8 - 200; 2 - D20 + 1 - D16 (bottom); dimensions 600 (depth) × 300 (breadth)
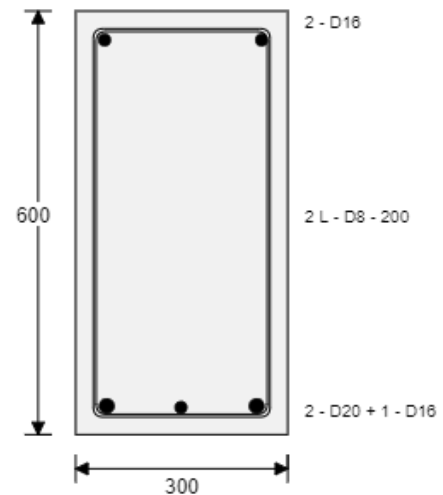
2.0 OUTPUT

Ref: BS 8110 - Part 1

2.1 Flexure Design (Sagging)

2.1.1 Tension Layer Effective Depth Calculation

2.1.1.1 Layer: 01

Rebars		**2 - D 20 + 1 - D 16**	
Area of Reinforcement Provided	A_{t1}	= **829.4** mm^2	
Depth of Layer 01	d_{t1}	= **557** mm	

Total Area of Tension Steel Provided	A_{st}	=**829.4** mm^2
Effective Depth for Tension	d	=**557** mm

2.1.2 Compression Layer Effective Depth Calculation

2.1.2.1 Layer: 01

Rebars		**2 - D 16**	
Area of Reinforcement Provided	A_{c1}	=**402.1** mm^2	
Depth of Layer 01	d_{c1}	=**41** mm	
Total Area of Compression Steel Provided	A_{sc}	=**402.1** mm^2	
Effective Depth for Compression	d_2	=**41** mm	
K Factor	K	=M / (b * d^2 * f$_{cu}$) = **0.043**	*Cl. 3.4.4.4*
K' Factor	K'	=0.2336 / γ_{mc} = **0.156**	
Lever Arm Distance	z	=d * min([0.5 + (0.25 - K / 0.9)$^{1/2}$], 0.95) = **529** mm	
Area of Tension Reinforcement	A_{smom}	=M / (f$_y$ * z / γ_{ms}) = **661.6** mm^2	
Minimum Area of Reinforcement	A_{min}	=0.13% * b * h = **234** mm^2	*Table 3.25*
Maximum Area of Reinforcement	A_{max}	=4% * b * h = **7200** mm^2	
Tension Reinforcement	A_{st}	=**829.4** mm^2	
Compression Reinforcement	A_{sc}	=**402.1** mm^2	

2.2 Crack Width
Ref: BS 8110 - Part 2

Modulus of Elasticity of Concrete	E_c	=(20000 + 200 * f$_{cu}$) / 2 = **13500** N/mm^2
Nearest Tension Bar Dia	D_1	=**20** mm
Tension Reinforcement Cover	C_o	=**33** mm
Tension Steel Ratio	p	=A$_{st}$ / (b * d) = **0.005**
Compression Steel Ratio	p'	=A$_{sc}$ / (b * d) = **0.002**
Spacing of Tension Bars (Outer layer)	S	=**107** mm
Modular Ratio	m	=E$_s$ / E$_c$ = **14.8**
Depth of Neutral Axis (By Iteration)	x	=d * [[(m * p + (m - 1) * p')^2 + 2 * (m * p + (m - 1) * (d$_2$ / d) * p')]$^{1/2}$ - (m * p + (m - 1) * p')] = **176.5** mm
Lever Arm Distance	z	=d - (x / 3) = **498.2** mm
K2 Factor	K2	=(x / (2 * d)) * (1 - (x / (3 * d))) = **0.14**
K3 Factor	K3	=(m - 1) * (1 - (d$_2$ / x)) = **10.61**
Reinforcement Stress	f$_s$	=M$_s$ / (A$_{st}$ * z) = **242** N/mm^2
Concrete Stress	f$_c$	= M$_s$ / ([(K2 * b * d^2) + (K3 * A$_{sc}$ * [1 - (d$_2$ / d)])]) = **7.6** N/mm^2
Strain at Soffit of Beam	ε_1	=(f$_s$ / E$_s$) * (h - x) / (d - x) = **0.00135**
Strain for Stiffening of Concrete btw. Cracks	ε_2	=[b * (h - x)^2] / [3 * E$_s$ * A$_{st}$ * (d - x)] = **0.00028**
Average Strain at Soffit of Beam	ε_m	=ε_1 - ε_2 = **0.00106** *eq:13*
Distance of Crack to Nearest Tension Bar	a_{cr}	=[(S / 2)^2 + (C$_o$ + D$_1$ / 2)^2]$^{1/2}$ - D$_1$ / 2 = **58.6** mm
Design Surface Crack Width	W_{cr}	=3 * a$_{cr}$ * ε_m / [1 + 2 * (a$_{cr}$ - C$_o$) / (h - x)] = **0.167** mm *eq:12*

3.0 SUMMARY

Description	Required	Actual	Status
Area of Tension Reinforcement (mm^2)	661.6	829.4	**PASS**
Minimum Area of Reinforcement (mm^2)	234	829.4	**PASS**
Maximum Area of Reinforcement (mm^2)	7200	829.4	**PASS**
Crack Width (mm)	0.3	0.167	**PASS**