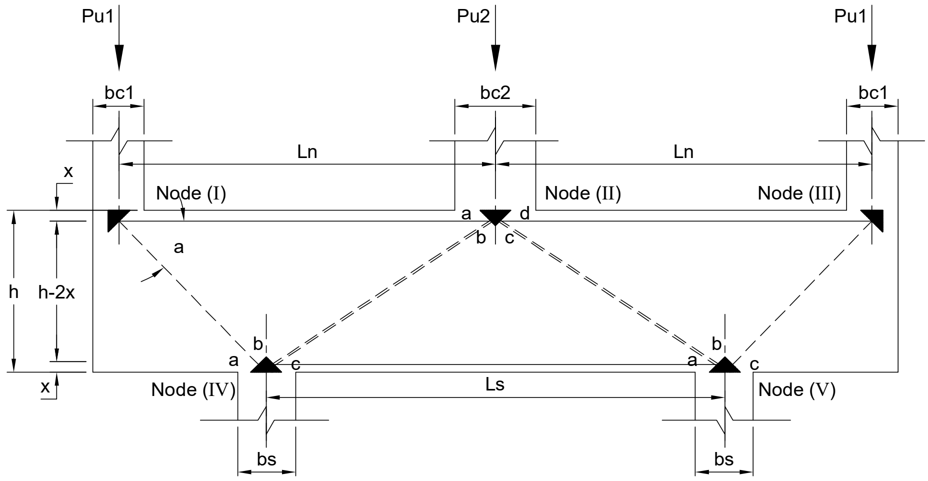
Design of Continuous Deep Beam by the Strut-and-Tie Model as per ACI318 Appendix A



System

Width of Deep Beam, b=			24.0 in
Height of Deep Beam, h=			144.0 in
Concrete Cover, co=			1.25 in
Depth of Deep Beam, d=	h - co	=	142.75 in
Upper End Distance of Truss Model, x_1=			6.0 in
Lower End Distance of Truss Model, x_2=			9.0 in
Span of Deep Beam, L_n=			24.0 ft
Exterior Planted Column Width, b_{c1}=			24.0 in
Interior Planted Column Width, b_{c2}=			56.0 in
Distance between Supports of Deep Beam, L_s=			24.0 ft
Support Column Width, b_s=			48.0 in
Support Column Depth, d_s=			24.0 in

Load

Dead Load for Exterior Column, P_{D1}=			100.0 kips
Live Load for Exterior Column, P_{L1}=			237.5 kips
Ultimate Load for Exterior Column, P_{u1}=	$1.2*P_{D1} + 1.6*P_{L1}$	=	500.0 kips
Dead Load for Interior Column, P_{D2}=			750.0 kips
Live Load for Interior Column, P_{L2}=			1000.0 kips
Ultimate Load for Interior Column, P_{u2}=	$1.2*P_{D2} + 1.6*P_{L2}$	=	2500.0 kips
Support Column Ultimate Load, P_u=	$P_{u1} + P_{u2}/2$	=	1750.0 kips

Material Properties

Concrete Strength, f'_c=	4000 psi
Yield Strength of Reinforcement, f_y=	60000 psi

Strength Reduction Factor (According to Cl.9.3.2 of ACI318), Φ= 0.75

Modification Factor for Lightweight Concrete, λ= 1.00

Friction Factor (According to Cl.11.6.4.3 of ACI318), μ= $1.4 * \lambda$ = 1.40

Check Deep Beam Requirements

Check on Height of Deep Beam Requirements (According to Cl.11.7.1 of ACI318),

R = IF(12*Ln/h<4; "Deep Beam Design"; "Normal Beam Design") = Deep Beam Design

Calculation of Effective Concrete Strength

(According to Cl.A.3.2 of ACI318) Factor of, β_s= 1.00

Effective Concrete Strength (According to Eq.A-3 of ACI 318),

f_{ce1}= $0.85 * \beta_s * f'_c$ = 3400 psi

Calculation of Effective Concrete Strength for Nodal Zones

For Nodal Zone IV Bounded by Three Struts (C-C-C Nodal Zone)

(According to Cl.A.5.2.1 of ACI318) Factor of, β_n= 1.00

Effective Concrete Strength (According to Eq.A-3 of ACI 318),

f_{ce2}= $0.85 * \beta_n * f'_c$ = 3400 psi

For Nodal Zone A&B Bounded by Three Struts (C-C-T Nodal Zone)

(According to Cl.A.5.2.2 of ACI318) Factor of, β_n= 0.80

Effective Concrete Strength (According to Eq.A-3 of ACI 318),

f_{ce3}= $0.85 * \beta_n * f'_c$ = 2720 psi

Minimum Effective Concrete Strength, f_{ce}= $MIN(f_{ce1}; f_{ce2}; f_{ce3};)$ = 2720 psi

Calculation of Forces in Struts

For Node IV Will Carry Exterior Column Load Strut, Fa= P_{u1} = 500.00 kips

For Node IV Other Struts B and C, Fbc= $0.5*(P_u - Fa)$ = 625.00 kips

Check Width of Struts at Node IV

Width of Strut a, Wsa= $\frac{Fa*1000}{\Phi * f_{ce} * b}$ = 10.21 in

Width of Strut b&c, Wsbc= $\frac{Fbc*1000}{\Phi * f_{ce} * b}$ = 12.77 in

Total Width of Struts, Ws= $Wsa + Wsbc * 2$ = 35.75 in

Check Validity= IF(Ws<b_s; "Valid"; "Invalid") = Valid

Check Width of Struts at Node I

Width of Strut, WsI= $\frac{P_{u1}*1000}{\Phi * f_{ce} * b}$ = 10.21 in

Check Validity= IF(WsI<b_{c1}; "Valid"; "Invalid") = Valid

Check Width of Struts at Node II

Width of Strut, WsII= $\frac{P_{u2}*1000}{\Phi*f_{ce}*b}$ = 51.06 in

Check Validity= IF(WsII<b_{c2}; "Valid"; "Invalid") = Valid

Calculation of Force in Strut I-IVa and Tie I-IIa

Horizontal Projection of Strut I-IVa, Lhiiva= $\frac{(L_n*2-L_s)*12}{2}-Wsbc$ = 131.23 in

Vertical Projection of Strut I-IVa, Lviiva= $h-(x_1+x_2)$ = 129.00 in

Horizontal Force in Strut I-IVa and Tie I-IIa, Fiiva= $P_{u1}*\frac{Lhiiva}{Lviiva}$ = 508.64 kips

Length of Strut I-IVa, Liiva= $\sqrt{Lhiiva^2+Lviiva^2}$ = 184.02 in

Compression Force in Strut I-IVa at Node I, Fi= $\frac{P_{u1}*Liiva}{h-(x_1+x_2)}$ = 713.26 kips

Check Validity= IF(Fi<f_{ce}; "Valid"; "Invalid") = Valid

Calculation of Width of Strut IIa-IVb

Horizontal Projection of Strut IIa-IVb, Lhiiaivb= $\frac{(Ln*2-Ls)*12}{2}-\frac{WsII*3}{8}$ = 124.9 in

Vertical Projection of Strut IIa-IVb, Lviiaivb= $h-(x_1+x_2*2)$ = 120.0 in

Vertical Force in Strut IIa-IVb, Fiiaivb= $Fiiva*\frac{Lhiiaivb}{Lviiaivb}$ = 529.4 kips

Calculation of Width of Strut IIa-IVc

Horizontal Projection of Strut IIa-IVb, Lhiiaivb= $\frac{(L_n*2-L_s)*12}{2}-\frac{WsII*3}{8}$ = 124.9 in

Vertical Projection of Strut IIa-IVb, Lviiaivb= $h-(x_1+x_2*2)$ = 120.0 in

Vertical Force in Strut IIa-IVb, Fiiaivb= $Fiiva*\frac{Lhiiaivb}{Lviiaivb}$ = 529.4 kips

Calculation of Width of Strut IIb-IVc

Horizontal Projection of Strut IIa-IVb, Lhiiaivb= $\frac{(L_n*2-L_s)*12}{2}-\frac{WsII*7}{50}$ = 136.9 in

Vertical Projection of Strut IIa-IVb, Lviiaivb= $h-(x_1+x_2*2)$ = 120.0 in

Vertical Force in Strut IIa-IVb, Fiiaivb= $Fi*\frac{Lhiiaivb}{Lviiaivb}$ = 813.7 kips

Calculation of Width of Tie IVc-Va

Force in Tie IVc-Va, Fivcva= $\frac{Fiiaivb*1000}{\Phi*f_{ce}*b}$ = 16.62 in

Calculation VL. and HZ. Reinforcement to Resist Splitting of Diagonal Struts

1. Vertical Reinforcement

Angle of Strut, α=			46.60 °
Provided Reinforcement, Bar=	SEL("ACI/Bar"; Bar;)	=	No.5
Provided Reinforcement, A_{sbv}=	TAB("ACI/Bar"; Asb; Bar=Bar)	=	0.31 in^2
Number of Bars, n_v=			2
Vertical Reinforcement, A_{sv}=	$A_{sbv} * n_v$	=	0.62 in^2
Provided Spacing between Bars, s=			10.00 in

Vertical Reinforcement (According to Eq.A4 of ACI318),

VL= $\frac{A_{sv}}{b*s} * \sin(90-\alpha)$ =0.00177

2. Horizontal Reinforcement

Provided Reinforcement, Bar=	SEL("ACI/Bar"; Bar;)	=	No.5
Provided Reinforcement, A_{sbh}=	TAB("ACI/Bar"; Asb; Bar=Bar)	=	0.31 in^2
Number of Bars, n_h=			2
Vertical Reinforcement, A_{sh}=	$A_{sbh} * n_h$	=	0.62 in^2
Provided Spacing between Bars, s=			10.00 in

Horizontal Reinforcement (According to Eq.A4 of ACI318),

HZ= $\frac{A_{sh}}{b*s} * \sin(\alpha)$ =0.00188

Check Validity=	IF(VL+HZ>0.003; "Valid"; "Invalid")	=	Valid

Calculation of Tension Reinforcement for Tie Connecting Joint I-IIa

Required Reinforcement Area, A_{sreq}=	$\frac{Fiiva*1000}{\Phi*fy}$	=	11.30 in^2
Provided Reinforcement, Bar=	SEL("ACI/Bar"; Bar;)	=	No.9
Number of Bars, n=			12.00
Provided Reinforcement, A_{sb}=	TAB("ACI/Bar"; Asb; Bar=Bar)	=	1.00 in^2
Total Provided Area, A_{sprov}=	n*Asb	=	12.00 in^2
Check Validity=	IF(Asprov>Asreq; "Valid"; "Invalid")	=	Valid

Design Summary

Provided Vertical Reinforcement, A_{sv}=	A_{sv}	=	0.62 in^2
Provided Horizontal Reinforcement, A_{sh}=	A_{sh}	=	0.62 in^2
Provided Tension Reinforcement, A_{sprov}=	A_{sprov}	=	12.00 in^2