Structural Design Report for Anchor Plate Template

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3. Summary

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1. Design Conditions

1) General Characteristics

(1) Project Name : Anchor Plate Template
(2) Design Code : ACI 318M-14
(3) Unit : Kips.in
(4) Strength Reduction Factors
Strut : 0.75
Tie : 0.75
Node : 0.75
(5) Scope of Report

The purpose of this report is to design structural concrete member using strut-tie model. The design is performed according to the ACI 318M-14 strut-tie model provisions.

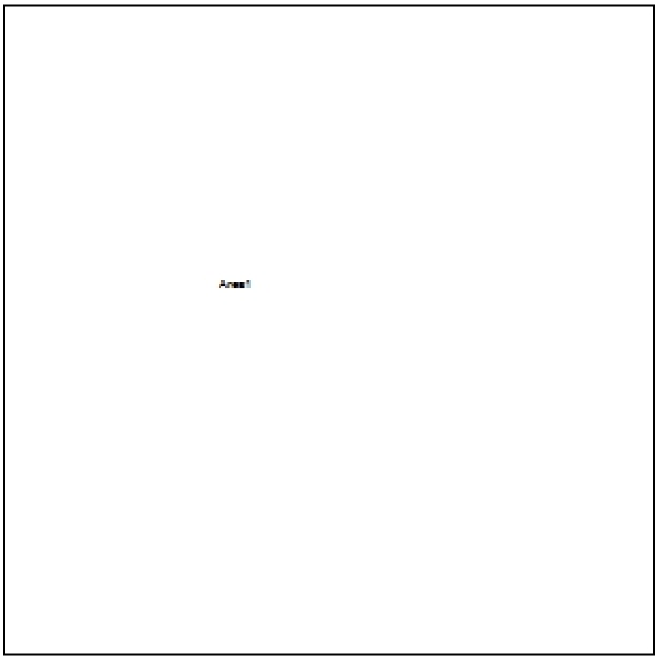
This report provides results of calculation for:
- check capacity of bearing plates
- design tie reinforcement
- check capacity of struts
- check capacity of nodal zones

2) Materials

(1) Concrete
- Mass : 147 lb/ft^3
- Weight : 149.6 lb/ft^3
- Poisson's ratio : 0.15
- Compressive Strength of Concrete, fck : 3480.9 lb/in^2
- Tensile Strength of Concrete, fct : 348.1 lb/in^2
- Elastic modulus of concrete, Ec : 4,039,177 lb/in^2

(2) Steel1
- Mass : 490 lb/ft^3
- Weight : 499.7 lb/ft^3
- Poisson's ratio : 0.15
- Yield strength of steel, fy : 58015.4 lb/in^2
- Elastic modulus of steel, Es : 29,007,699 lb/in^2

3) Geometrical Shape

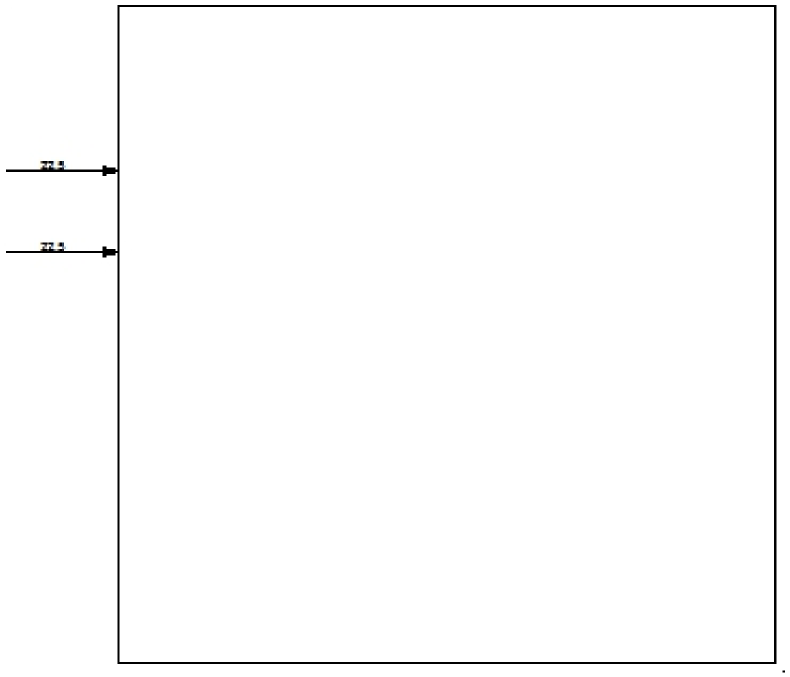


- Thickness : 20.00 in

4) Loads and Load Combinations

(1) Loads

PS ()



(2) Load Combinations

1) LC01 : 1.00PS

5) Reference

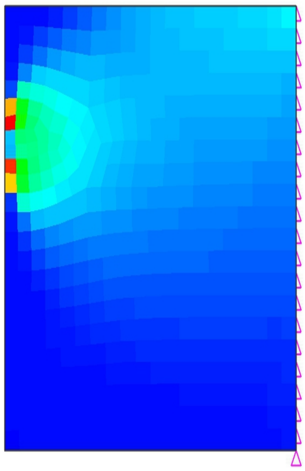
(1) Designer : Hangil IT
(2) Date : 2017-07-15
(3) Note : Design of Anchor Plate using Template (ACI 318-14)

2. Strut-Tie Model Design (Load Combination-1)

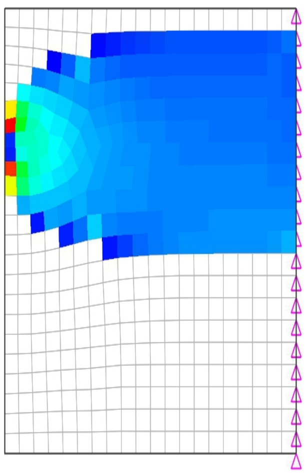
1) Construction of Strut-Tie Model

(1) ESO (Evolutionary Structural Optimization)

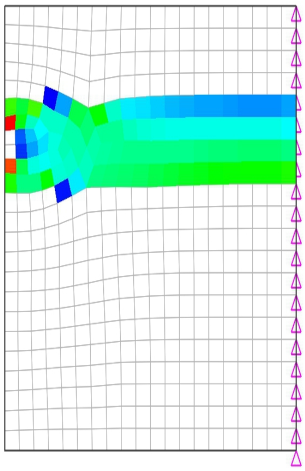
1. STAGE-01 (Initial shape)



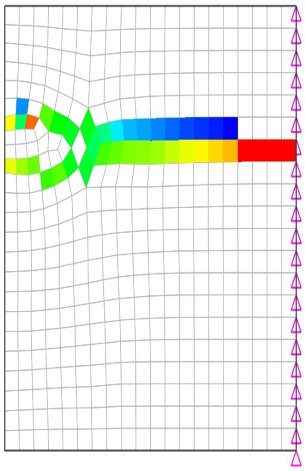
2. STAGE-08 (Elimination ratio = 53%)



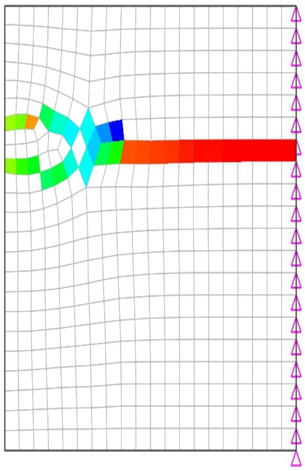
3. STAGE-15 (Elimination ratio = 77%)



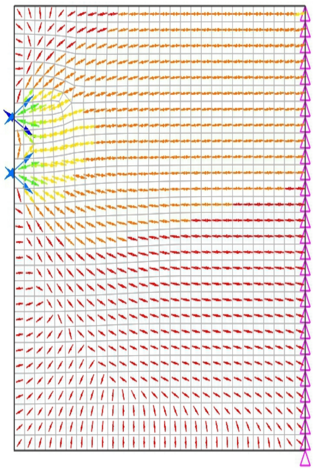
4. STAGE-22 (Elimination ratio = 90%)



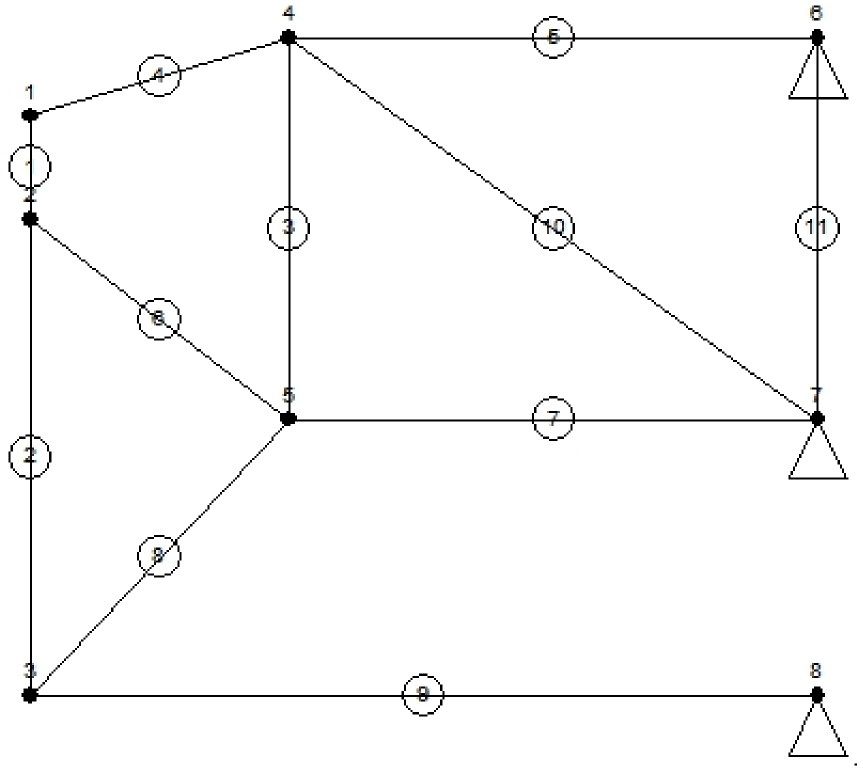
5. STAGE-24 (Elimination ratio = 92%)



(2) Compressive Principal Stress Flow



(3) Constructed Strut-Tie Model



(A) Nodal Coordinates

Node No.	X coordi.	Z coordi.	Node No.	X coordi.	Z coordi.
1	4.000	60.000	2	4.000	50.000
3	4.000	4.000	4	29.000	67.500
5	29.000	30.667	6	80.000	67.500
7	80.000	30.667	8	80.000	4.000

(B) Element Connectivity

Element No.	Start Node	End Node	Element No.	Start Node	End Node
1	1	2	2	2	3
3	4	5	4	1	4
5	4	6	6	2	5
7	5	7	8	3	5
9	3	8	10	4	7
11	6	7			

(C) Restraints

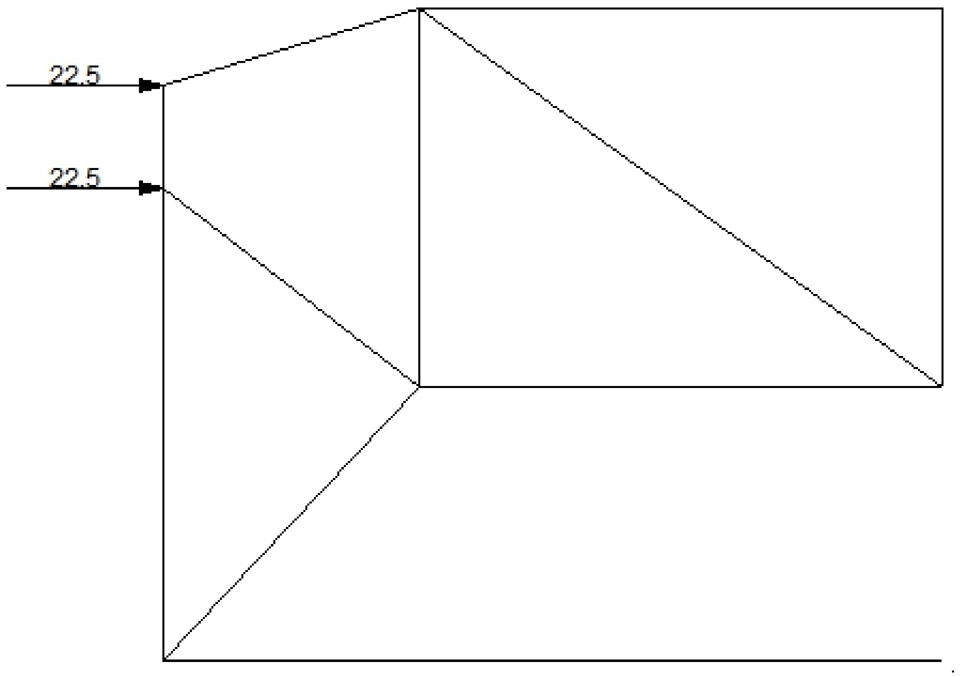
Node	Ux	Uy	Uz	Rx	Ry	Rz

6	0	0	0	0	-	0
7	0	0	0	0	-	0
8	0	0	0	0	-	0

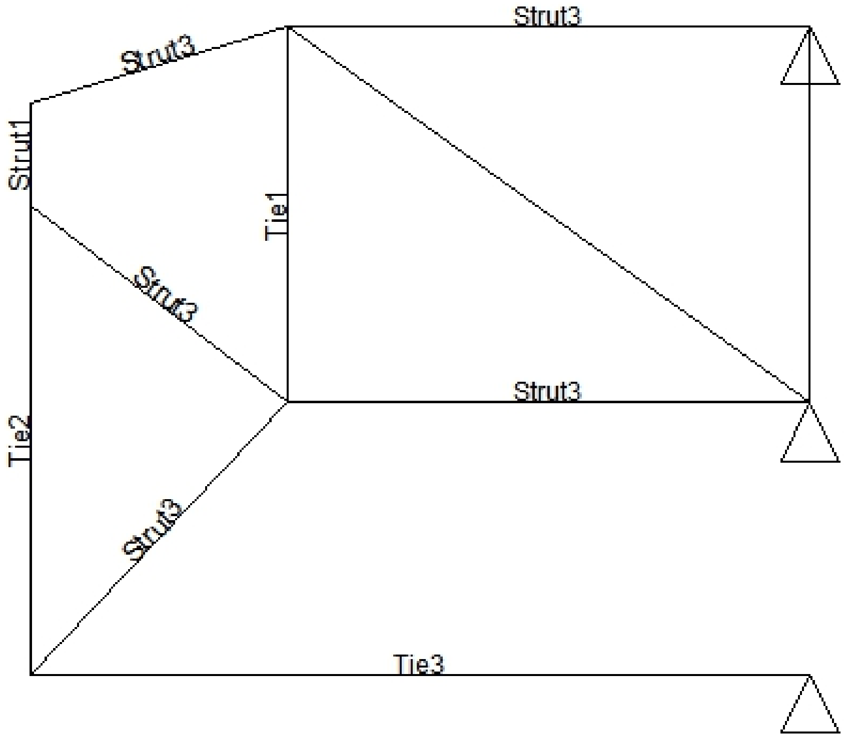
2) Analysis of Strut-Tie Model

(1) Loading Conditions

(1) (PS)

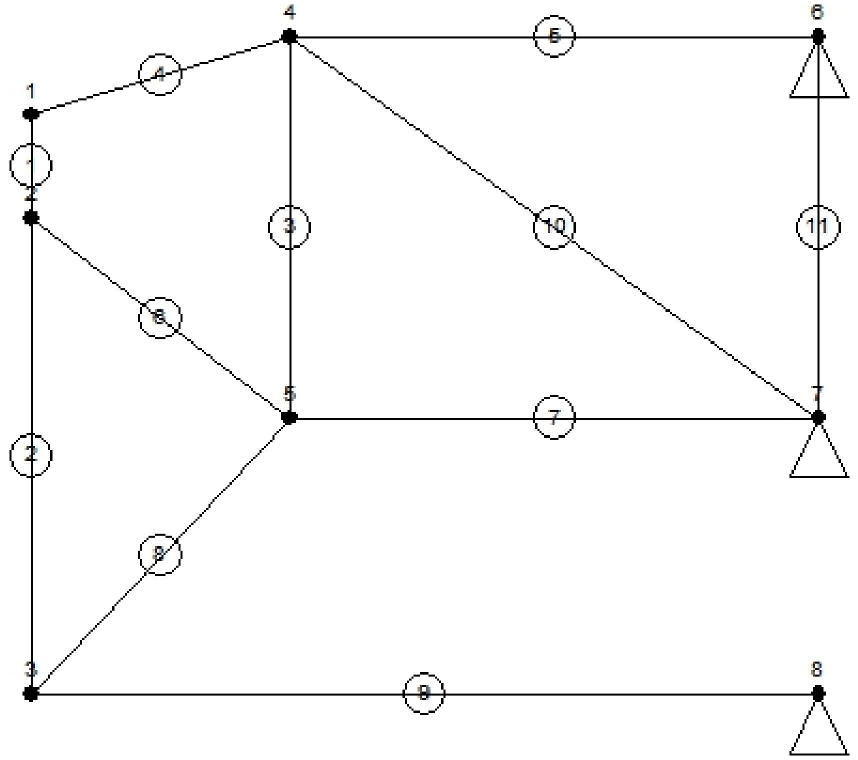


(2) Strut and Tie Types



- Strut1 : Prismatic Strut
- Strut3 : Bottle Shape Strut (Not Satisfying ACI 318M-14 23.5.3)
- Strut5 : All Other Cases
- Tie1 : Tie for intermediate vertical rebars
- Tie2 : Tie for intermediate vertical rebars
- Tie3 : Tie for bottom rebars

(3) Strut and Tie Forces



Elem. No.	Force (kip)	Elem. No.	Force (kip)	Elem. No.	Force (kip)	Elem. No.	Force (kip)
1	-6.7	2	10.6	3	6.7	4	-23.5
5	-22.5	6	-28.4	7	-32.5	8	-14.6
9	10.0	10	-0.0	11	0.0		

3) Strength Verification and Required Rebars

(1) Strength under Bearing/Loading Plates

phi fce = phi·0.85·beta·fck < Fu / A
beta = 1.00 (for the nodal zone bounded by struts, bearing areas, or both)
0.80 (for the nodal zone anchoring one tie)
0.60 (for the nodal zone anchoring two or more ties)
A = Area of bearing plates (= BxW)

Node	beta	fce(lb/in²)	Fu (kip)	B (in)	W (in)	Fu/A (lb/in²)	Note
1	1.00	2219.09	22.5	20.0	10.0	112.500	O.K
2	0.80	1775.27	22.5	20.0	10.0	112.500	O.K

(2) Required Area of Rebars

1) Main Rebars

(A) Horizontal Rebars

As.req = Fu / phi·fy·cos theta < As.used
where,
Fu = member force of steel tie
phi = strength reduction factor of steel tie : 0.75
fy = yield strength of steel : 58015.4 lb/in²
theta = angle of steel tie measured from positive horizontal axis
(+: counterclockwise)

Tie No.	Types	Fu (kip)	theta (deg.)	Rebars	As.req (in²)	As.used (in²)	Note
9	Bottom	2.24	0.0	4-#3	0	0	O.K

2) Transverse Rebars

(A) Vertical Rebars

Tie No.	Fu (kip)	theta (deg.)	Rebars	Weff,tie (in)	Sv (in)	phi Fn (kip)	Note
2	2.39	90.0	2-#3	0.3	0.2	4.3	O.K
3	1.52	90.0	2-#3	1.0	0.3	6.8	O.K

phi·Fn = phi·Av·fy·Weff,tie·sin theta / Sv > Fu
where,
Fu = member force of steel tie
phi = strength reduction factor of steel tie : 0.75
fy = yield strength of steel : 58015.4 lb/in²
theta = angle of steel tie measured from positive horizontal axis

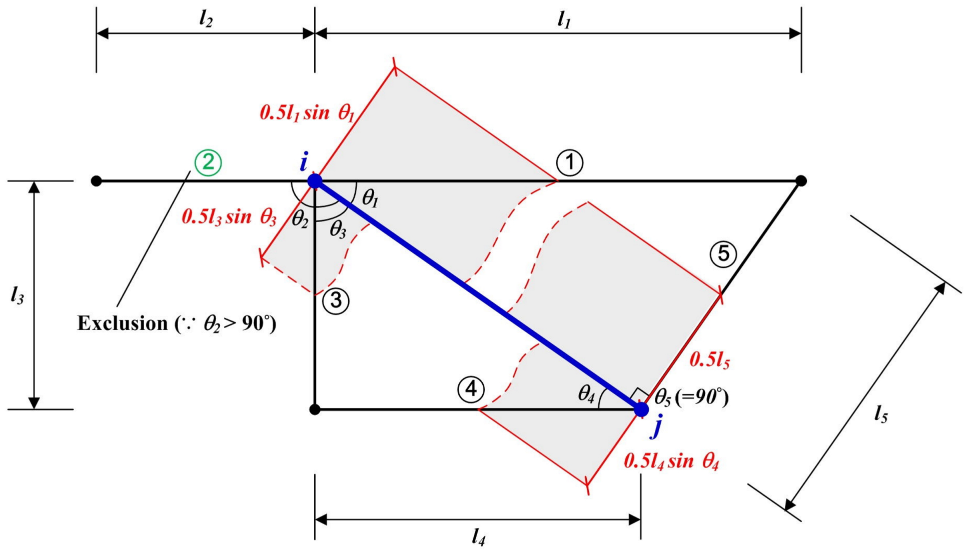
(+: counterclockwise)
Sv = spacing of vertical rebars
Weff,tie = effective width of tie

(3) Available Widths of Struts and Nodal Zones

1) Node without bearing plate
The available widths of a strut at both ends and nodal zone faces are determined by taking the minimum ones from the values calculated below for case 1 and case 2.

2) Node with bearing plate
The available widths of a strut at both ends and nodal zone faces are determined by taking the values calculated below for case 3.

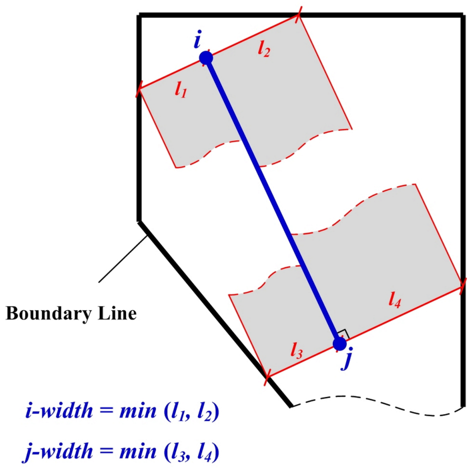
[CASE 1]



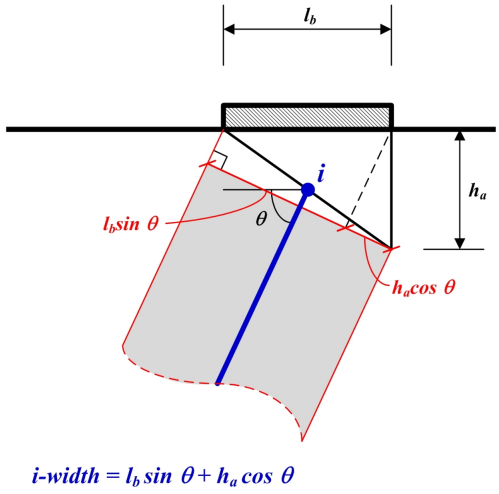
$i\text{-width} = \min(l_1 \sin\theta_1, l_3 \sin\theta_3)$

$j\text{-width} = \min(l_4 \sin\theta_4, l_5)$

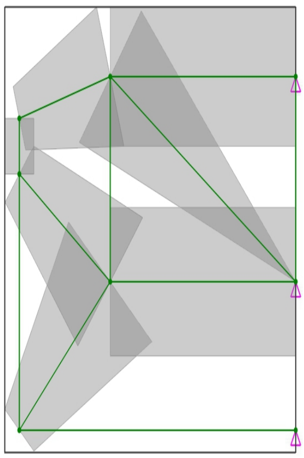
[CASE 2]



[CASE 3]



The available widths of struts and ties determined by the methods introduced above are shown below



Elem. No.	i-width	j-width	Available Width	Elem. No.	i-width	j-width	Available Width
1	8.0	8.0	8.0	4	11.8	26.1	11.8
5	25.0	25.0	25.0	6	12.8	29.1	12.8
7	26.6	26.6	26.6	8	10.9	31.4	10.9

(4) Strength of Struts

Wreq = Fu / phi·0.85·bata·fck·b < Wprov (See ACI 318M-14 Section 23.4)
beta = 1.00 (prismatic strut - uniform cross-sectional area along length)
0.75 (bottle-shaped strut satisfying ACI 318M-14 Section 23.5.3)
0.60 (bottle-shaped strut unsatisfying ACI 318M-14 Section 23.5.3)
0.40 (strut in tension zones)
0.60 (all other cases)
phi = strength reduction factor of concrete strut = 0.75

Strut No.	beta	theta	Fu (kip)	b (in)	Wreq (in)	Wprov (in)	Note
1	1.00	90.0	6.7	20.0	0.2	8.0	O.K
4	0.60	16.7	23.5	20.0	0.9	11.9	O.K
5	0.60	0.0	22.5	20.0	0.8	25.0	O.K
6	0.60	37.7	28.4	20.0	1.1	12.8	O.K
7	0.60	0.0	32.5	20.0	1.2	26.7	O.K
8	0.60	46.8	14.6	20.0	0.5	11.0	O.K

(5) Strength of Nodal Zones

The verification of the nodal zone strength should be done through comparing the available nodal zone area with that required. In this report, if the thickness of the structural concrete is consistent, the verification will be done by comparing the available nodal zone width, Wprov, with that required, Wreq

Wreq = Fu / phi·0.85·beta·fck·b < Wprov (See ACI 318M-14 Section 23.9)
beta = 1.00 (for the nodal zone bounded by struts, bearing areas, or both)
0.80 (for the nodal zone anchoring one tie)
0.60 (for the nodal zone anchoring two or more ties)

Node No.	beta	Type	Element	Fu (kip)	Wreq (in)	Wprov (in)	Note
1	1.00	CCC	H	5.1	0.1	10.0	O.K
			C-1	6.7	0.2	8.0	O.K
			C-4	23.5	0.5	11.9	O.K
2	0.80	CCT	H	5.1	0.1	10.0	O.K
			C-1	6.7	0.2	8.0	O.K
			T-2	10.6	0.3	8.0	O.K
			C-6	28.4	0.8	12.8	O.K
3	0.60	CTT	T-2	10.6	0.4	8.0	O.K
			C-8	14.6	0.5	11.0	O.K
			T-9	10.0	0.4	8.0	O.K
4	0.80	CCT	T-3	6.7	0.2	25.0	O.K
			C-4	23.5	0.7	26.1	O.K
			C-5	22.5	0.6	25.0	O.K
5	0.80	CCT	T-3	6.7	0.2	25.0	O.K
			C-6	28.4	0.8	29.1	O.K
			C-7	32.5	0.9	26.7	O.K
			C-8	14.6	0.4	31.5	O.K
6	1.00	CCC	C-5	22.5	0.5	25.0	O.K

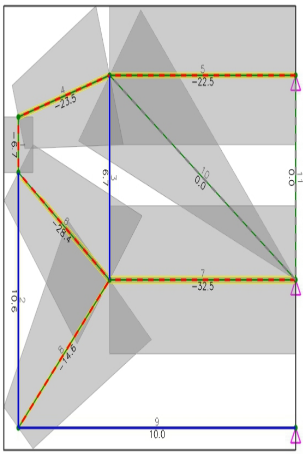
7	1.00	CCC	C-7	32.5	0.7	26.7	O.K
8	0.60	TTT	T-9	10.0	0.4	8.0	O.K

C: compression; T: tension; V: vertical force; H: horizontal force

3. Summary

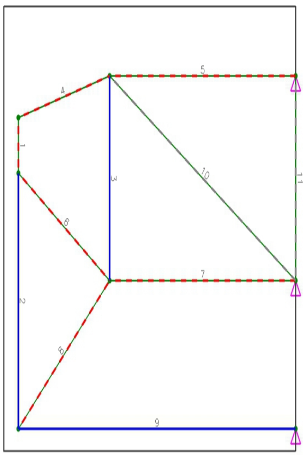
1) Dimensioned Shape

1) Load Combination - 1



2) Required and Used Areas of Rebars

1) Load Combination - 1



(A) Main Rebars

Tie No.	Types	Fu (kip)	theta (deg.)	Rebars	As.req (in^2)	As.used (in^2)	Note
9	Bottom	2.24	0.0	4-#3	0	0	O.K

(B) Transverse Rebars

- Vertical Rebars

Tie No.	Fu (kip)	theta (deg.)	Rebars	Weff,tie (in)	Sv (in)	phi Fn (kip)	Note
2	2.39	90.0	2-#3	0.3	0.2	4.3	O.K
3	1.52	90.0	2-#3	1.0	0.3	6.8	O.K