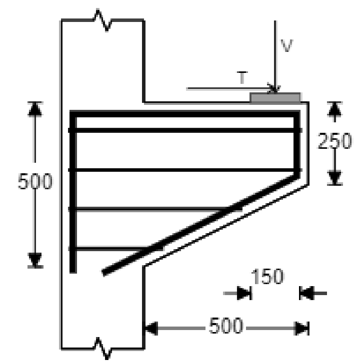
1.0 INPUT

1.1 Dimensions

Width of Corbel	b	= **200** mm
Horizontal Length	a	= **500** mm
Distance from Load to Column Face	a_v	= **400** mm
Free End Depth	h_1	= **250** mm
Overall Depth of Corbel	h	= **500** mm



1.2 Bearing Plate

Length of Bearing Plate	L_b	= **150** mm
Width of Bearing Plate	W_b	= **150** mm

1.3 Reinforcement

1.3.1 Main

No. of Bars	N_m	= **3**
Diameter of Bar	D_m	= **20** mm

1.3.2 Shear

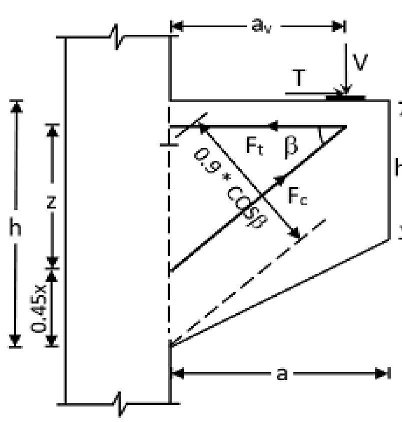
Diameter of Bar	D_s	= **10** mm
Spacing Between Stirrups	L_s	= **120** mm

1.3.3 Cover

Clear Cover	C_c	= **25** mm

1.4 Loads

Ultimate Axial Load	V	= **250** kN
Ultimate Horizontal Load	T	= **30** kN
Service Axial Load	V_{sl}	= **150** kN
Service Horizontal Load	T_{sl}	= **20** kN



Strut and Tie Analogy

1.5 Materials

Concrete Grade	f_{cu}	= **25** N/mm^2
Main Reinforcement Grade	f_y	= **500** N/mm^2
Shear Reinforcement Grade	f_{yv}	= **460** N/mm^2
Modulus of Elasticity of Steel	E_s	= **200000** N/mm^2

1.6 Material Safety Factors

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

1.7 Crack Width

Check for Crack Width		**Yes**
Maximum Allowable Crack Width	W_k	= **0.35** mm

2.0 OUTPUT

Ref: BS 8110 - Part 1

2.1 Bearing Stress

Maximum Bearing Stress	f_b	$= 0.8 * f_{cu} =$ **20** N/mm^2	*Cl. 5.2.3.4*
Actual Bearing Stress	f_a	$= V / (W_b * L_b) =$ **11.111** N/mm^2	

2.2 Reinforcement

Effective Depth	d	$= h - C_c - (D_m / 2) =$ **465** mm
Horizontal Force	H	= max(T, 0.5 * V) = **125** kN
Tension Reinforcement	A_{stp}	= **942.5** mm^2

2.3 Strut and Tie Method

Lever arm Distance	z	= d - 0.45 * x	
Angle of Inclination	β	$= \cot^{-1}(a_v / z)$	
Steel Tension Force	F_t	$= V * a_v / z + T$	
Concrete Strut Force in Compression	F_c	$= V / \sin(\beta)$	
Depth of Neutral Axis (Iteration)	x	$= F_c * \gamma_{mc} / (0.603 * f_{cu} * b * \cos(\beta))$	
		= **250.8** mm	
Lever Arm Distance	z	= **352.2** mm	
Tensile Force on Steel Member	F_t	= **314** kN	
Concrete Strut Force in Compression	F_c	= **378.32** kN	
Design Moment	M_a	$= (V * a_v) + (H * z) =$ **144** kNm	
Area of Reinforcement Required	A_{sreq}	$= M_a / ((f_y / \gamma_{ms}) * z) =$ **940.6** mm^2	
Minimum Area of Reinforcement	A_{smin}	= 0.004 * b * h = **400** mm^2	*Table: 3.25*
Maximum Area of Reinforcement	A_{smax}	= 0.04 * b * h = **4000** mm^2	

2.4 Shear Design

Shear Stress	v	= V / (b * d) = **2.688** N/mm^2	*Cl.3.4.5.2*
Design Concrete Shear Stress	v_c	= **0.635** N/mm^2	*Table: 3.8*
Enhanced Shear Stress	v'_c	$= 2 * (d / a_v) * v_c =$ **1.476** N/mm^2	*Cl.3.4.5.8*
Maximum Shear Stress	v_{max}	$= \min(0.8 * \sqrt{f_{cu}}, 5) =$ **4** N/mm^2	*Cl.3.4.5.2*
Shear Strength Required	v_s	$= \max(v - v'_c, 0.4) =$ **1.212** N/mm^2	
Area of Shear Reinforcement Required /m	A_{svreq}	$= \max(v_s * b / (f_{yv} / \gamma_{ms}) , 0.5 * A_{sreq})$	
		= **606.1** mm^2	*Table: 3.7*

Distribution Depth	d_d	$= (2 / 3) * d =$ **310** mm	

2.5 Ultimate Anchorage Bond Stress

Tensile Force in Steel at Start of Bend	F_{bt}	$= (F_t / N_m) * (A_{sreq} / A_{stp}) =$ **104.4** kN	
Design Ultimate Anchorage Bond Stress	F_{bu}	$= \beta * \sqrt{} f_{cu} =$ **2.5** N/mm^2	*Cl. 3.12.8.4*
Anchorage Bond Length Required	L_r	$= F_{bt} / (\pi * D_m * F_{bu}) =$ **664.9** mm	*Cl. 3.12.8.3*
Internal Radius of Bend	R	$= 4 * D_m =$ **80** mm	
Bond Stress Limit	F_{lim}	$= (2 / 3) * F_{bt} / (R * D_m) =$ **43.52** N/mm^2	
Bond Stress	F_{be}	$= (2 * f_{cu}) / (1 + (2 * D_m / (C_c + D_m))$	
		= **26.471** N/mm^2	

2.6 Crack Width Calculation

Ref: BS 8110 - Part 2

Spacing of Tension Bars	s	= **333.3** mm	
Modulus of Elasticity of Concrete	E_c	$= (20000 + 200 * f_{cu}) / 2 =$ **12500** N/mm^2	
Modular Ratio	m	$= E_s / E_c =$ **16**	
Depth of Neutral Axis (Iteration)	x	$= ((m * A_{stp}) / b) * ([(1 + 2 * b * d) / (A_{stp} * m)]^{1/2} - 1)$	
		= **199.9** mm	
Lever Arm Distance	z	$= d - (x / 3) =$ **398.4** mm	
Service Design Moment	M_s	$= (V_{sl} * a_v) + (T_{sl} * z) =$ **68** kNm	
Stress in Reinforcement	F_s	$= M_s / (A_{stp} * z) =$ **178.567** N/mm^2	
	ε_1	$= ((h - x) / (d - x)) * (F_s / E_s) =$ **0.001011**	
	ε_2	$= (b * (h - x)^2) / (3 * E_s * A_{stp} * (d - x))$	
		= **0.00012**	
Average Strain	ε	$= \varepsilon_1 - \varepsilon_2 =$ **0.000891**	*Eq. 13*
Distance of Crack to Nearest Tension Bar	a_{cr}	$= [(s / 2)^2 + (C_c + D_m / 2)^2]^{1/2} - (D_m / 2)$	
		= **160.298** mm	
Design Surface Crack Width	W_{cr}	$= (3 * a_{cr} * \varepsilon) / (1 + 2 * (a_{cr} - C_c) / (h - x))$	*Eq. 12*
		= **0.225** mm	*Eq. 12*

3.0 SUMMARY

Description	Required		Actual		Status
Bearing Stress (N/mm^2)	f_b	<= **20**	f_a	= **11.111**	**PASS**
Minimum Area of Reinforcement (mm^2)	A_{smin}	>= **400**	A_{stp}	= **942.5**	**PASS**
Maximum Area of Reinforcement (mm^2)	A_{smax}	<= **4000**	A_{stp}	= **942.5**	**PASS**
Area of Main Reinforcement (mm^2)	A_{sreq}	>= **940.6**	A_{stp}	= **942.5**	**PASS**
Area of Shear Reinforcement (mm^2/m)	A_{svreq}	>= **606.1**	A_{svp}	= **654.5**	**PASS**
Bond Stress (N/mm^2)	F_{lim}	<= **43.52**	F_{be}	= **26.471**	**PASS**
Crack Width (mm)	W_k	<= **0.35**	W_{cr}	= **0.225**	**PASS**