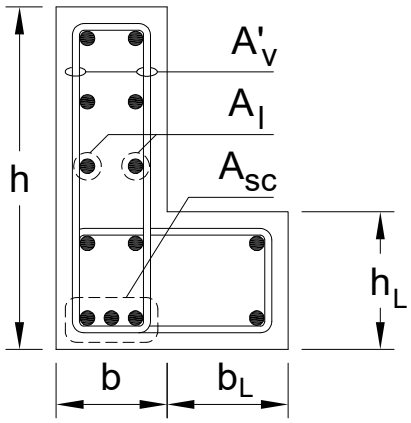
Design Precast Spandrel Beam for Combined Shear and Torsion as per ACI 318-11 Chapter 11



System

Width of Beam, b=			16.0 in
Height of Beam, h=			48.0 in
Width of Beam Ledge, b_L=			8.0 in
Height of Beam Ledge, h_L=			16.0 in
Concrete Cover, co=			2.50 in
Concrete Cover to Center of Stirrup, co'=			1.50 in
Effective Depth of Beam, d=	h -co	=	45.50 in

Load

Ultimate Bending Moment, M_u=			1316.0 kip*ft
Ultimate Torsional Moment, T_u=			108.6 kip*ft
Ultimate Shear Force, V_u=			127.2 kips

Material Properties

Concrete Strength, f'c=			5000 psi
Yield Strength of Reinforcement, f_y=			60000 psi
Yield Strength of Stirrups Reinforcement, f_{yt}=			60000 psi
Shear Strength Reduction Factor (According to Cl.9.3.2 of ACI318), Φ_s=			0.75
Tension Strength Reduction Factor (According to Cl.9.3.2 of ACI318), Φ_t=			0.90
Modification Factor for Lightweight Concrete, λ=			1.00
Friction Factor (According to Cl.11.6.4.3 of ACI318), μ= 1.4* λ		=	1.40

Determine Concrete Cracking Torque

Area Enclosed by Outside Perimeter of Spandrel Beam Including the Ledge,

A_{cp}=	$b * h + b_L * h_L$	=	896 in^2

Outside Perimeter of Spandrel Beam Including the Ledge,

P_{cp}=	$2 * (b + b_L + h)$	=	144 in

Concrete Cracking Torque, $T_{cr}=4*\lambda*\sqrt{f'_c}*\frac{A_{cp}^2}{P_{cp}}/12000$ = 131.4 kip*ft

Torsional Moment should be: IF($T_u<\Phi_s*T_{cr}/4$;"Neglected";"Checked") = Checked

Calculation of Torsion Reinforcement

Area Enclosed by Centerline of The Outermost Closed Transverse Torsional Reinforcement (According to Cl.11.5.3.6 of ACI318),

$A_{oh}=$ $(h-2*co')*(b-2*co')+(b_L)*(h_L-2*co')$ = 689.0 in^2

$A_o=$ $0.85*A_{oh}$ = 585.6 in^2

Angle of Compression Diagonal Struts (According to 11.5.3.6 of ACI318),

$\Theta=$ 45 °

Required Area for Torsion Shear per Stirrups Spacing (According to Eq. 11-20, 21 of ACI318),

$A'_{vt}=\frac{T_u*12000}{2*\Phi_s*A_o*f_{yt}*(1/\tan(\Theta))}$ = 0.025 in^2 per in

Calculation of Shear Reinforcement

Nominal Shear Strength Provided by Concrete (According to Eq.11-3 of ACI318),

$V_c=2*\lambda*\sqrt{f'c}*\frac{b*d}{1000}$ = 102.95 kips

Nominal Shear Strength Provided by Reinforcement (According to Eq.11-2 of ACI318),

$V_s=$ V_u/Φ_s-V_c = 66.65 kips

Required Area for Direct Shear per Stirrups Spacing (According to Eq. 11-1, 2 of ACI318),

$A'_{vs}=\frac{V_s*1000}{f_{yt}*d}$ = 0.024 in^2 per in

Calculation of Combined Shear and Torsion Reinforcement

Total Required Area for Torsion & Shear per Stirrups Spacing (According to Cl.11.5.3.8 of ACI318),

$A'_v=$ $A'_{vt}+A'_{vs}/2$ = 0.037 in^2 per in per leg

Provided Reinforcement, Bar= SEL("ACI/Bar"; Bar;) = No.4

Provided Reinforcement, $A_{sb}=$ TAB("ACI/Bar"; Asb; Bar=Bar) = 0.20 in^2

Required Stirrups Spacing, $s_{\_Req}=$ A_{sb}/A'_v = 5.41 in

Provided Stirrups Spacing, $s_{\_Prov}=$ 5.00 in

Check Validity= IF($s_{\_Prov}\leq s_{\_Req}$; "Valid"; "Invalid") = Valid

Perimeter of Stirrups, Ph= $2*(b-2*co'+h-2*co')+2*b_L$ = 132.00 in

Maximum Stirrups Spacing Due to Torsion (According to Cl.11.6.6 of ACI318),

$s_{max\_t}=$ MIN(Ph/8; 12) = 12.00 in

Maximum Stirrups Spacing Due to Shear (According to Cl.11.4.5 of ACI318),

$s_{max\_v}=$ MIN(d/2; 24) = 22.75 in

Maximum Stirrups Spacing, s_{max}= MIN(s_{max_t}; s_{max_v}) = 12.00 in

Check Validity= IF($s_{\_Prov} \le s_{max}$; "Valid"; "Invalid") = Valid

Calculation of Longitudinal Torsion Reinforcement

Required Area of Longitudinal Torsion Reinforcement (According to Cl.11.5.3.7 of ACI318),

$A_{l\_i} = \frac{A'_{vt} * Ph}{\tan(\Theta)^2} * \frac{f_{yt}}{f_y}$ = 3.30 in^2

Minimum Area of Longidudinal Torsion Reinforcement (According to Eq.11-24 of ACI318),

$A_{l\_min} = \frac{5 * \sqrt{f'_c} * A_{cp}}{f_y} - A'_{vt} * Ph * \frac{f_{yt}}{f_y}$ = 1.98 in^2

A_{l_Req}= MAX(A_{l_i} ; A_{l_min}) = 3.30 in^2

Provided Reinforcement, Bar= SEL("ACI/Bar"; Bar;) = No.5

Provided Reinforcement, A_{sb}= TAB("ACI/Bar"; Asb; Bar=Bar) = 0.31 in^2

Number of Bars, n= 12

Provided Longitudinal Reinforcement, A_{l_Prov}= A_{sb} * n = 3.72 in^2

Check Validity= IF($A_{l\_Prov} \ge A_{l\_Req}$; "Valid"; "Invalid") = Valid

Calculation of Required Flexural Reinforcement

$R_n = \frac{M_u * 12 * 1000}{\Phi_t * b * d^2}$ = 530 psi

$\rho = \frac{0.85 * f'_c}{f_y} * \left(1 - \sqrt{1 - \frac{2 * R_n}{0.85 * f'_c}}\right)$ = 0.0095

Area of Flexural Reinforcement, A_s= ρ*b*d = 6.92 in^2

Calculation of Total Bottom Reinforcement at Mid-Span

Percentage of Torsional Reinforcement Concentrated on Bottom Side, Per= 16 %

Total Area of Bottom Reinforcement at Mid-Span,

A_{sc_Req}= A_{l_Req} * Per / 100 + A_s = 7.45 in^2

Provided Reinforcement, Bar= SEL("ACI/Bar"; Bar;) = No.11

Provided Reinforcement, A_{sb}= TAB("ACI/Bar"; Asb; Bar=Bar) = 1.56 in^2

Number of Bars, n= 5

Total Area of Bottom Reinforcement, A_{sc_Prov}= A_{sb} * n = 7.80 in^2

Check Validity= IF($A_{sc\_Prov} \ge A_{sc\_Req}$; "Valid"; "Invalid") = Valid

Design Summary

Total Required Area for Torsion & Shear per Stirrups Spacing,

A'_v= A'_v = 0.037 in^2 per in per leg

Provided Stirrups Spacing, $s_{\_Prov}$= $s_{\_Prov}$ = 5.00 in

Provided Longitudinal Reinforcement, $A_{l\_Prov} = A_{l\_Prov}$ = 3.72 in^2

Total Area of Bottom Reinforcement, $A_{sc\_Prov} = A_{sc\_Prov}$ = 7.80 in^2