MAJEVU DARAJA LA CHINI

[MAJEVU FOOTBRIDGE]

Same, Tanzania

Designers: Karina Rosales and Maja Sagaser

Project Advisor: Kevin Dong

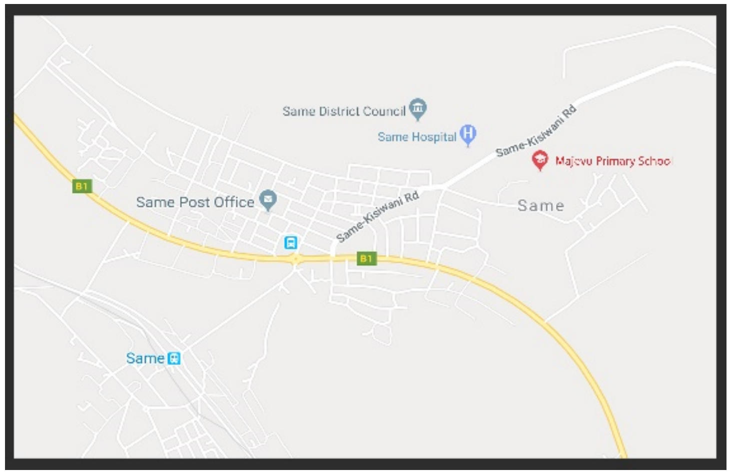
Pedestrian Bridge in Tanzania

Senior Project

Karina Rosales and Maja Sagaser

Objective:

Our project objective is to design a pedestrian bridge in Same, Tanzania. The bridge will connect the two sides of a deep creek bed and ease access to the community school, Majevu. Following the design process, we will be travelling to Same to help construct the bridge.



Map of Same, Tanzania

Personal Goals:

Through this project we hope to utilize the structural engineering practices and theory that we have learned during our time at Cal Poly. The bridge will be designed in a manner that prioritizes the desires of the community, safety, and the surrounding environment.

Location of Bridge and Majevu in relation to surrounding community.

During the construction process of the bridge, we will be working in an interdisciplinary team of Architectural Engineering students, Architecture students, and the local Tanzanian Builders. This will allow a more encompassing approach to the bridge design by addressing cultural significance, ease of construction, and structural integrity. We are excited to learn about the process of designing the bridge, leading a team, and putting design into action.

Project Goals:

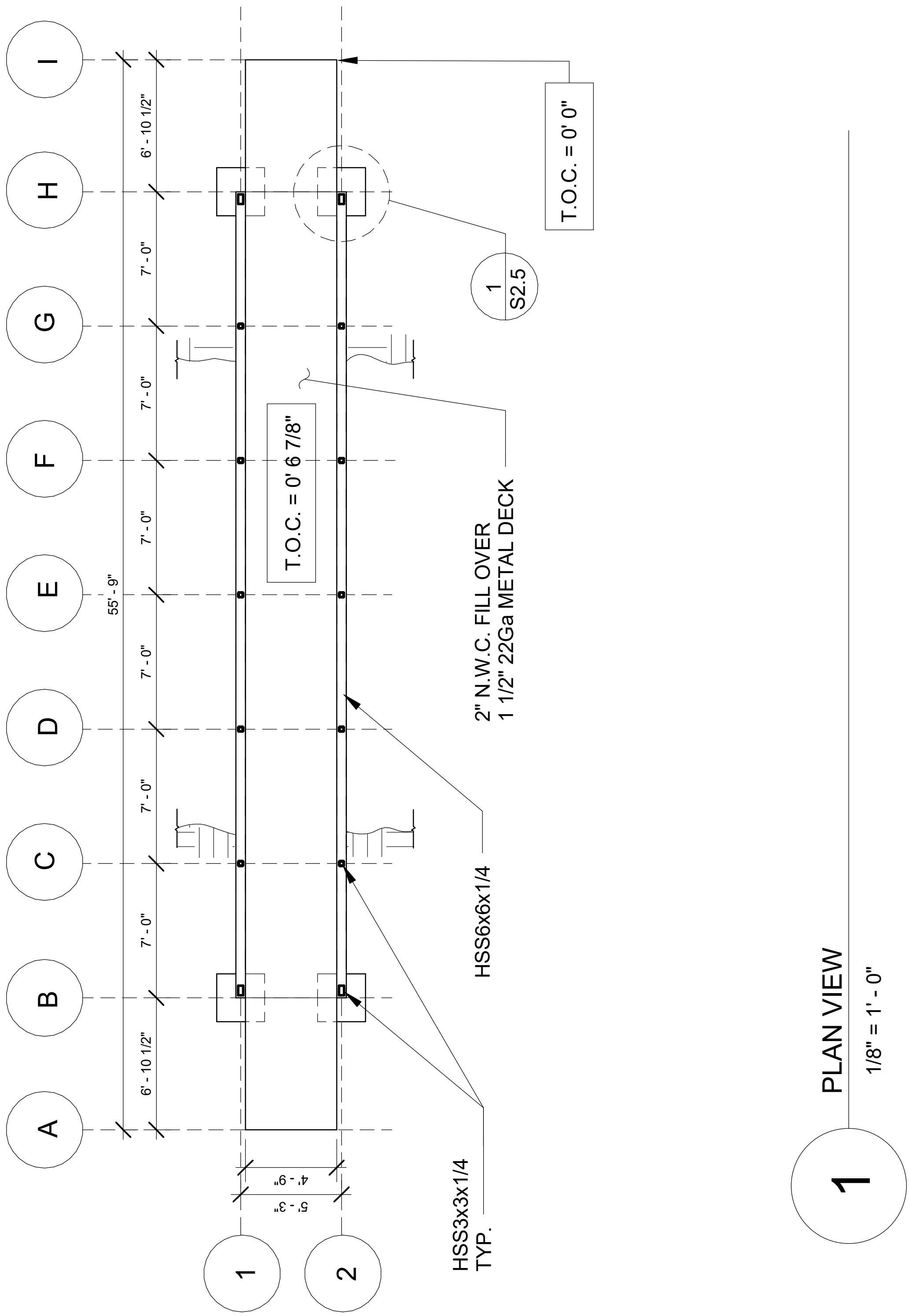
The bridge design and construction will be done with special attention to the available materials and resources in Tanzania. The bridge will meet the needs of the Same community and have lasting structural integrity.

MAJEVU DARAJA LA CHINI

MICHORO YA UJENZI

[CONSTRUCTION DRAWINGS]

BRIDGE SITE PLAN



California Polytechnic State University, San Luis Obispo

Majevu Daraja la Chini

PLAN

Project number	435.07	S1.1	
Date	01.05.19		
Drawn by	KR & MS		
Checked by	KJD	Scale	1/8" = 1'-0"

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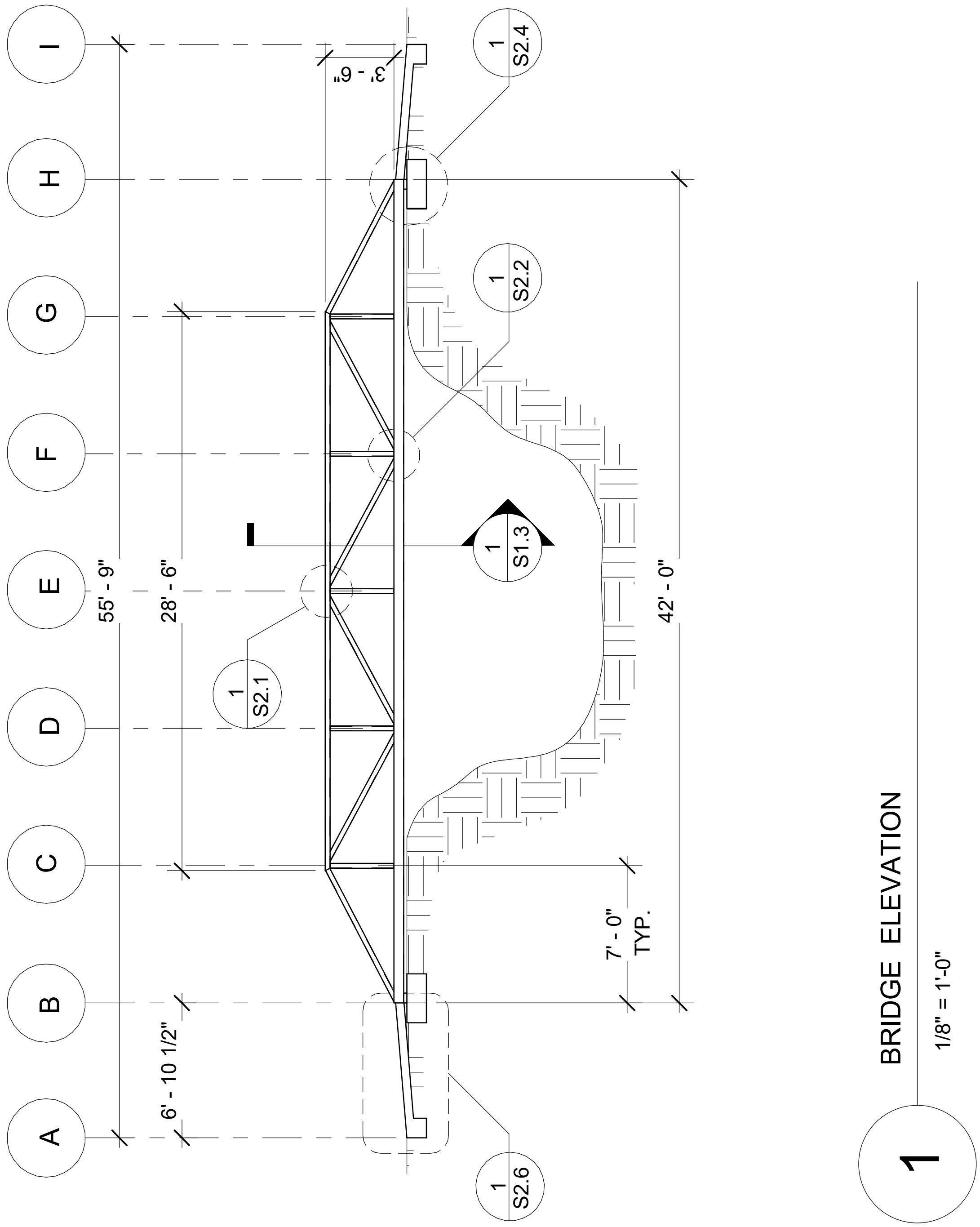

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	ELEVATION	
		Project number 435.07	S1.2
		Date 01.05.19	
		Drawn by KR & MS	
		Checked by KJD	Scale 1/8" = 1'-0"

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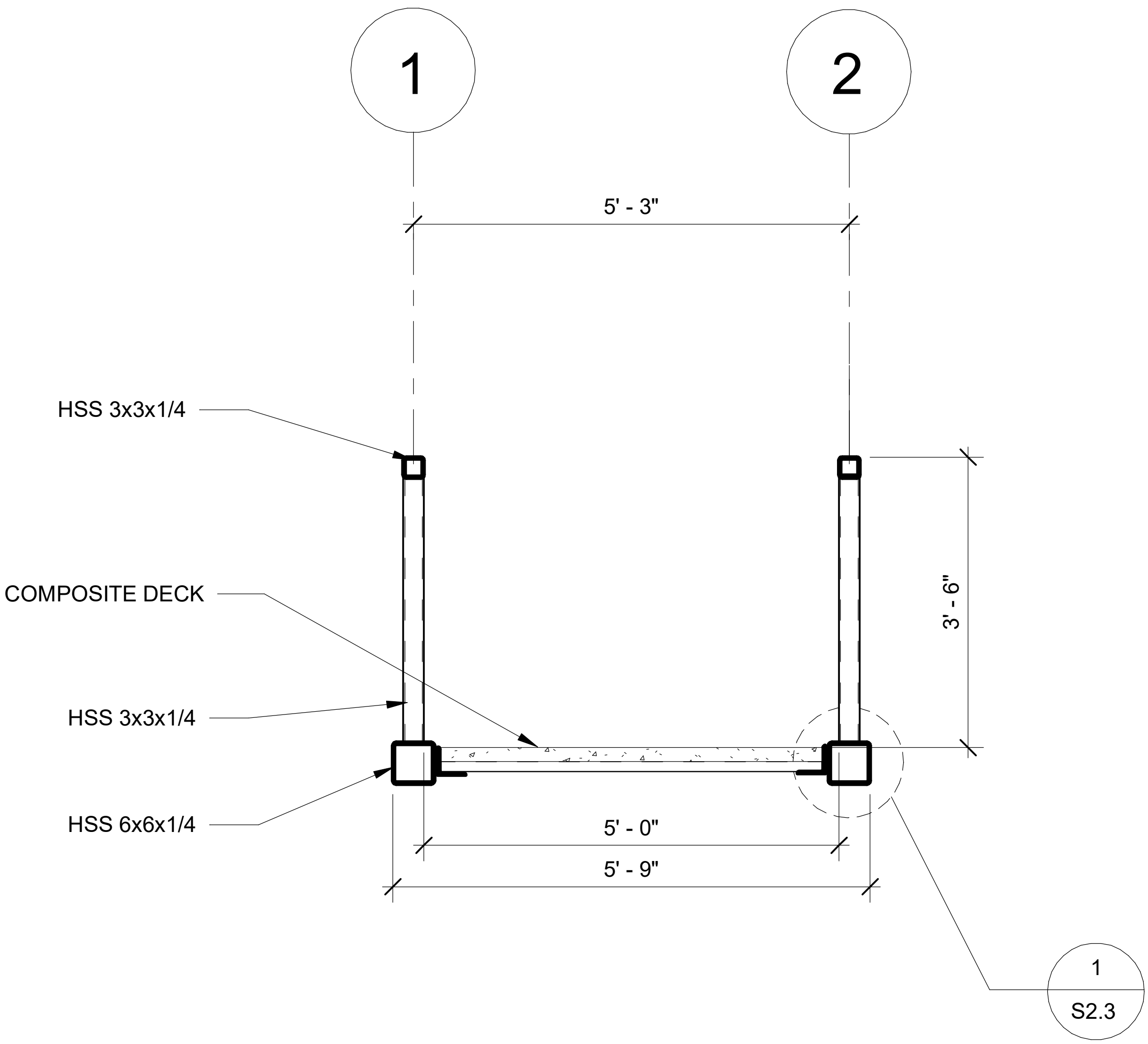

1 BRIDGE SECTION

1/2" = 1'-0"

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	ELEVATION	
		Project number 435.07	S1.3
		Date 01.05.19	
		Drawn by KR & MS	
		Checked by KJD	Scale 1/2" = 1'-0"

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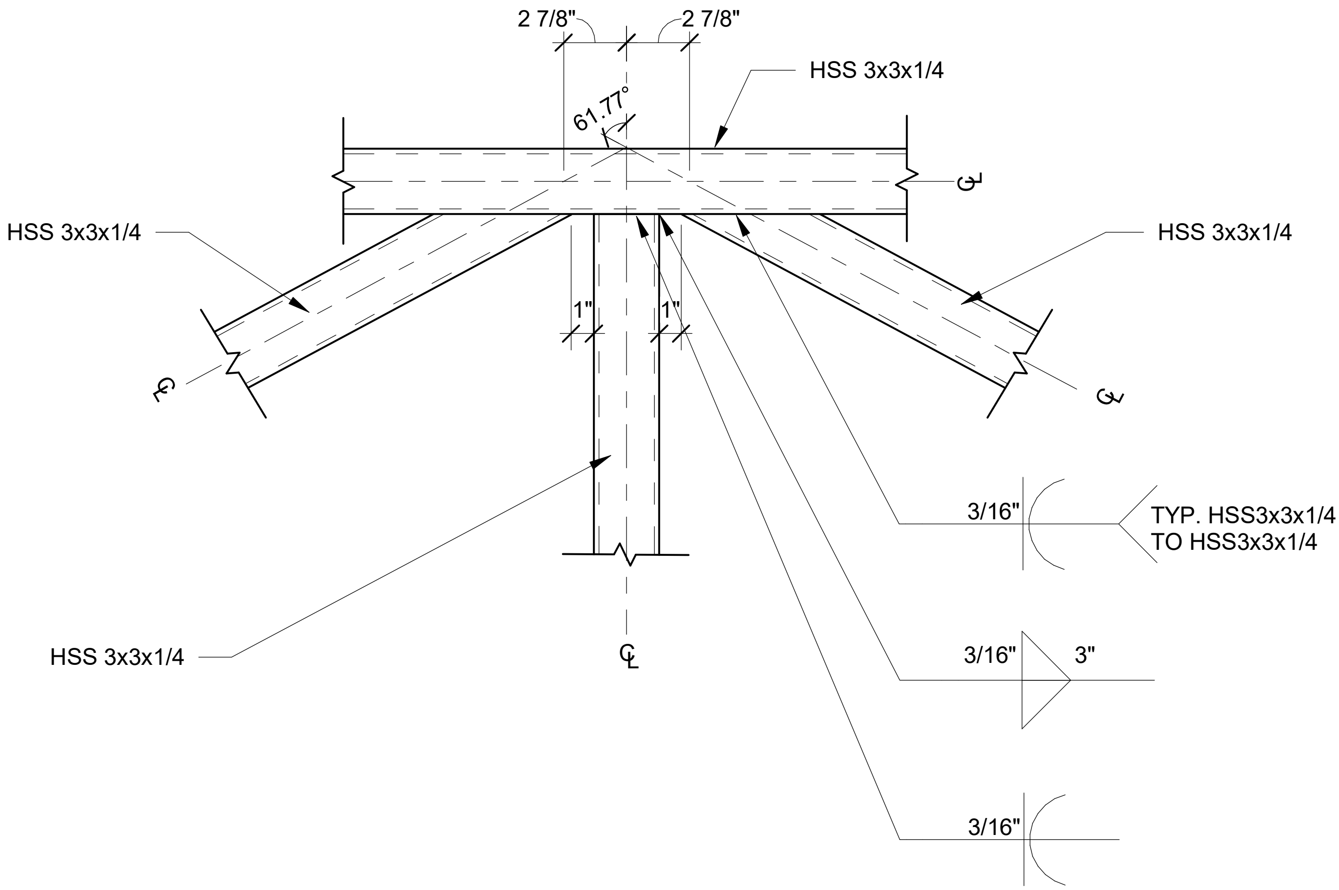

1 BRACES TO TOP CHORD

1 1/2" = 1' - 0"

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	DETAILS	
		Project number 435.07	S2.1
		Date 01.05.19	
		Drawn by KR & MS	
		Checked by KJD	Scale 1 1/2" = 1'-0"

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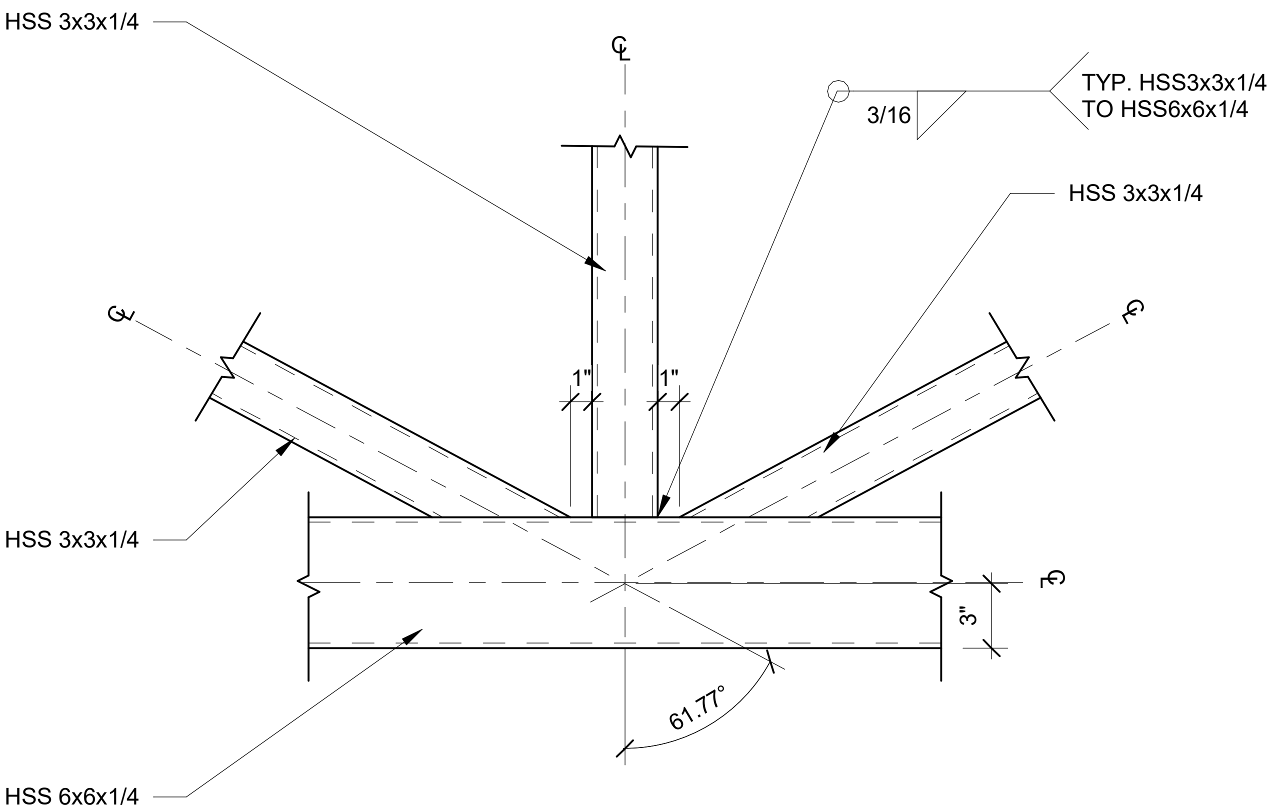

1 BRACES TO BOTTOM CHORD

1 1/2" = 1' - 0"

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	DETAILS		
		Project number	435.07	S2.2
		Date	01.05.19	
		Drawn by	Author	
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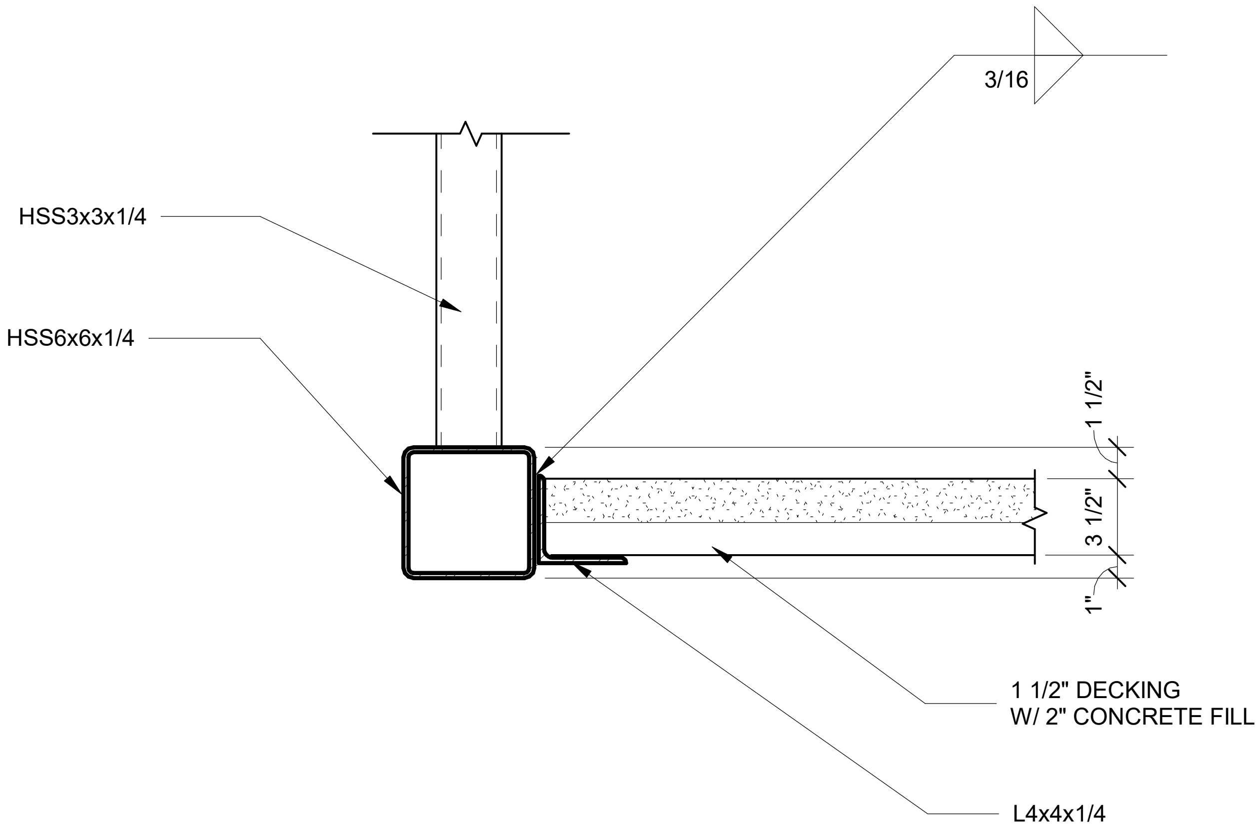

1 DECKING TO BEAM

1 1/2" = 1' - 0"

California Polytechnic State University, San Luis Obispo

Majevu Daraja la Chini

DETAILS

Project number	435.07	S2.3
Date	01.05.19	
Drawn by	Author	
Checked by	Checker	Scale 1 1/2" = 1'-0"

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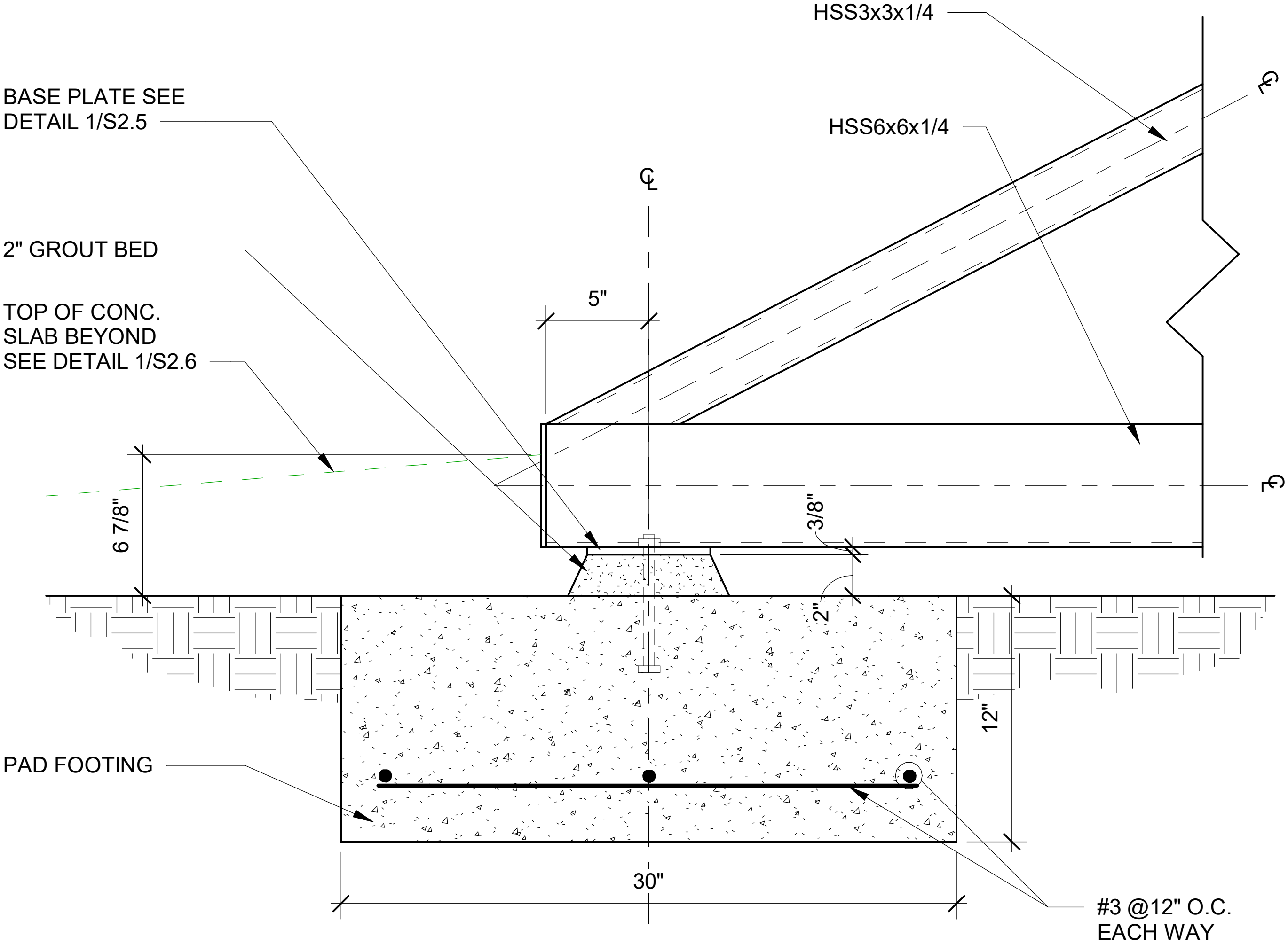

1 FOOTING SECTION

1 1/2" = 1'-0"

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	DETAILS
		Project number 435.07
		Date 01.05.19
		Drawn by Author
		Checked by Checker
		S2.4
		Scale 1 1/2" = 1'-0"

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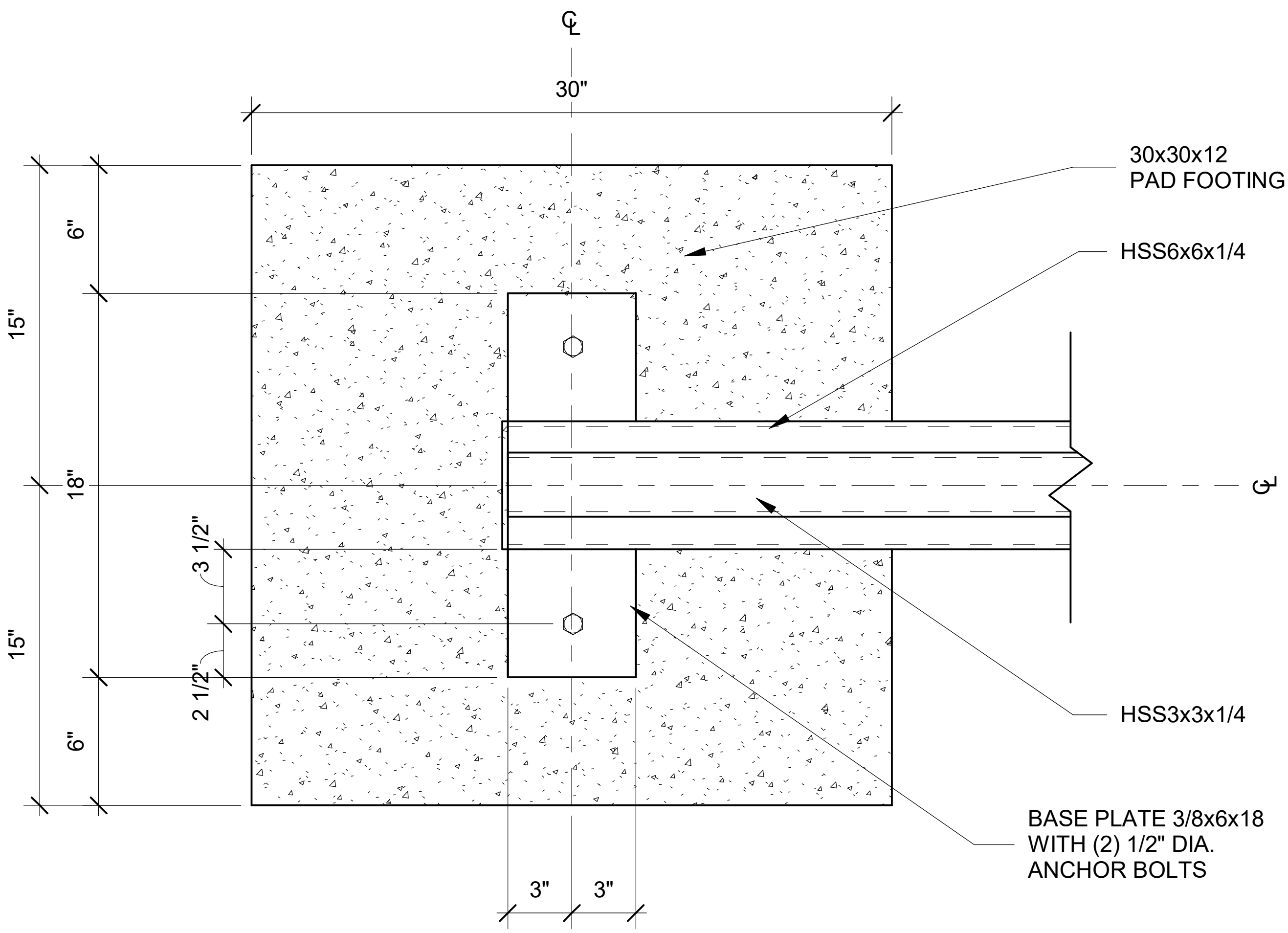

1 FOOTING PLAN

1 1/2" = 1' - 0"

California Polytechnic State University, San Luis Obispo

Majevu Daraja la Chini

DETAILS

Project number	435.07	S2.5
Date	01.05.19	
Drawn by	Author	
Checked by	Checker	Scale 1 1/2" = 1'-0"

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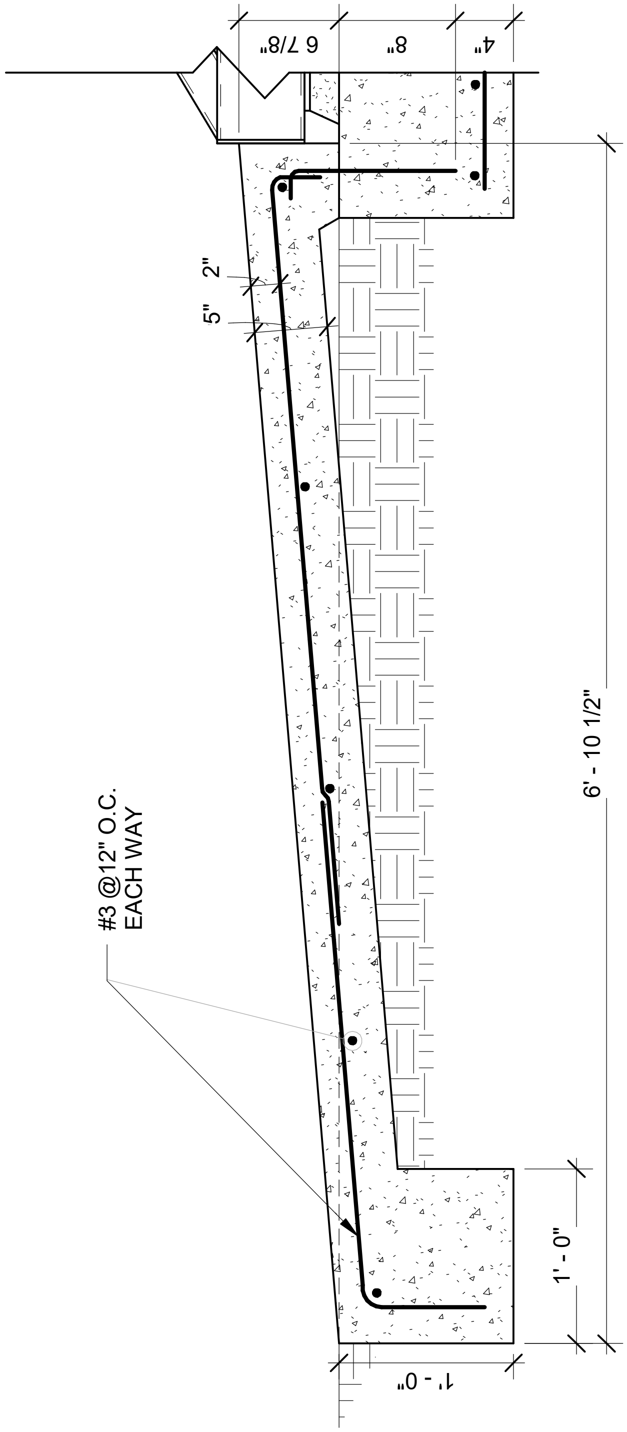

1 RAMP TO BRIDGE
1" = 1' - 0"

California Polytechnic State University, San Luis Obispo	Majevu Daraja la Chini	DETAILS	
		Project number 435.07	S2.6
		Date 01.05.19	
		Drawn by Author	
		Checked by Checker	Scale 1" = 1'-0"

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MAJEVU DARAJA LA CHINI

MAKADIRIO YA NYENZO

[MATERIAL ESTIMATE]

Materials Take Off

Item

Concrete						
W= 150 pcf						
Footings	6.25	ft^3	x	4	25	ft^3
Decking	35	ft^3	x	1	35	ft^3
Ramp	19.6	ft^3		2	39.2	ft^3
TOTAL					**99.2**	**ft^3**

HSS3X3X1/4						
Top Chord	26.5	ft	x	2	53	ft
Columns	3.25	ft	x	10	32.5	ft
Braces	7.33	ft	x	12	87.96	ft
TOTAL					**173.46**	**ft**

HSS6X6X1/4						
Bottom Chord	42	ft	x	2	84	ft
TOTAL					**84**	**ft**

Rebar						
Footings	12	ft	x	4	48	ft
Ramp	27	ft	x	2	54	ft
TOTAL #3's					**102**	**ft**

Metal Decking						
Span=	42	ft	x	5	210	ft^2
TOTAL					**210**	**ft^2**

MAJEVU DARAJA LA CHINI

MAHESABU

[CALCULATIONS]

MAJEVU BRIDGE | ENGINEER: MS, KR, KD

CALCULATION SUMMARY

DECK DESIGN

22 Ga 1½" PLB DECK W/ 2" N.W.C. FILL

HSS 6x6x1/4 (BOTTOM CHORD)

MAX FORCE = 35^k (TENSION)

CHECKING USING 36 ksi STEEL:

$\phi T_n = 169.7^k$

$\phi P_n = 158.6^k$

HSS 3x3x1/4 (TOP CHORD)

MAX FORCE = 31.1^k (COMPRESSION)

USING 36 ksi STEEL:

$\phi T_n = 79.06^k$

$\phi P_n = 57.16^k$

DEFLECTION

$\Delta_{all} = 2.1"$ $\Delta_{act} = 0.492"$ (RISA)

WELDS

USE 3/16" FILLET OR GROOVE WELDS

FREQUENCY

$f_n = 7.89$ Hz

DEAD LOAD

ITEM	CALC (IF APPL.)	WEIGHT (PSF)
22 Ga. MTL DECK 1½" DEEP	FROM VERCO CATALOG = 1.9 PSF	2 PSF
N.W. CONC FILL 3"	150 PCF × (3"/12) = 37.5 PSF	40 PSF
TOP/BOTT. HSS 6×6×1/4	19.02 PLF × (42' + 35') = 1465# 1465# / 210 SF = 6.9 PSF	7 PSF
MIDDLE CHORD HSS 3×3×1/4	8.81 PLF × [(7.83' × 6) + (3.5' × 5)] = 568 # 568# / 210 SF = 2.7 PSF	3 PSF

TOTAL DL = 52 PSF

LIVE LOAD

FROM ASCE 7-16:

TOTAL LL = 100 PSF

CONVERTING TO PLF FOR SINGLE TRUSS RISA ANALYSIS:

DL = 52 PSF × (5'/2) = 130 PLF

LL = 100 PSF × (5'/2) = 250 PLF

MAX FACTORED LOAD

ASCE 7-16 LRFD COMBO 2:

$$1.2D + 1.6L = 1.2(130) + 1.6(250)$$

$$w = 556 \text{ PLF}$$

NOTE: Replacing top railing w/ HSS 3×3×1/4 reduces weight by only 2 PSF. Continue using 556 PSF as this is not significant.

DECK DESIGN

SPAN = 5'-0"

DECK SPANS = 1

FOR 22 Ga PLB 1½" DECK + 2" CONC.

ALLOWABLE SUPER IMPOSED LOAD = 353 PSF

FROM LOAD TAKE OFF:

DESIGN LOAD = 52 PSF (1.2) + 100 PSF (1.6) = 222.4 PSF

222.4 PSF ≤ 353 PSF <u>OK</u>

USE 22Ga 1½" PLB DECK W/ 2" N.W.C. FILL

MAX MOMENT

$$M = \frac{w l^2}{8}$$

$$M = \frac{556\,PLF\,(42')^2}{8}\left(\frac{1\,k}{1000\#}\right) = 122.6^{k'}$$

MAX T/C FORCE

$$T = C = \frac{M}{d}$$

$$\frac{M}{d} = \frac{122.6^{k'}}{3.5'}$$

$T = C = 35^{k}$

RISA ANALYSIS: $T = 35^{k}$ ✓

CHECK TENSION (HSS 6x6x1/4)

TENSILE YIELDING:

$P_n = F_y A_g$ $\qquad \phi = 0.9$

$\phi P_n = 0.9[50\,ksi \cdot 5.24\,in^2]$

$\phi P_n = \phi T_u = 235.8^{k}$

$\phi T_u > T$ OK

NOTE: 36ksi steel
$\phi T_u = 0.9(36ksi)(5.24)$
$\phi T_n = 169.7^{k}$
OK

CHECK COMPRESSION

SLENDERNESS CHECK:
HSS 6x6x1/4 $\quad \frac{b}{t} = 22.8$ (ASCE TBL 1-12)

LIMITING RATIO, λ:

$$\lambda = 1.4\sqrt{\frac{E}{F_y}} = 1.4\sqrt{\frac{29000\,ksi}{50\,ksi}}$$

$\lambda = 33.7$

$\lambda > \frac{b}{t}$ ∴ WON'T BUCKLE

FLEXURAL BUCKLING CHECK:

$P_n = F_{cr} A_g$

$$\frac{L_c}{r} = \frac{7' \times 12''/'}{2.34''} = 35.9$$

$$4.71\sqrt{\frac{E}{f_y}} = 4.71\sqrt{\frac{29000}{50}} = 113.43$$

$$\frac{L_c}{r} < 4.71\sqrt{\frac{E}{f_y}}$$

$$\therefore F_{cr} = (0.658)^{\frac{F_y}{F_e}} \cdot F_y$$

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} = \frac{\pi^2\, 29000}{(35.9)^2} = 222.08$$

$$F_{cr} = (0.658^{50/222.08}) \cdot 50 = 45.5 \text{ ksi}$$

$$\phi P_n = 0.9(45.5 \text{ ksi} \cdot 5.24 \text{ in}^2) = 214.58^k$$

$\phi P_n > C$ OK

VERIFY W/ ASCE TBL 4-4:
$\phi P_n = 215^k$ ✓

NOTE: WILL ALSO WORK USING 36 ksi STEEL

TENSION:

$$\phi T_n = 0.9(36 \text{ ksi})(5.24 \text{ in}^2)$$

$$\phi T_n = 169.7^k > T = 35^k$$

OK

COMPRESSION:

$$\lambda = 1.4\sqrt{\frac{29000}{36}} = 39.7 > b/t = 22.8$$

$$\phi P_n = \phi F_{cr} A_g$$

$$\frac{L_c}{r} = 35.9$$

$$4.71\sqrt{\frac{29000}{36}} = 133.68 > \frac{L_c}{r}$$

$$\therefore F_{cr} = (0.658)^{36/222.08} \cdot 36$$

$$F_{cr} = 33.64 \text{ ksi}$$

$$\phi P_n = 0.9(33.64 \text{ ksi})(5.24 \text{ in}^2) = 158.6^k$$

$\phi P_n > C = 35^k$ OK

ALLOWABLE DEFLECTION

FROM IBC TABLE 1604.3:

$$\Delta_{all} = l/240$$

$$\Delta_{all} = \frac{42' \times 12''/1'}{240}$$

$$\Delta_{all} = 2.1''$$

ACTUAL DEFLECTION

$$\Delta_{act} = \frac{5wl^4}{384\,EI}$$

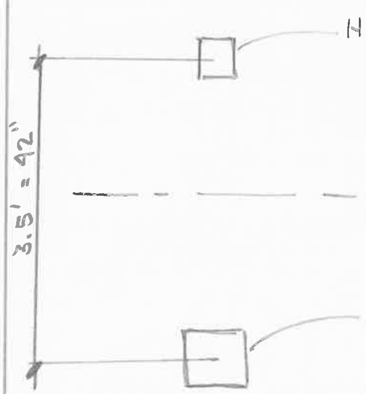
NOTE: DEFLECTION IS A SERVICE LOAD ∴ D+L

$$w = 380\ \text{PLF} \times \frac{1\ \text{FT}}{12\ \text{IN}} = 31.67\#/\text{IN}$$

$$E = 29{,}000{,}000\ \text{PSI}$$

$$l = 42' \times 12''/1' = 504''$$

CALCULATE I_x FOR COMPOSITE SECTION:



HSS 3×3×1/4 $\quad I_{x_{3\times3}} = 3.16\,in^4$

HSS 6×6×1/4 $\quad I_{x_{6\times6}} = 30.3\,in^4$

$$I_x = \Sigma\left[I_{x_o} + A\left(\frac{d}{2}\right)^2\right]$$

$$= \left[3.16\,in^4 + 2.59\,in^2\left(\frac{21''}{2}\right)^2\right] + \left[30.3\,in^4 + 5.59\,in^2\left(\frac{21''}{2}\right)^2\right]$$

$$I_x = 935.305\,in^4$$

$$\Delta_{act} = \frac{5 \cdot 31.67\#/IN \cdot (504'')^4}{384 \cdot 29{,}000{,}000\,PSI \cdot 935.305\,in^4}$$

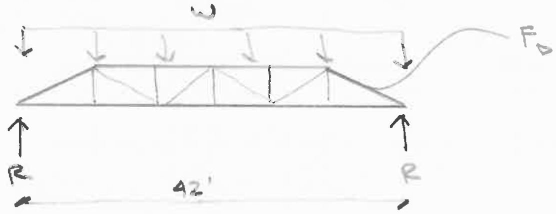
$$\Delta_{act} = 0.98'' < \Delta_{all} = 2.1''$$

OK

$$\Delta_{RISA} = 0.492''$$

CALCULATIONS FOR HSS 3×3×1/4 SECTION

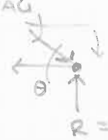
SIMPLIFIED ANALYSIS:

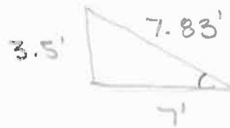


$w = 556$ PLF

$$R = \frac{wL}{2} = \frac{556\,\text{PLF} \cdot 42'}{2} = 11676\,\# = 11.676^k$$

METHOD OF JOINTS





$$\tan\theta = \frac{3.5}{7}$$

$$\tan^{-1}\left(\frac{3.5}{7}\right) = \theta$$

$$\theta = 26.57^\circ$$

$$\sin\theta = \frac{11.68}{\text{DIAG.}}$$

$$\frac{11.68}{\sin(26.57)} = \text{DIAG.}$$

DIAG. F = 26.11^k COMPRESSION

FROM RISA: $F_D = 22.3^k$ ——— PRETTY CLOSE

MAXIMUM FORCES

MAX COMP. FORCE = 31.1^k (TOP CHORD)
MAX TENS. FORCE = 12^k (INNER DIAG.)

CHECK TENSION:

$$P_n = F_y A_g$$

$$\phi P_n = 0.9\,(50\,\text{ksi})(2.44\,\text{in}^4)$$

$$\phi P_n = \phi T_n = 109.8^k$$

$\phi T_n > T$ OK

CHECK COMPRESSION:

FROM ASCE TABLE 4-4 (50ksi)

L = 7.83'

L = 7 ——→ $\phi P_n = 72.2$
L = 8 ——→ $\phi P_n = 63.5$ INTERPOLATE

$$\phi P_n = 64.98^k$$

$\phi P_n > C$ OK

HSS 3x3x1/4 USING 36 ksi

TENSION:

$\phi T_n = 0.9\,(36\text{ ksi})(2.44\text{ in}^2)$

$\phi T_n = 79.06^k$

$\phi T_n > T = 12.2^k$

OK

COMPRESSION:

$\frac{L_c}{r} = \frac{(7.83' \times 12''/1')}{1.10''} = 85.42$

$4.71\sqrt{\frac{29000}{36}} = 133.68 > \frac{L_c}{r}$

$\therefore F_{cr} = (0.658)^{F_y/F_e} \cdot F_y$

$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} = \frac{\pi^2(29000\text{ ksi})}{(85.42)^2} = 39.23\text{ ksi}$

$F_{cr} = (0.658)^{36/39.23} \cdot 36$

$F_{cr} = 24.52\text{ ksi}$

$\phi P_n = \phi F_{cr} A_g$

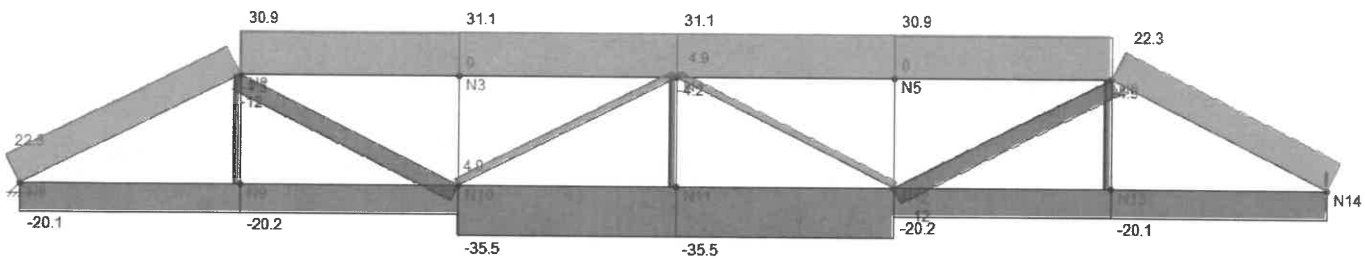
$\phi P_n = 0.9\,(24.52\text{ ksi})\,2.59\text{ in}^2$

$\phi P_n = 57.16\text{ k}$

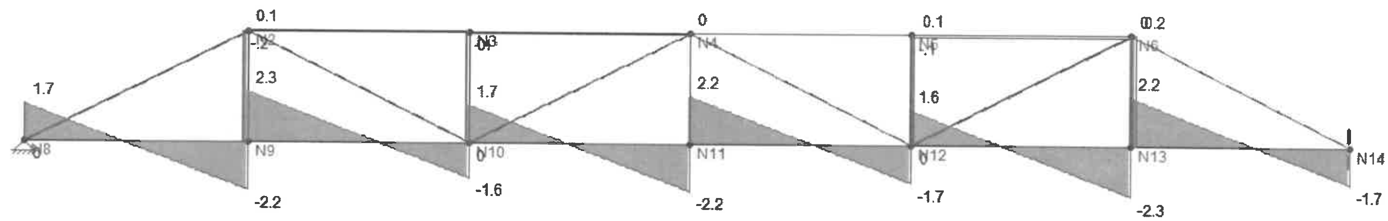
$C_{max} = 31.1^k < \phi P_n$ OK

RESULTS FOR LRFD 1.2D+1.6L

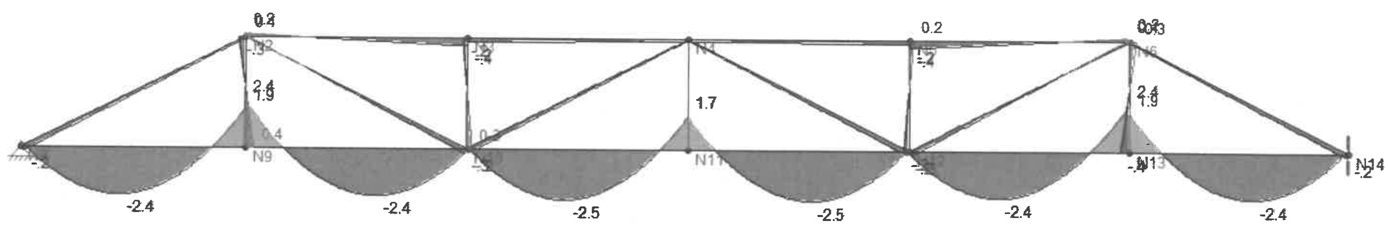
Axial



Shear



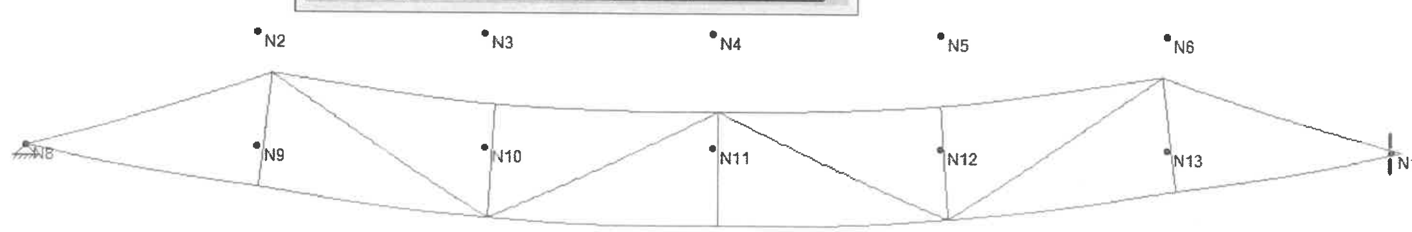
Moment



Deflection

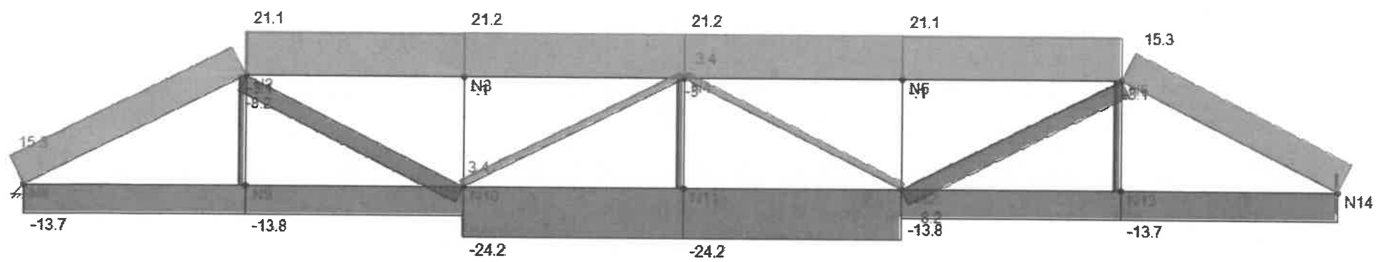
Joint Deflections (By Combination)

	L...	Joint Label	X [in]	Y [in]	Rotation [rad]
1	3	N2	.144	-.372	-3.365e-03
2	3	N3	.098	-.649	-1.863e-03
3	3	N4	.052	-.716	0
4	3	N5	.006	-.649	1.863e-03
5	3	N6	-.04	-.372	3.365e-03
6	3	N8	0	0	-5.586e-03
7	3	N9	.014	-.375	-3.793e-03
8	3	N10	.028	-.649	-2.079e-03
9	3	N11	.052	-.72	0
10	3	N12	.077	-.649	2.079e-03
11	3	N13	.091	-.375	3.793e-03
12	3	N14	.105	0	5.586e-03

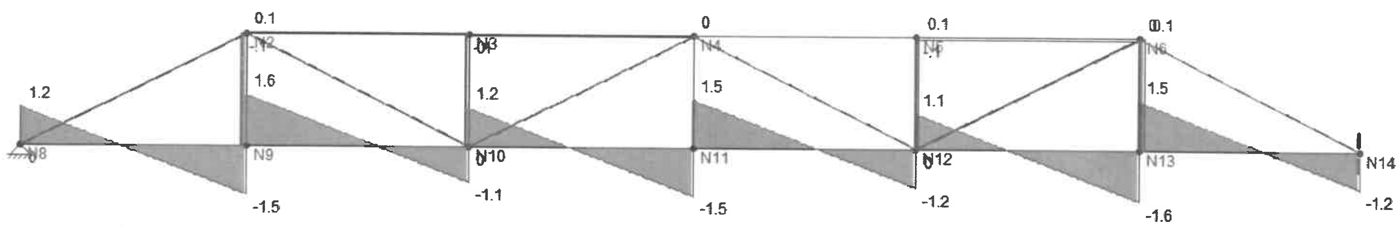


RESULTS FOR ASD D+L LOAD CASE

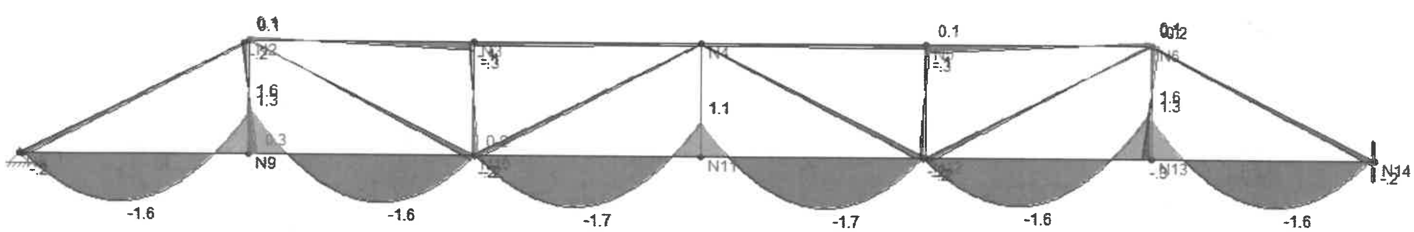
Axial



Shear



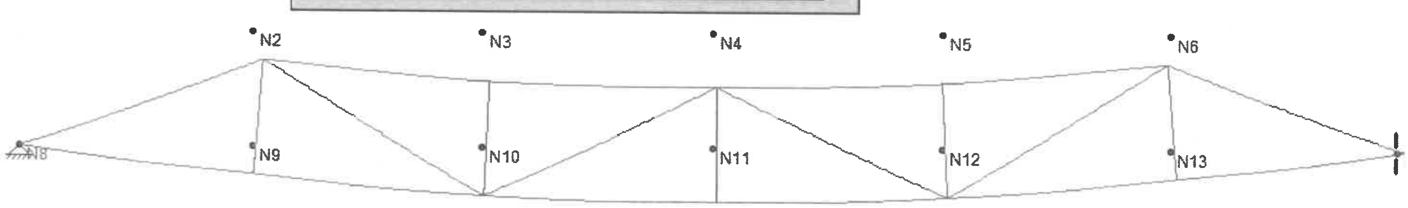
Moment



Deflection

Joint Deflections (By Combination)

	L...	Joint Label	X [in]	Y [in]	Rotation [rad]
1	1	N2	.099	-.254	-2.3e-03
2	1	N3	.067	-.443	-1.275e-03
3	1	N4	.036	-.489	0
4	1	N5	.004	-.443	1.275e-03
5	1	N6	-.027	-.254	2.3e-03
6	1	N8	0	0	-3.818e-03
7	1	N9	.009	-.256	-2.591e-03
8	1	N10	.019	-.444	-1.421e-03
9	1	N11	.036	-.492	0
10	1	N12	.053	-.444	1.421e-03
11	1	N13	.062	-.256	2.591e-03
12	1	N14	.071	0	3.818e-03



FREQUENCY

$$f_n = 0.18\sqrt{\frac{g}{\Delta}}$$ (AISC Ref. Eqn 3.3)

$g = 386\ in/s^2$

$\Delta = 0.201"$ (D+0.1L LOAD CASE IN RISA MODEL)

$$f_n = 0.18\sqrt{\frac{386^{\#}/s^2}{0.201"}}$$

$$f_n = 7.89\ Hz$$

ACCEPTABLE IF PEAK ACCEL., a_p IS < a_o

$$\frac{a_p}{g} = \frac{P_o \exp(-0.35 f_n)}{\beta \cdot W} < \frac{a_o}{g}$$

$P_o = 92^{\#}$

β = DAMP. ≈ $0.01 < \beta < 0.02$

W = D + 10% L ~~= (130 PLF + 0.1(250 PLF)) × 42'~~

= [(130 PLF + 0.1(250 PLF)) + 30.6 PSF (2.5')] 42

W = 9723#

$$\frac{a_p}{g} = \frac{92 \exp(-0.35 \cdot 7.89\ Hz)}{0.015 \cdot 9723^{\#}}$$

$$\frac{a_p}{g} = 0.0398 \longrightarrow 3.98\%\ g$$

RECOMMENDED: $\frac{a_o}{g} = 5\%\ g$

$\frac{a_p}{g} < \frac{a_o}{g}$ ∴ <u>OKAY</u>

RISA DYNAMIC ANALYSIS

Modes: 2

Damping Ratio: zeta=2%

Combination Method: CQC

Run D+0.1L Load Case

FREQUENCIES

Frequencies and Participation

	Mode	Freque...	Period ...	SX Par...	SY Par...
1	1	8.624	.116	1.04	76.107
2	2	25.455	.039	4.696	.031
3	Totals:			5.735	76.138

MODE SHAPES

Mode Shape 1 Period .116

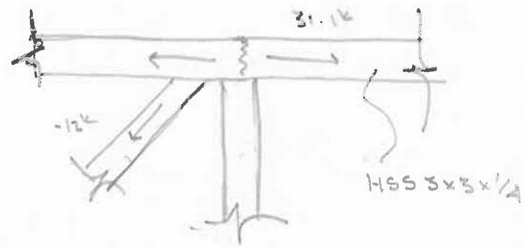
	Joint	X	Y	Rotation
1	N2	2.121	-5.332	-5.056e-02
2	N3	1.454	-9.514	-2.803e-02
3	N4	.784	-10.583	1.51e-04
4	N5	.115	-9.491	2.828e-02
5	N6	-.551	-5.291	5.055e-02
6	N8	0	0	-6.625e-02
7	N9	.203	-5.361	-5.87e-02
8	N10	.408	-9.515	-3.164e-02
9	N11	.791	-10.639	1.309e-04
10	N12	1.171	-9.492	3.195e-02
11	N13	1.365	-5.32	5.859e-02
12	N14	1.55	0	6.558e-02

WELD CALCULATIONS

ELECTRODE STRENGTH: E70xx ELECTRODE

MAX FORCE = 31.1^k (Factored)

(SEE RISA ANALYSIS)



$f_w = \frac{F_{max\,T}}{A}$

$f_w = \phi(.60)(70\text{ ksi})$

$= 0.75(.60)(70\text{ ksi})$

$f_w = 31.5$ ksi

$F_{max} = 31.1^k$ (COMP → TREAT AS T IS CONSERVATIVE)

$A = 2\text{ sides} \times 3"\text{ long} \times t = 6t$

SOLVE FOR WELD THICKNESS

$31.5\text{ ksi} = \frac{31.1^k}{6t}$

$189t = 31.1^k$

$t = 0.165" < 3/16"$

> 3/16" FILLET WELD ON BOTH SIDES IS ADEQUATE

CHECK HSS 6x6x1/4

$F_{max} = 35.5^k$ (TENSION)

$A = 2 \times 6" \times t = 12t$

$31.5\text{ ksi} = \frac{35.5^k}{12t}$

$t = 0.0939 < 3/16"$ <u>OK</u>

• ASD L.C. — IBC 1605.3

IBC TABLE 1806.2: PRESUMPTIVE LOAD-BEARING VALUES

CONSERVATIVELY USE SOIL TYPE 5 – Clay/Silt

σ_{all} = 1,500 PSF

SIZING FOUNDATION

$w_{service\ loads}$ = 380 PLF (PAGE 2)

$R = \frac{wl}{2} = \frac{380\ PLF \times 42'}{2}$

R = 7980#

$A_{REQ} = \frac{R}{\sigma_{all}} = \frac{7980\#}{1500\ PSF}$

A_{REQ} = 5.32 SF

→ assume/take 1' DEEP SHALLOW FND.

B = 2.5'

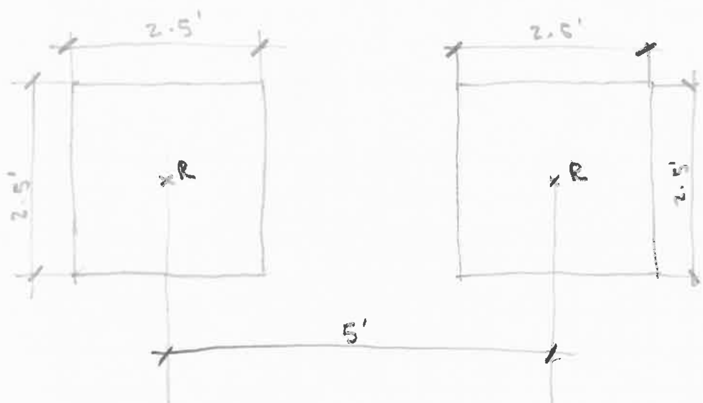


TABLE 1806.2
PRESUMPTIVE LOAD-BEARING VALUES

CLASS OF MATERIALS	VERTICAL FOUNDATION PRESSURE (psf)	LATERAL BEARING PRESSURE (psf/ft below natural grade)	LATERAL SLIDING RESISTANCE	
			Coefficient of friction[a]	Cohesion (psf)[b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500	100	—	130

For SI: 1 pound per square foot = 0.0479kPa, 1 pound per square foot per foot = 0.157 kPa/m.

a. Coefficient to be multiplied by the dead load.

b. Cohesion value to be multiplied by the contact area, as limited by Section 1806.3.2