

Structural Design Report for Anchor Plate Template

Table of Contents

1. Design Conditions

- 1) General Characteristics
 - (1) Project Name
 - (2) Design Code
 - (3) Unit
 - (4) Strength Reduction Factors
 - (5) Scope of Report
- 2) Materials
 - (1) Concrete
 - (2) Steel
- 3) Geometrical Shape
- 4) Loads and Load Combinations
 - (1) Loads
 - (2) Load Combinations
- 5) Reference
 - (1) Designer
 - (2) Date
 - (3) Note

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

- 1) Construction of Strut-Tie Model
 - (1) ESO (Evolutionary Structural Optimization)
 - (2) Compressive Principal Stress Flow
 - (3) Constructed Strut-Tie Model
- 2) Analysis of Strut-Tie Model
 - (1) Loading Conditions
 - (2) Strut and Tie Types
 - (3) Strut and Tie Forces
- 3) Strength Verification and Required Rebars
 - (1) Strength under Bearing/Loading Plates
 - (2) Required Area of Rebars
 - (3) Available Widths of Struts and Nodal Zones
 - (4) Strength of Struts
 - (5) Strength of Nodal Zones

3. Summary

- 1) Dimensioned Shape
- 2) Required and Used Areas of Rebars
- 3) Placement of Rebars

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

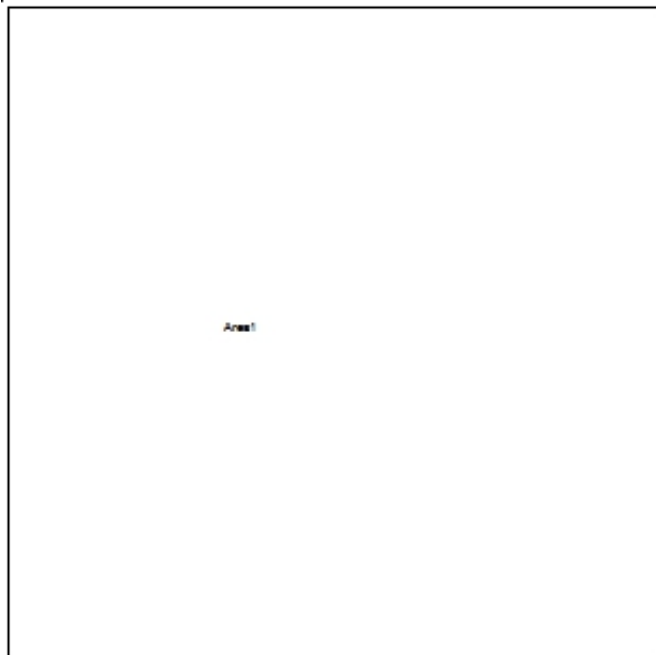
(1) Concrete

- Mass : 147 lb/ft³
- Weight : 149.6 lb/ft³
- Poisson's ratio : 0.15
- Compressive Strength of Concrete, f_{ck} : 3480.9 lb/in²
- Tensile Strength of Concrete, f_{ct} : 348.1 lb/in²
- Elastic modulus of concrete, E_c : 4,039,177 lb/in²

(2) Steel

- Mass : 490 lb/ft³
- Weight : 499.7 lb/ft³
- Poisson's ratio : 0.15
- Yield strength of steel, f_y : 58015.4 lb/in²
- Elastic modulus of steel, E_s : 29,007,699 lb/in²

3) Geometrical Shape



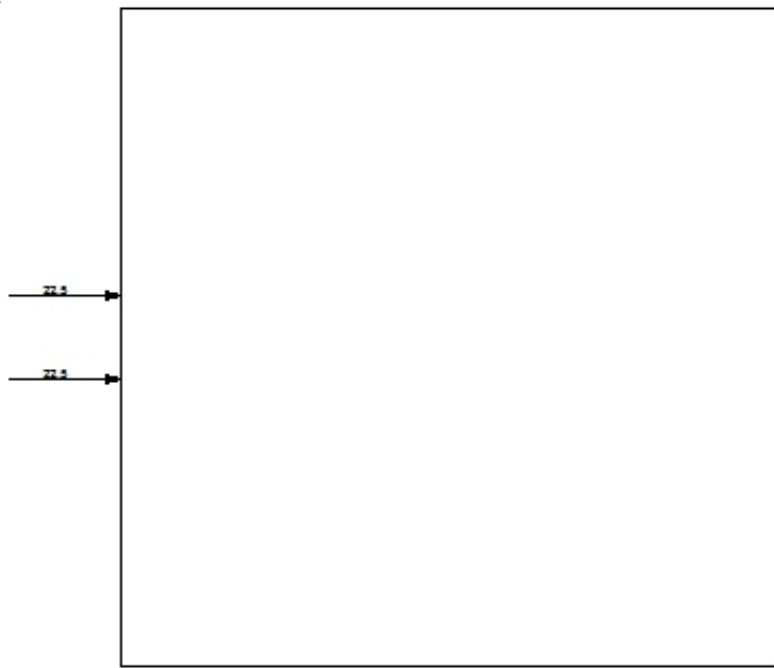
- Thickness : 20.00 in

1. Design Conditions

4) Loads and Load Combinations

(1) Loads

PS ()



(2) Load Combinations

1) LC01 : 1.00PS

5) Reference

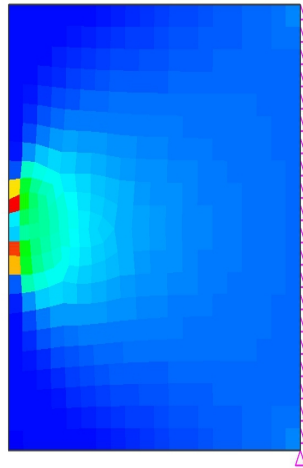
- (1) Designer : Hangil IT
- (2) Date : 2017-07-15
- (3) Note : Design of Anchor Plate using Template (ACI 318-14)

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

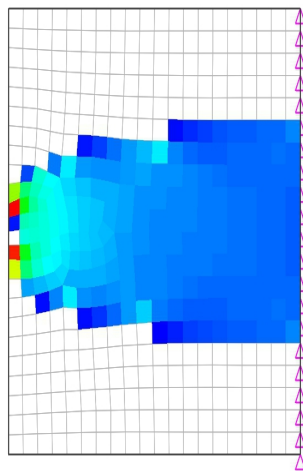
1) Construction of Strut-Tie Model

(1) ESO (Evolutionary Structural Optimization)

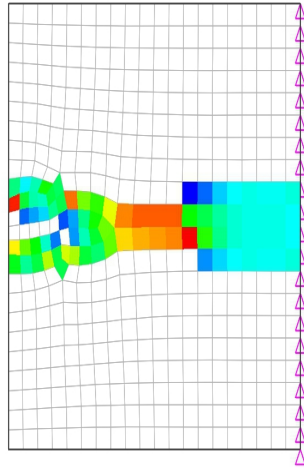
1. STAGE-01 (Initial shape)



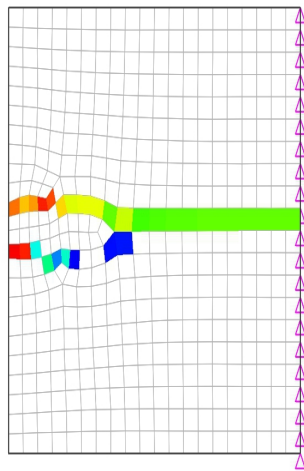
2. STAGE-09 (Elimination ratio = 55%)



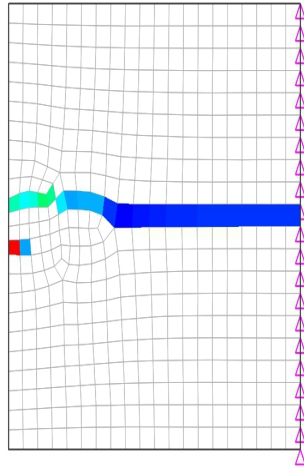
3. STAGE-17 (Elimination ratio = 81%)



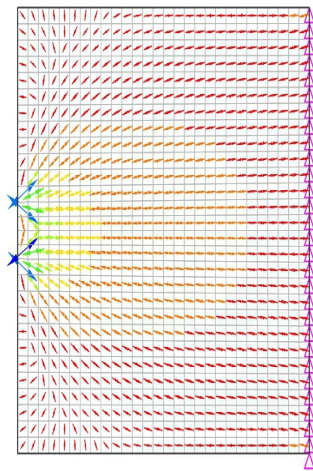
4. STAGE-25 (Elimination ratio = 92%)



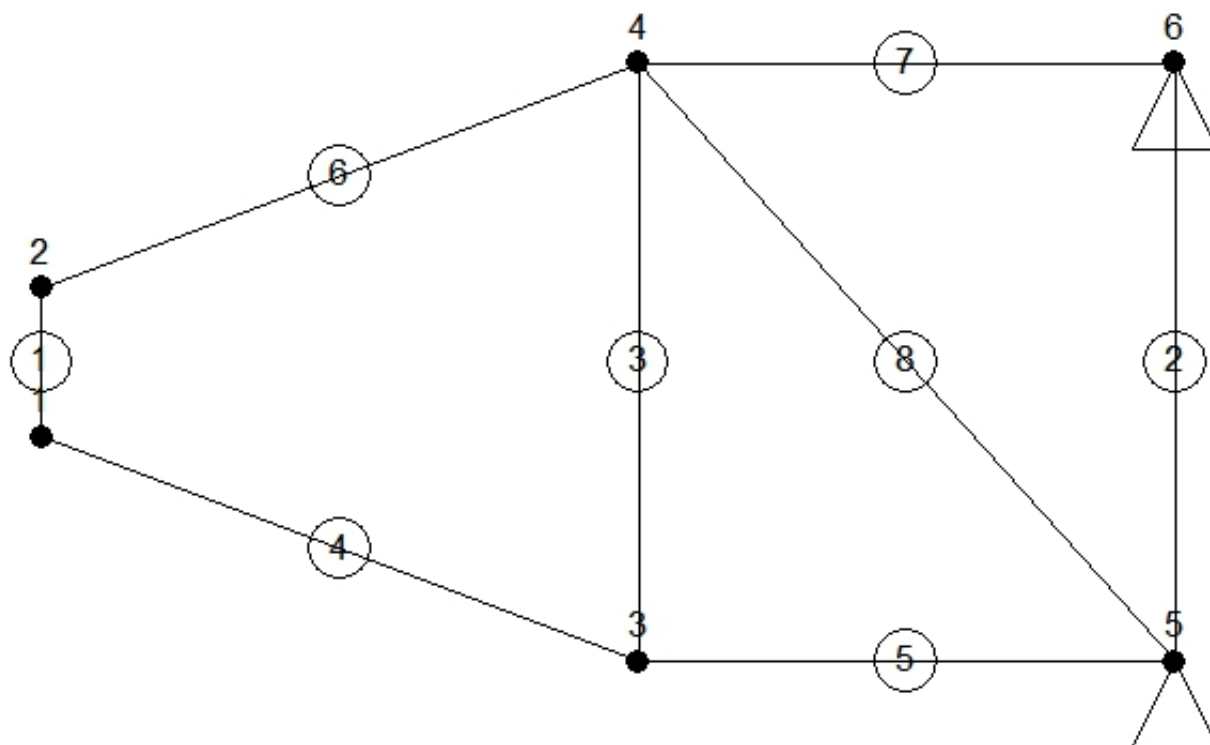
5. STAGE-27 (Elimination ratio = 94%)



(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	35.000	2	4.000	45.000
3	44.000	20.000	4	44.000	60.000
5	80.000	20.000	6	80.000	60.000

(B) Element Connectivity

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

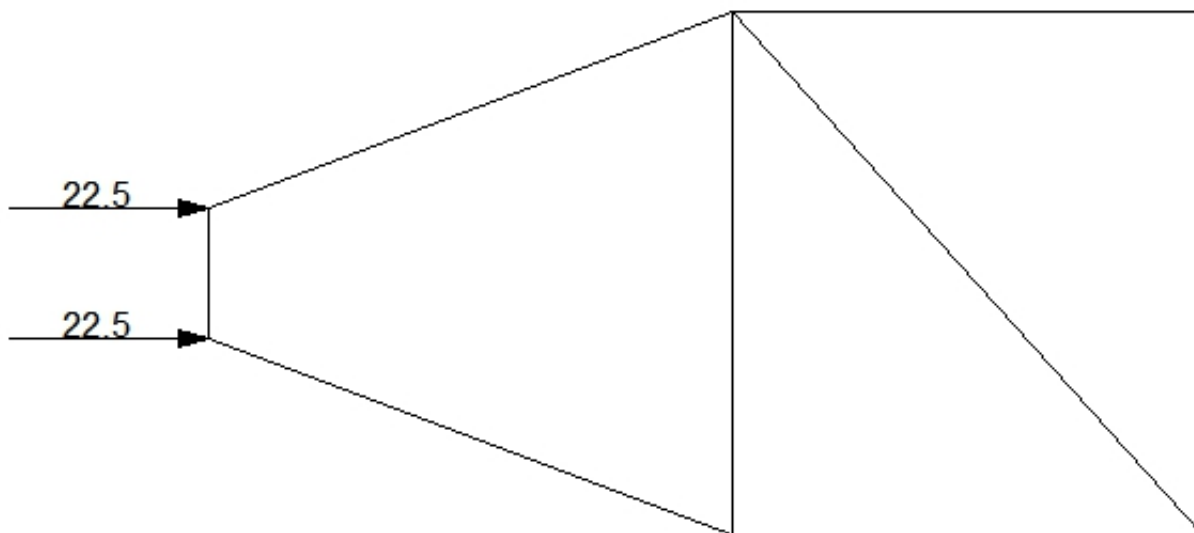
(C) Restraints

Node	Ux	Uy	Uz	Rx	Ry	Rz
5	0	0	0	0	-	0
6	0	0	0	0	-	0

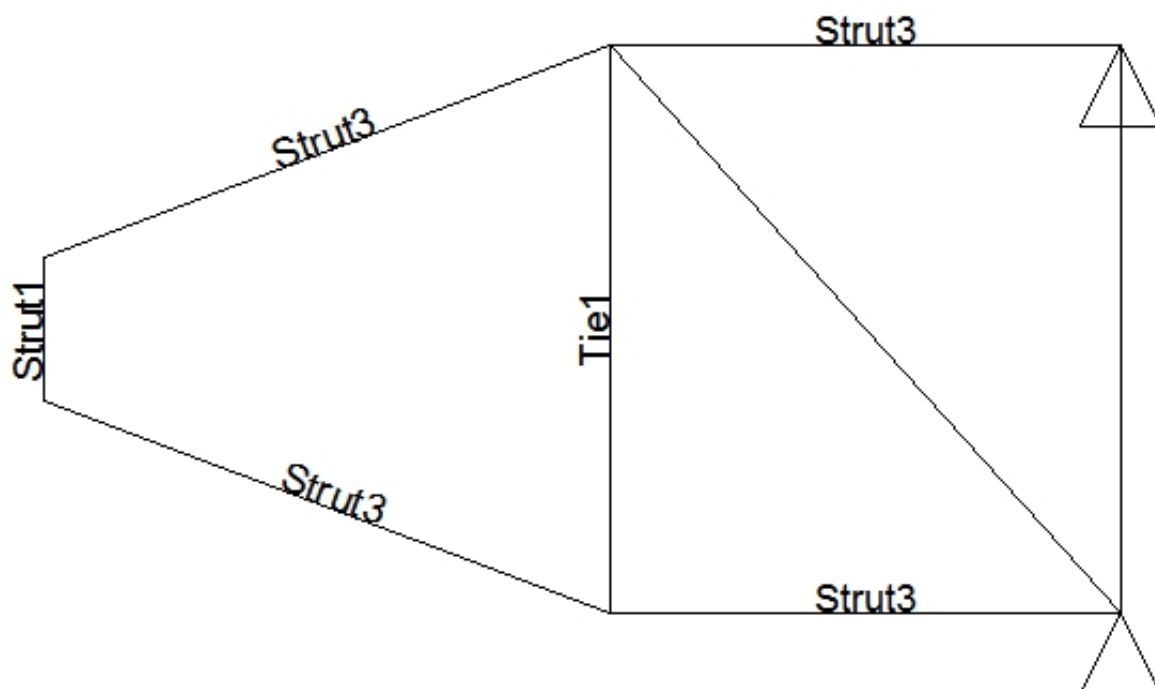
2) Analysis of Strut-Tie Model

(1) Loading Conditions

(1) (PS)

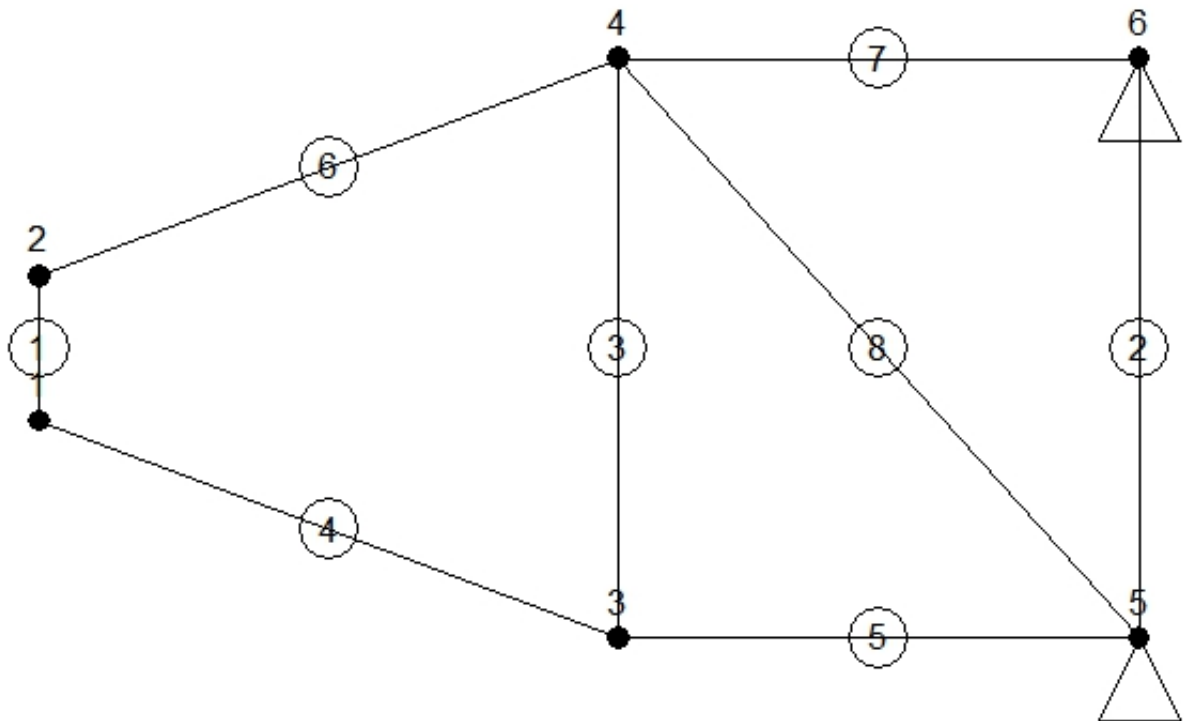


(2) Strut and Tie Types



- 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

(3) Strut and Tie Forces



Elem. No.	Force (kip)	Elem. No.	Force (kip)	Elem. No.	Force (kip)	Elem. No.	Force (kip)
1	-8.4	2	0.0	3	8.4	4	-24.0
5	-22.5	6	-24.0	7	-22.5	8	0.0

3) Strength Verification and Required Rebars

(1) Strength under Bearing/Loading Plates

$\phi f_{ce} = \phi \cdot 0.85 \cdot \beta \cdot f_{ck} < F_u / A$
 $\beta = 1.00$ (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)
 $A = \text{Area of bearing plates (= BxW)}$

Node	beta	f _{ce} (lb/in ²)	F _u (kip)	B (in)	W (in)	F _u /A (lb/in ²)	Note
1	1.00	2219.09	22.5	20.0	10.0	112.500	0.K
2	1.00	2219.09	22.5	20.0	10.0	112.500	0.K

(2) Required Area of Rebars

1) Transverse Rebars

(A) Vertical Rebars

Tie No.	F _u (kip)	theta (deg.)	Rebars	W _{eff,tie} (in)	S _v (in)	phi F _n (kip)	Note
3	1.90	90.0	2-#3	1.4	0.3	9.7	0.K

$\phi \cdot F_n = \phi \cdot A_v \cdot f_y \cdot W_{eff,tie} \cdot \sin \theta / S_v > F_u$

where,

F_u = member force of steel tie
 ϕ = strength reduction factor of steel tie : 0.75
 f_y = yield strength of steel : 58015.4 lb/in²
 θ = angle of steel tie measured from positive horizontal axis
 (+: counterclockwise)
 S_v = spacing of vertical rebars
 $W_{eff,tie}$ = effective width of tie

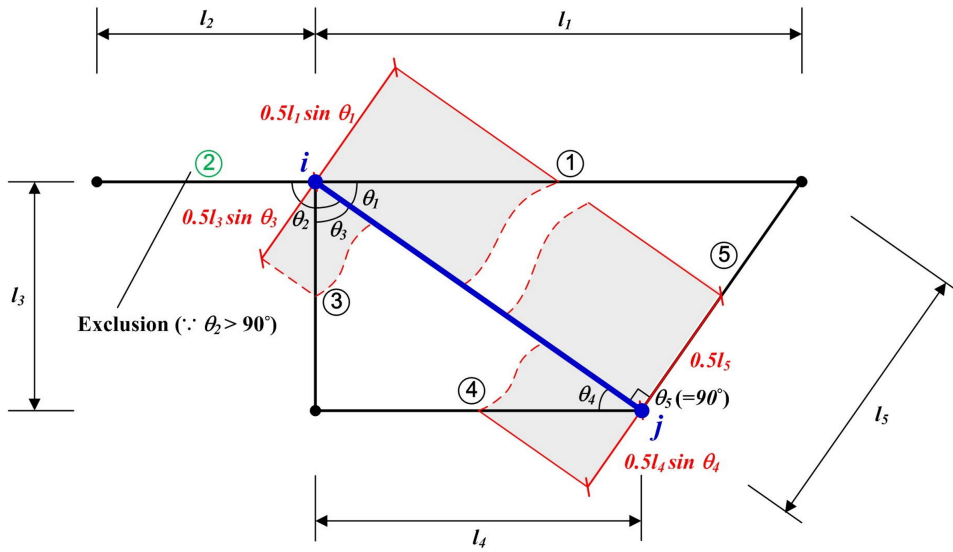
(3) Available Widths of Struts and Nodal Zones

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.

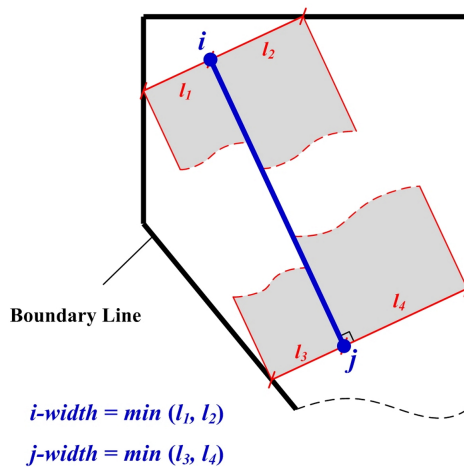
2) Node with bearing plate

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]

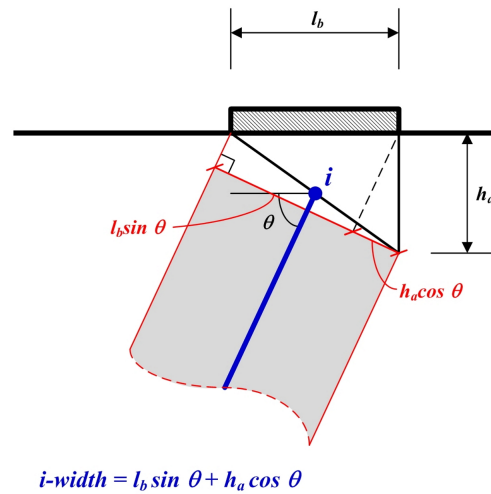
$$i\text{-width} = \min(l_1 \sin \theta_1, l_3 \sin \theta_3)$$

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

[CASE 2]

$$i\text{-width} = \min(l_1, l_2)$$

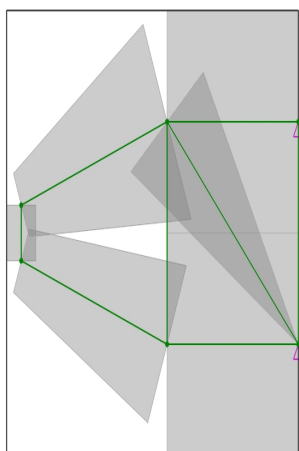
$$j\text{-width} = \min(l_3, l_4)$$

[CASE 3]

$$i\text{-width} = l_b \sin \theta + h_a \cos \theta$$

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

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	12.1	30.1	12.1
5	40.0	40.0	40.0	6	12.1	37.4	12.1
7	40.0	40.0	40.0				

(4) Strength of Struts

$W_{req} = F_u / \phi \cdot 0.85 \cdot \beta_a \cdot f_{ck} \cdot b < W_{prov}$ (See ACI 318M-14 Section 23.4)
 $\beta_a = 1.00$ (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)
 $\phi = \text{strength reduction factor of concrete strut} = 0.75$

Strut No.	beta	theta	Fu (kip)	b (in)	Wreq (in)	Wprov (in)	Note
1	1.00	90.0	8.4	20.0	0.2	8.0	O.K
4	0.60	20.6	24.0	20.0	0.9	12.2	O.K
5	0.60	0.0	22.5	20.0	0.8	40.0	O.K
6	0.60	20.6	24.0	20.0	0.9	12.2	O.K
7	0.60	0.0	22.5	20.0	0.8	40.0	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

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



available nodal zone width, w_{prov} , with that required, w_{req}

$$w_{req} = F_u / \phi \cdot 0.85 \cdot \beta \cdot f_{ck} \cdot b < w_{prov} \text{ (See ACI 318M-14 Section 23.9)}$$

$\beta = 1.00$ (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)

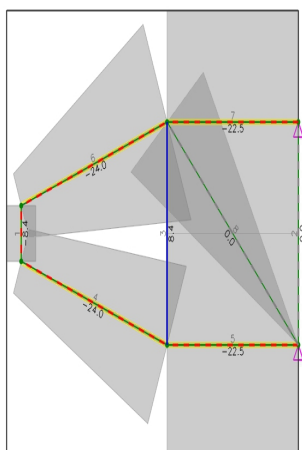
Node No.	beta	Type	Element	F_u (kip)	w_{req} (in)	w_{prov} (in)	Note
1	1.00	CCC	H	5.1	0.1	10.0	O.K
			C-1	8.4	0.2	8.0	O.K
			C-4	24.0	0.5	12.2	O.K
2	1.00	CCC	H	5.1	0.1	10.0	O.K
			C-1	8.4	0.2	8.0	O.K
			C-6	24.0	0.5	12.2	O.K
3	0.80	CCT	T-3	8.4	0.2	36.0	O.K
			C-4	24.0	0.7	30.2	O.K
			C-5	22.5	0.6	40.0	O.K
4	0.80	CCT	T-3	8.4	0.2	36.0	O.K
			C-6	24.0	0.7	37.5	O.K
			C-7	22.5	0.6	40.0	O.K
5	1.00	CCC	C-5	22.5	0.5	40.0	O.K
6	1.00	CCC	C-7	22.5	0.5	40.0	O.K

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

3. Summary

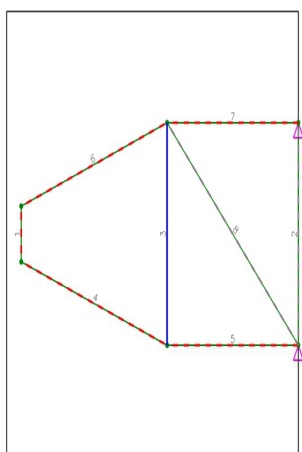
1) Dimensioned Shape

1) Load Combination - 1



2) Required and Used Areas of Rebars

1) Load Combination - 1



(A) Transverse Rebars

- Vertical Rebars

Tie No.	Fu (kip)	theta (deg.)	Rebars	Weff,tie (in)	Sv (in)	phi Fn (kip)	Note
---------	-------------	-----------------	--------	------------------	---------	-----------------	------

3. Summary



3	1.90	90.0	2-#3	1.4	0.3	9.7	0.K
---	------	------	------	-----	-----	-----	-----