Precision Structural Engineering, Inc.

STRUCTURAL ENGINEERING CALCULATIONS

PROJECT: Stainless Cable & Railing

PROJECT LOCATION: Washington & California

PSE PROJECT NUMBER: Stainless Cable & Railing
216-2 Railing

DATE: January 16, 2017

BY: Nabil Taha, Ph.D., P.E.

1-16-17

NABIL M. TAHA
STATE OF WASHINGTON
41133
REGISTERED
PROFESSIONAL ENGINEER
EXPIRES 7-26-17

1-16-17

REGISTERED PROFESSIONAL ENGINEER
NABIL M. TAHA
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EXP. 12-31-18
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PROJECT NO. Stainless Cable 216-2 SHEET ____ OF ____

PROJECT NAME ____ DESIGNED BY AF DATE ____

SUBJECT Conclusion CHECKED BY ____ DATE ____

Conclusion

1- post : 316 SS , tube 2" * 2" * 0.118"

2- Base plate : 316 SS , minimum size is

[4.0" * 4.0" * 0.35"]

3- Mini. Anchor bolt size as follows:

- 3/8" ϕ w/min 4" Embed, Red head ITW wedge
- 3/8" ϕ w/min 4" Embed, Red head LDT (5LDT-3816)
- 3/8" ϕ lag screw w/min 8" Embed. on wood
- 3/8" ϕ thru-bolt w/min 6" wood blocking underneath

4- 1/8" or 3/16" ϕ Cables.

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References:

1- Literature:

a. 2015 International Building Code (IBC)

b. 2016 California Building Code based on 2015 International Building Code (IBC)

2- Software:

a. RISA 3D Version 15.0.0
RISA Technologies,
26212 Dimension Dr. Suite 200

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Design Criteria:

1- Location: Washington & California

2- Live Load on Handrail & guards:

a. Uniform Distributed load 50 p/f
b. Single Concentrated load 200 lbs

**Other criteria assumed as stated in design calculations.

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GUARD RAIL ANALYSIS & DESIGN:

Pages 1,000 - 1,999

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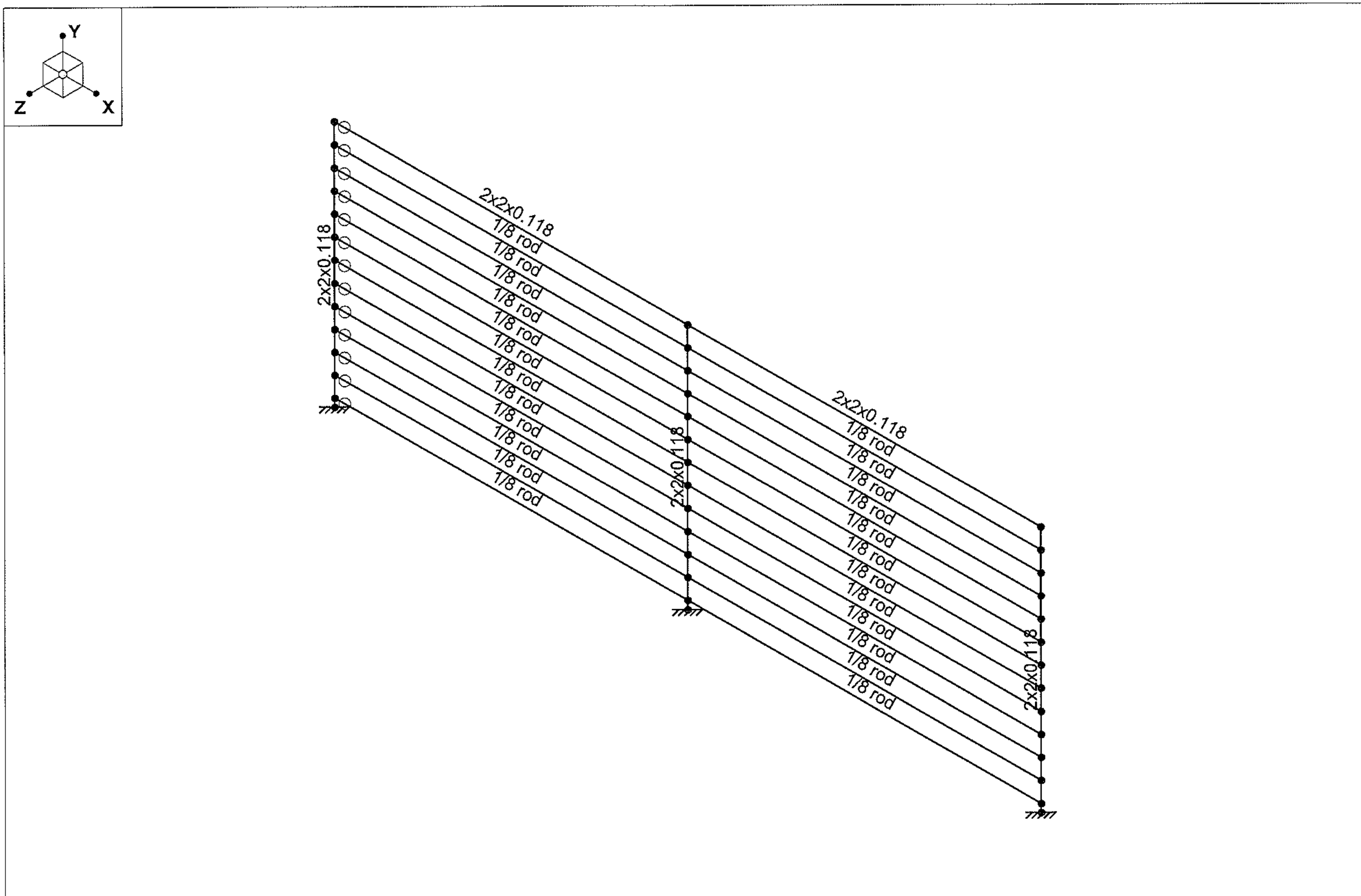

1000

Envelope Only Solution

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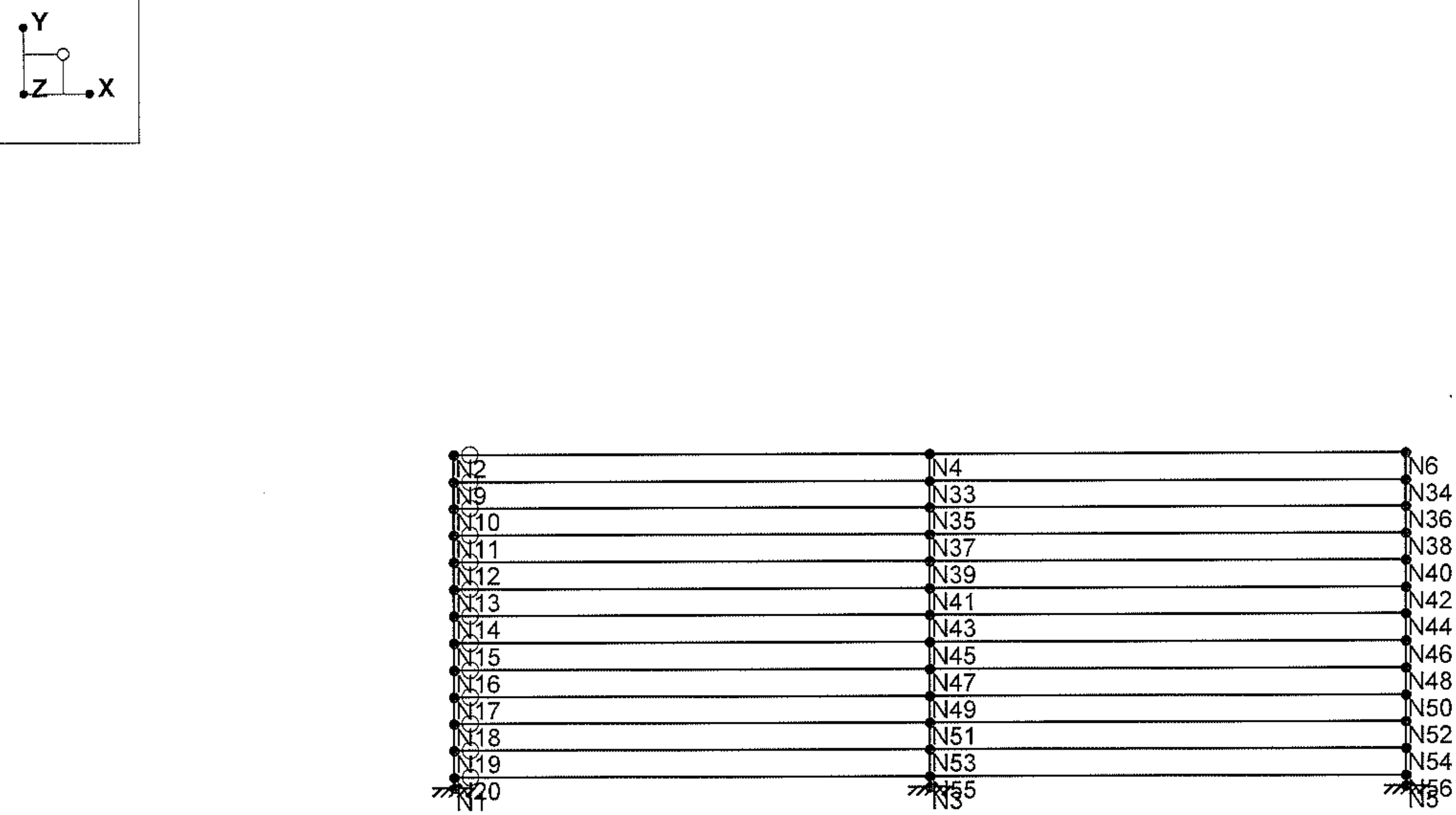
AF		Dec 5, 2016 at 4:41 PM
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES-2x2...



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Envelope Only Solution

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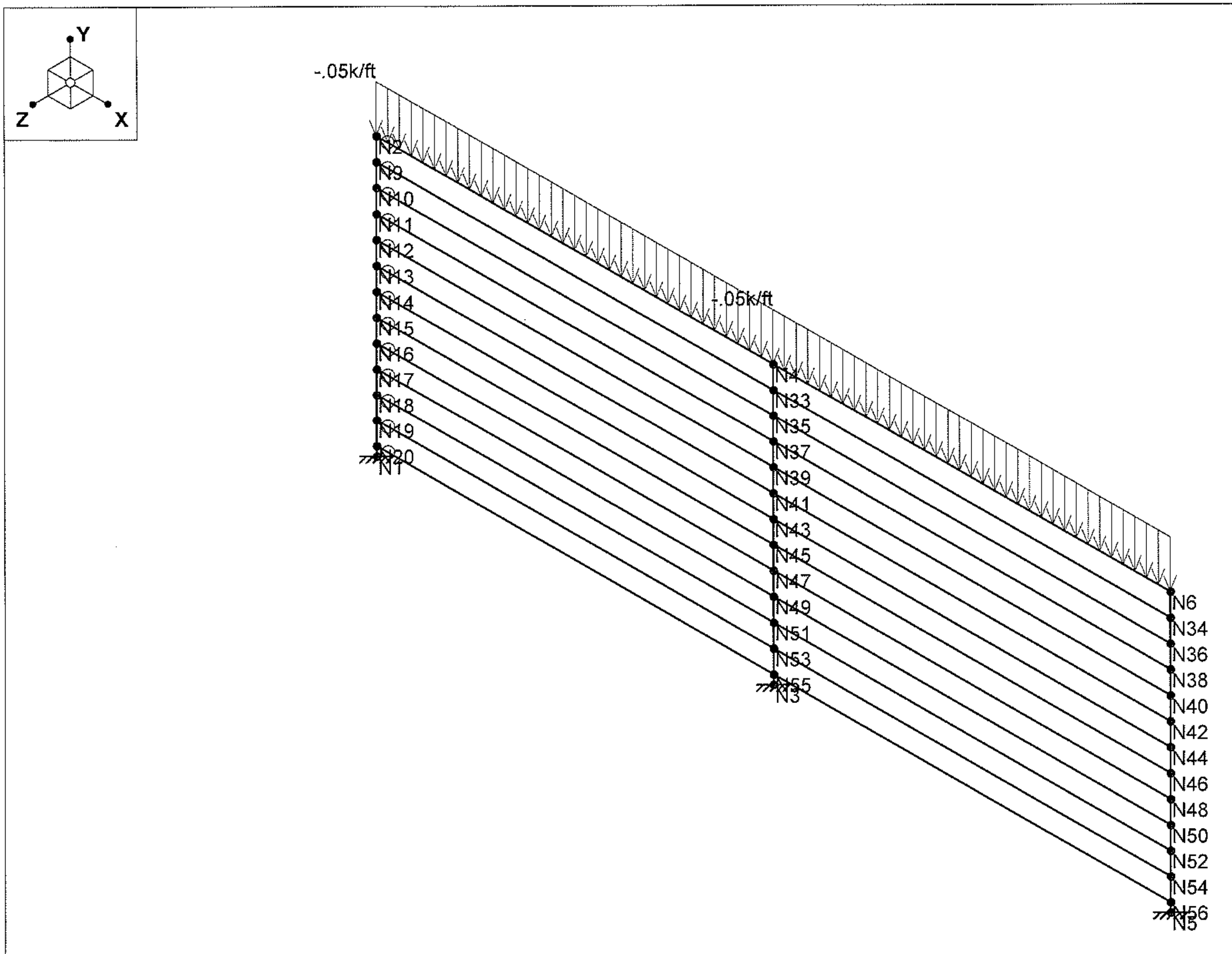
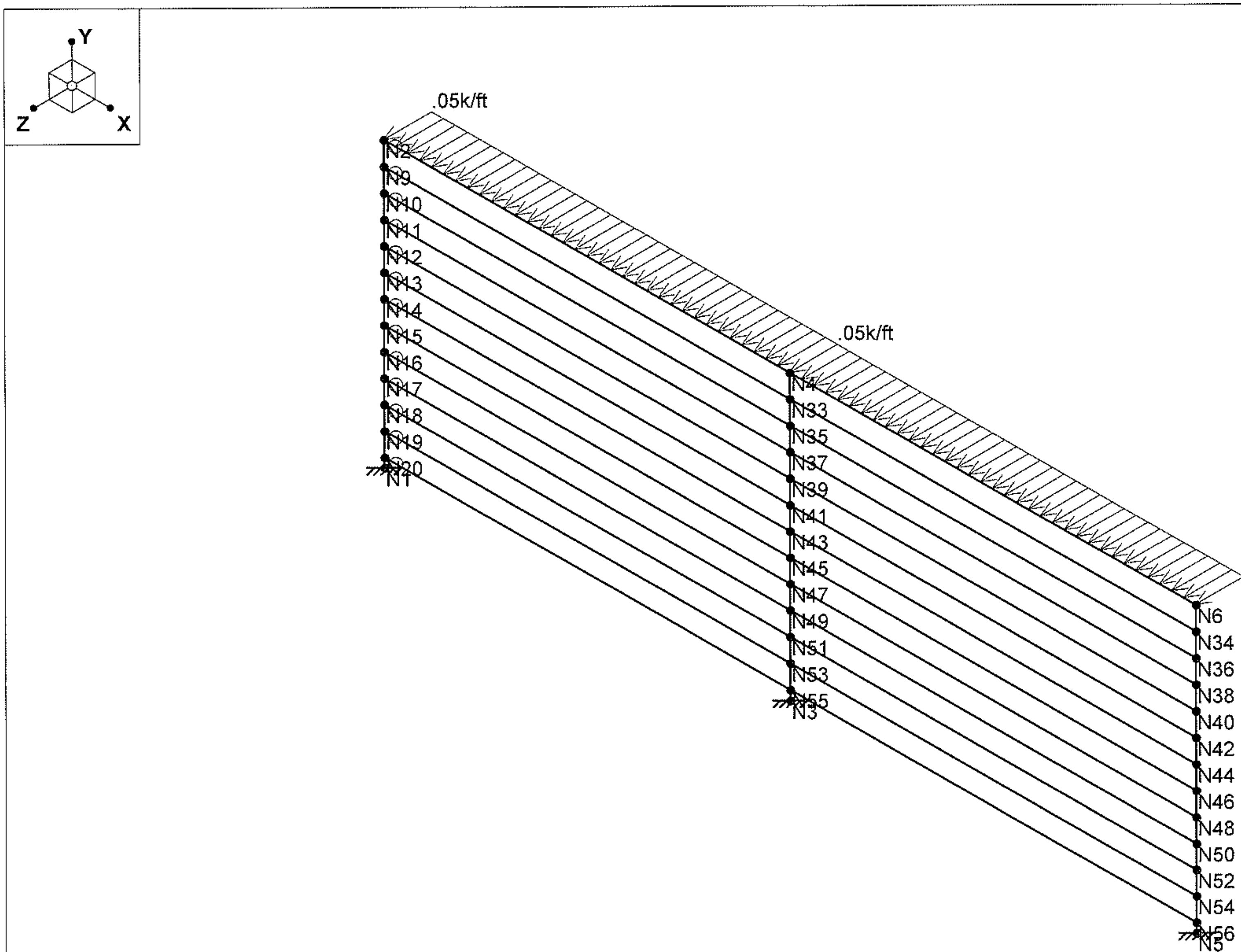
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES.r3d



Loads: BLC 1, Distributed load-y at the top of
Envelope Only Solution

PSEI	GUARD RAIL SYSTEM WITH CABLES	SK - 6
AF		Nov 30, 2016 at 9:58 AM
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES.r3d

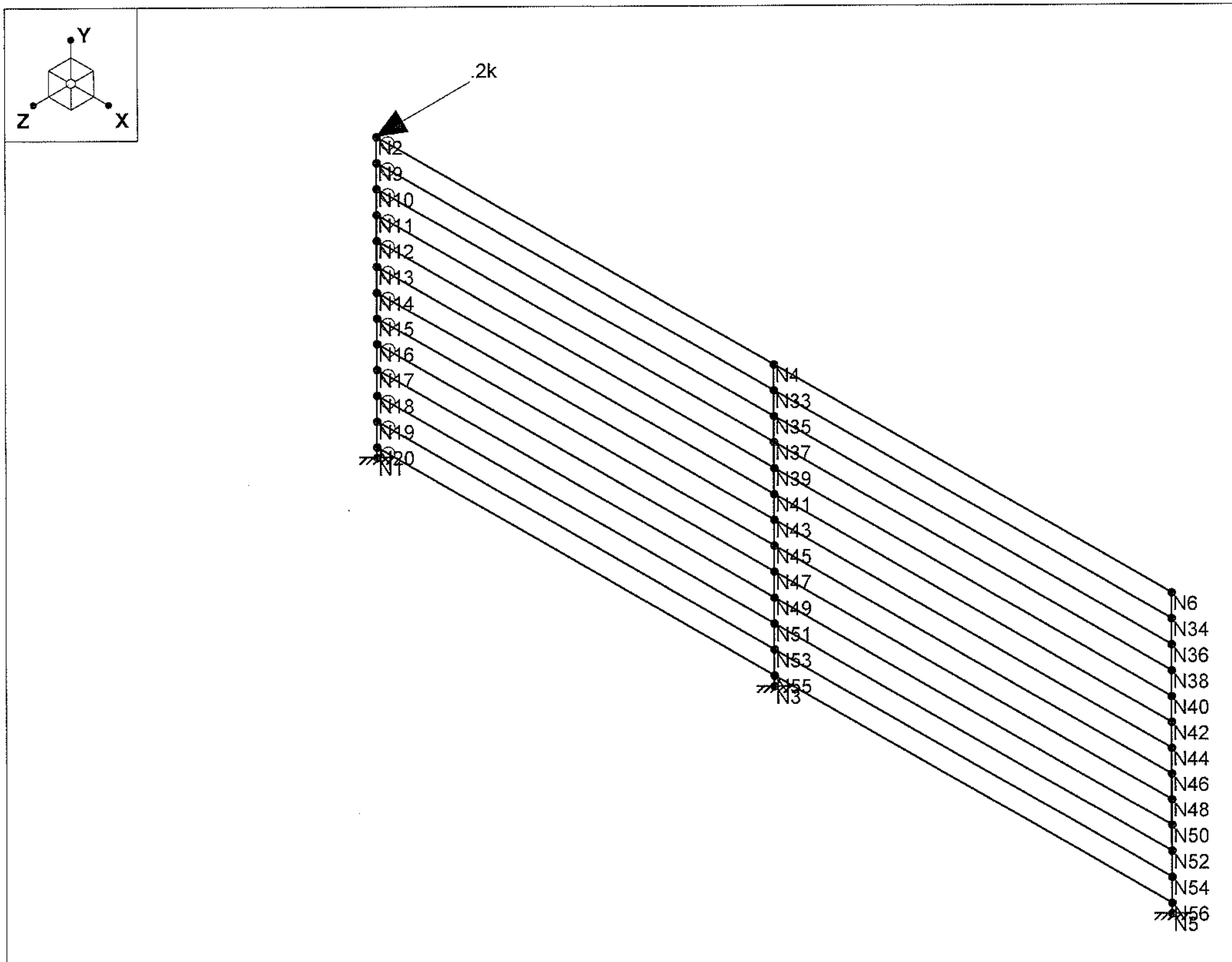
1002



Loads: BLC 2, Distributed load-X at the side o
Envelope Only Solution

PSEI	GUARD RAIL SYSTEM WITH CABLES	SK - 3
AF		Nov 30, 2016 at 9:57 AM
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES.r3d

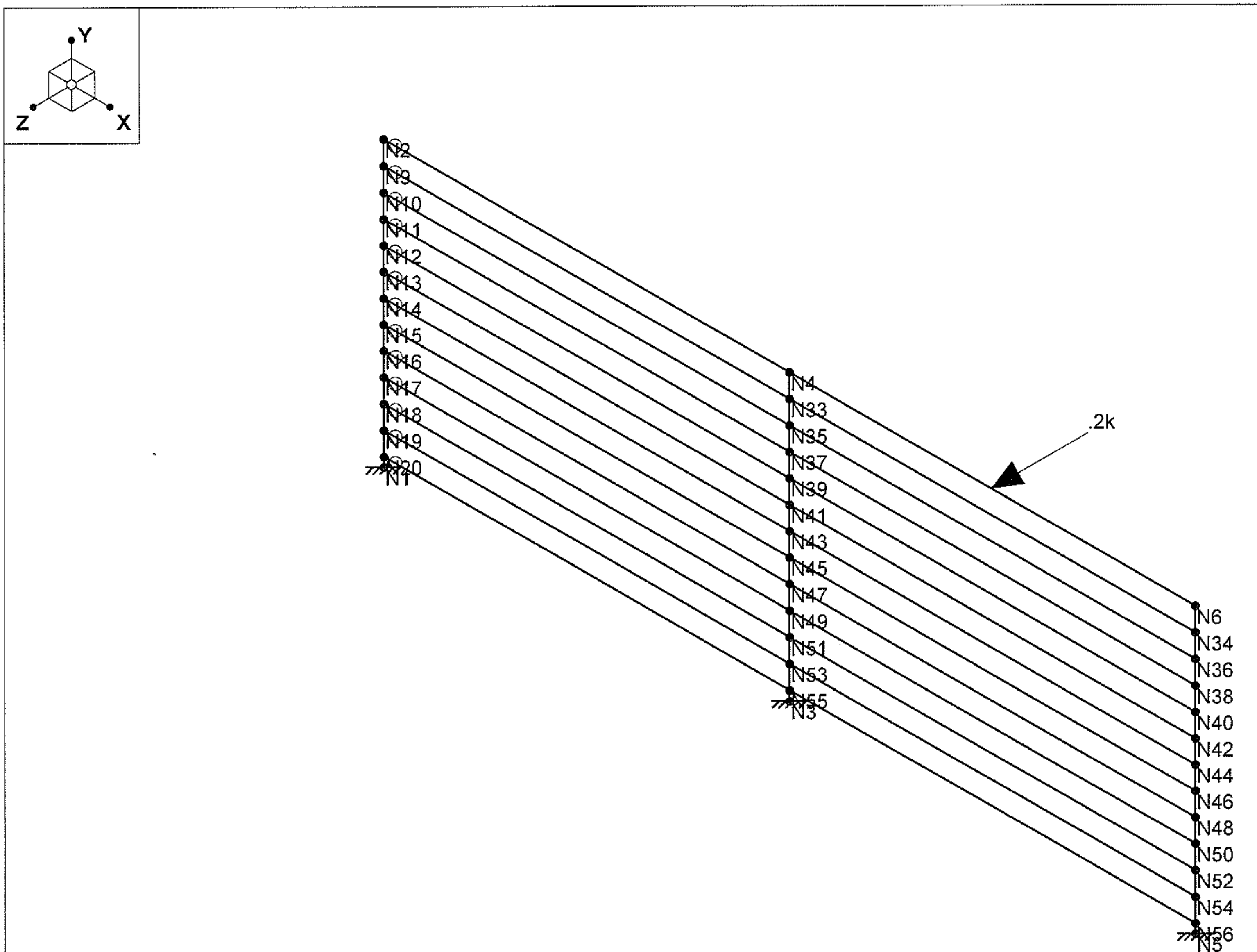
1003



Loads: BLC 3, Point load applied at the corner
Envelope Only Solution

PSEI	GUARD RAIL SYSTEM WITH CABLES	SK - 4
AF		Nov 30, 2016 at 9:57 AM
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES.r3d

1004



1005

Loads: BLC 4, Point load applied at the middle
Envelope Only Solution

PSEI	GUARD RAIL SYSTEM WITH CABLES	SK - 5
AF		Nov 30, 2016 at 9:57 AM
Stainless Cable & Railing 216-2		5' SPACING GUARD RAIL WITH CABLES.r3d

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1...	Density[k/ft^3]	Yield[ksi]	Ry	Fu[ksi]	Rt
1	A36 Gr.36	29000	11154	.3	.65	.49	36	1.5	58	1.2
2	A572 Gr.50	29000	11154	.3	.65	.49	50	1.1	65	1.1
3	A992	29000	11154	.3	.65	.49	50	1.1	65	1.1
4	A500 Gr.42	29000	11154	.3	.65	.49	42	1.4	58	1.3
5	A500 Gr.46	29000	11154	.3	.65	.49	46	1.4	58	1.3
6	316SS	28000	10732	.3	.65	.501	30	1.4	75	1.2

Aluminum Properties

	Label	E [ksi]	G [ksi]	Nu	Therm ...	Density...	Table B.4	kt	Ftu[ksi]	Fty[ksi]	Fcy[ksi]	Fsu[ksi]	Ct
1	3003-H14	10100	3787.5	.33	1.3	.173	Table B.4-1	1	19	16	13	12	141
2	6061-T6	10100	3787.5	.33	1.3	.173	Table B.4-2	1	38	35	35	24	141
3	6063-T5	10100	3787.5	.33	1.3	.173	Table B.4-2	1	22	16	16	13	141
4	6063-T6	10100	3787.5	.33	1.3	.173	Table B.4-2	1	30	25	25	19	141
5	5052-H34	10200	3787.5	.33	1.3	.173	Table B.4-1	1	34	26	24	20	141
6	6061-T6 W	10100	3787.5	.33	1.3	.173	Table B.4-1	1	24	15	15	15	141

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design ...	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	CABLE	1/8 rod	HBrace	None	A36 Gr.36	Typical	.012	1.2e-5	1.2e-5	2.4e-5
2	Post	2x2x0.118	Column	RECT	316SS	Typical	.888	.526	.526	.787

Aluminum Section Sets

	Label	Shape	Type	Design List	Material	Design Ru...	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	POST-1	2.375x2.375x.100	Column	A-N Wide Flange	6063-T6	Typical	.91	.786	.786	1.177
2	TOP RAIL	3.15x1.575x0.078	Beam	Rectangular Tub...	6063-T6	Typical	.713	.313	.929	.722
3	BOTTOM RAIL	.735x2.125x.07	Beam	Rectangular Tub...	6063-T6	Typical	.381	.035	.2	.096

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
1	N1	0	0	0	0	
2	N2	0	3.5	0	0	
3	N3	5	0	0	0	
4	N4	5	3.5	0	0	
5	N5	10	0	0	0	
6	N6	10	3.5	0	0	
7	N9	0	3.217708	0	0	
8	N10	0	2.935417	0	0	
9	N11	0	2.653125	0	0	
10	N12	0	2.370833	0	0	
11	N13	0	2.088542	0	0	
12	N14	0	1.80625	0	0	
13	N15	0	1.523958	0	0	
14	N16	0	1.241667	0	0	
15	N17	0	0.959375	0	0	
16	N18	0	0.677083	0	0	
17	N19	0	0.394792	0	0	
18	N20	0	0.1125	0	0	
19	N33	5	3.217708	0	0	
20	N34	10	3.217708	0	0	
21	N35	5	2.935417	0	0	

Joint Coordinates and Temperatures (Continued)

	Label	X [ft]	Y [ft]	Z [ft]	Temp [F]	Detach From Diap...
22	N36	10	2.935417	0	0	
23	N37	5	2.653125	0	0	
24	N38	10	2.653125	0	0	
25	N39	5	2.370833	0	0	
26	N40	10	2.370833	0	0	
27	N41	5	2.088542	0	0	
28	N42	10	2.088542	0	0	
29	N43	5	1.80625	0	0	
30	N44	10	1.80625	0	0	
31	N45	5	1.523958	0	0	
32	N46	10	1.523958	0	0	
33	N47	5	1.241667	0	0	
34	N48	10	1.241667	0	0	
35	N49	5	0.959375	0	0	
36	N50	10	0.959375	0	0	
37	N51	5	0.677083	0	0	
38	N52	10	0.677083	0	0	
39	N53	5	0.394792	0	0	
40	N54	10	0.394792	0	0	
41	N55	5	0.1125	0	0	
42	N56	10	0.1125	0	0	

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Z [k/in]	X Rot.[k-ft/rad]	Y Rot.[k-ft/rad]	Z Rot.[k-ft/rad]
1	N1	Reaction	Reaction	Reaction	Reaction	Reaction	Reaction
2	N3	Reaction	Reaction	Reaction	Reaction	Reaction	Reaction
3	N5	Reaction	Reaction	Reaction	Reaction	Reaction	Reaction

Hot Rolled Steel Design Parameters

	Label	Shape	Length[ft]	Lbyy[ft]	Lbzz[ft]	Lcomp top[ft]	Lcomp bot[ft]	L-torqu...	Kyy	Kzz	Cb	Function
1	M1	Post	3.5			Lbyy						Lateral
2	M2	Post	5			Lbyy						Lateral
3	M3	Post	3.5			Lbyy						Lateral
4	M4	Post	5			Lbyy						Lateral
5	M5	Post	3.5			Lbyy						Lateral
6	M8	CABLE	5			Lbyy						Lateral
7	M9	CABLE	5			Lbyy						Lateral
8	M10	CABLE	5			Lbyy						Lateral
9	M11	CABLE	5			Lbyy						Lateral
10	M12	CABLE	5			Lbyy						Lateral
11	M13	CABLE	5			Lbyy						Lateral
12	M14	CABLE	5			Lbyy						Lateral
13	M15	CABLE	5			Lbyy						Lateral
14	M16	CABLE	5			Lbyy						Lateral
15	M17	CABLE	5			Lbyy						Lateral
16	M18	CABLE	5			Lbyy						Lateral
17	M19	CABLE	5			Lbyy						Lateral
18	M32	CABLE	5			Lbyy						Lateral
19	M33	CABLE	5			Lbyy						Lateral
20	M34	CABLE	5			Lbyy						Lateral
21	M35	CABLE	5			Lbyy						Lateral
22	M36	CABLE	5			Lbyy						Lateral
23	M37	CABLE	5			Lbyy						Lateral
24	M38	CABLE	5			Lbyy						Lateral

Hot Rolled Steel Design Parameters (Continued)

	Label	Shape	Length[ft]	Lbyy[ft]	Lbzz[ft]	Lcomp top[ft]	Lcomp bot[ft]	L-torqu...	Kyy	Kzz	Cb	Function
25	M39	CABLE	5			Lbyy						Lateral
26	M40	CABLE	5			Lbyy						Lateral
27	M41	CABLE	5			Lbyy						Lateral
28	M42	CABLE	5			Lbyy						Lateral
29	M43	CABLE	5			Lbyy						Lateral

Aluminum Design Parameters

Label	Shape	Length[ft]	Lbyy[ft]	Lbzz[ft]	Lcomp top[ft]	Lcomp bot[ft]	L-torqu...	Kyy	Kzz	Cb	Function
No Data to Print ...											

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu...	Area(M...	Surface...
1	Distributed load-y at the top of	None		-1				2		
2	Distributed load-X at the side o	None		-1				2		
3	Point load applied at the corner	None		-1		1				
4	Point load applied at the middle	None		-1			1			

Load Combinations

	Description	Solve	PDelta	S...	BLC	Fact...	BLC	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...	B...	Fa...
1	Distributed load-y a...	Yes	Y		1	1																
2	Distributed load-X ...	Yes	Y		2	1																
3	Point load applied ...	Yes	Y		3	1																
4	Point load applied ...	Yes	Y		4	1																

Load Combination Design

	Description	ASIF	CD	ABIF	Service	Hot Rolled	Cold For...	Wood	Concrete	Masonry	Footings	Aluminum	Connecti...
1	Distributed l...					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Distributed l...					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Point load a...					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	Point load a...					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Joint Loads and Enforced Displacements (BLC 3 : Point load applied at the corner)

	Joint Label	L,D,M	Direction	Magnitude[(k,k-ft), (in,rad), (k*s^2/ft...
1	N2	L	Z	.2

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
1	N1	max	.001	1	.115	1	.002	4	0	1	0	1	-.001	2
2		min	0	2	.018	2	-.184	3	-.566	3	0	1	-.015	1
3	N3	max	0	2	.331	1	0	1	0	1	.043	4	-.001	2
4		min	-.001	1	.032	2	-.247	2	-.782	2	-.037	3	-.013	1
5	N5	max	0	1	.123	1	.006	3	0	1	0	1	0	2
6		min	0	2	.018	3	-.133	2	-.504	2	-.064	2	-.01	1
7	Totals:	max	0	1	.568	1	0	1						
8		min	0	3	.068	3	-.5	2						

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
1	M1	1	max	.115	1	0	2	.002	4	0	1	.566	3	-.001	2
2			min	.018	2	-.001	1	-.184	3	0	1	0	1	-.015	1
3		2	max	.112	1	0	2	.002	4	0	1	.405	3	0	2
4			min	.015	2	-.002	1	-.184	3	0	1	0	1	-.014	1
5		3	max	.109	1	0	2	.002	4	0	1	.256	2	0	2
6			min	.012	2	-.004	1	-.184	3	0	1	0	1	-.011	1
7		4	max	.106	1	0	2	.002	4	0	1	.151	2	0	3
8			min	.009	2	-.007	1	-.184	3	0	1	0	1	-.006	1
9		5	max	.103	1	0	3	.002	4	0	1	.049	4	0	1
10			min	.006	2	-.007	1	-.184	3	0	1	-.079	3	0	1
11	M2	1	max	.007	1	.016	3	-.006	2	.079	3	0	1	0	1
12			min	0	3	-.12	2	-.103	1	-.049	4	0	1	0	1
13		2	max	.007	1	.016	3	-.002	2	.079	3	-.005	2	.111	2
14			min	0	3	-.057	2	-.037	1	-.049	4	-.088	1	-.02	3
15		3	max	.007	1	.016	3	.029	1	.079	3	-.005	2	.143	2
16			min	0	3	0	1	.002	3	-.049	4	-.093	1	-.039	3
17		4	max	.007	1	.068	2	.096	1	.079	3	0	2	.097	2
18			min	0	3	0	1	.006	3	-.049	4	-.014	1	-.059	3
19		5	max	.007	1	.13	2	.162	1	.079	3	.147	1	0	1
20			min	0	3	0	1	.009	3	-.049	4	.008	3	-.079	3
21	M3	1	max	.317	1	.028	1	0	1	.043	4	.085	2	.013	1
22			min	.019	2	.002	2	-.248	2	-.037	3	-.047	3	.001	2
23		2	max	.32	1	.012	1	0	1	.043	4	0	1	0	3
24			min	.022	2	0	2	-.248	2	-.037	3	-.132	2	-.007	1
25		3	max	.324	1	.001	1	0	1	.043	4	0	1	0	2
26			min	.025	2	0	2	-.248	2	-.037	3	-.349	2	-.014	1
27		4	max	.327	1	0	3	0	1	.043	4	0	1	0	2
28			min	.029	2	-.001	1	-.248	2	-.037	3	-.565	2	-.014	1
29		5	max	.331	1	0	2	0	1	.043	4	0	1	-.001	2
30			min	.032	2	-.001	1	-.247	2	-.037	3	-.782	2	-.013	1
31	M4	1	max	.035	1	0	1	-.009	2	.039	2	.16	1	0	1
32			min	.002	3	-.117	2	-.155	1	-.009	4	.009	2	-.052	4
33		2	max	.035	1	0	1	-.005	2	.039	2	.008	1	.083	2
34			min	.002	3	-.103	4	-.089	1	-.009	4	0	2	-.034	3
35		3	max	.035	1	.097	4	-.001	2	.039	2	-.004	2	.205	4
36			min	.002	3	-.006	3	-.022	1	-.009	4	-.062	1	-.026	3
37		4	max	.035	1	.097	4	.044	1	.039	2	-.003	2	.083	4
38			min	.002	3	-.006	3	.002	3	-.009	4	-.048	1	-.018	3
39		5	max	.035	1	.133	2	.111	1	.039	2	.049	1	0	1
40			min	.002	3	-.006	3	.006	3	-.009	4	.003	3	-.064	2
41	M5	1	max	.111	1	-.002	3	.006	3	0	1	.009	4	-.003	3
42			min	.006	3	-.035	1	-.133	2	-.064	2	-.039	2	-.049	1
43		2	max	.114	1	-.001	3	.006	3	0	1	0	1	-.001	3
44			min	.009	3	-.019	1	-.133	2	-.064	2	-.155	2	-.023	1
45		3	max	.117	1	0	3	.006	3	0	1	0	1	0	2
46			min	.012	3	-.005	1	-.133	2	-.064	2	-.272	2	-.012	1
47		4	max	.12	1	0	3	.006	3	0	1	0	1	0	2
48			min	.015	3	0	1	-.133	2	-.064	2	-.388	2	-.01	1
49		5	max	.123	1	0	1	.006	3	0	1	0	1	0	2
50			min	.018	3	0	2	-.133	2	-.064	2	-.504	2	-.01	1
51	M8	1	max	0	1	0	1	0	3	0	3	0	1	0	1
52			min	0	2	0	2	0	2	0	4	0	1	0	1
53		2	max	0	1	0	1	0	3	0	3	0	3	0	2
54			min	0	2	0	2	0	2	0	4	0	2	0	1
55		3	max	0	1	0	1	0	3	0	3	0	3	0	2
56			min	0	2	0	2	0	2	0	4	0	2	0	1

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
57		4	max	0	1	0	1	0	3	0	3	0	3	0	2
58			min	0	2	0	2	0	2	0	4	0	2	0	1
59		5	max	0	1	0	1	0	3	0	3	0	3	0	2
60			min	0	2	0	2	0	2	0	4	0	2	0	1
61	M9	1	max	0	3	0	1	0	3	0	3	0	1	0	1
62			min	0	1	0	2	0	2	0	2	0	1	0	1
63		2	max	0	3	0	1	0	3	0	3	0	3	0	2
64			min	0	1	0	2	0	2	0	2	0	2	0	1
65		3	max	0	3	0	1	0	3	0	3	0	3	0	2
66			min	0	1	0	2	0	2	0	2	0	2	0	1
67		4	max	0	3	0	1	0	3	0	3	0	3	0	2
68			min	0	1	0	2	0	2	0	2	0	2	0	1
69		5	max	0	3	0	1	0	3	0	3	0	3	0	2
70			min	0	1	0	2	0	2	0	2	0	2	0	1
71	M10	1	max	0	3	0	1	0	3	0	3	0	1	0	1
72			min	0	1	0	2	0	2	0	2	0	1	0	1
73		2	max	0	3	0	1	0	3	0	3	0	3	0	2
74			min	0	1	0	2	0	2	0	2	0	2	0	1
75		3	max	0	3	0	1	0	3	0	3	0	3	0	2
76			min	0	1	0	2	0	2	0	2	0	2	0	1
77		4	max	0	3	0	1	0	3	0	3	0	3	0	2
78			min	0	1	0	2	0	2	0	2	0	2	0	1
79		5	max	0	3	0	1	0	3	0	3	0	3	0	2
80			min	0	1	0	2	0	2	0	2	0	2	0	1
81	M11	1	max	0	3	0	1	0	3	0	3	0	1	0	1
82			min	0	1	0	2	0	2	0	2	0	1	0	1
83		2	max	0	3	0	1	0	3	0	3	0	3	0	2
84			min	0	1	0	2	0	2	0	2	0	2	0	1
85		3	max	0	3	0	1	0	3	0	3	0	3	0	2
86			min	0	1	0	2	0	2	0	2	0	2	0	1
87		4	max	0	3	0	1	0	3	0	3	0	3	0	2
88			min	0	1	0	2	0	2	0	2	0	2	0	1
89		5	max	0	3	0	1	0	3	0	3	0	3	0	2
90			min	0	1	0	2	0	2	0	2	0	2	0	1
91	M12	1	max	0	3	0	1	0	3	0	3	0	1	0	1
92			min	0	1	0	2	0	2	0	2	0	1	0	1
93		2	max	0	3	0	1	0	3	0	3	0	3	0	2
94			min	0	1	0	2	0	2	0	2	0	2	0	1
95		3	max	0	3	0	1	0	3	0	3	0	3	0	2
96			min	0	1	0	2	0	2	0	2	0	2	0	1
97		4	max	0	3	0	1	0	3	0	3	0	3	0	2
98			min	0	1	0	2	0	2	0	2	0	2	0	1
99		5	max	0	3	0	1	0	3	0	3	0	3	0	2
100			min	0	1	0	2	0	2	0	2	0	2	0	1
101	M13	1	max	0	3	0	1	0	4	0	3	0	1	0	1
102			min	-.001	1	0	2	0	2	0	2	0	1	0	1
103		2	max	0	3	0	1	0	4	0	3	0	4	0	2
104			min	-.001	1	0	2	0	2	0	2	0	2	0	1
105		3	max	0	3	0	1	0	4	0	3	0	4	0	2
106			min	-.001	1	0	2	0	2	0	2	0	2	0	1
107		4	max	0	3	0	1	0	4	0	3	0	4	0	2
108			min	-.001	1	0	2	0	2	0	2	0	2	0	1
109		5	max	0	3	0	1	0	4	0	3	0	4	0	2
110			min	-.001	1	0	2	0	2	0	2	0	2	0	1
111	M14	1	max	0	3	0	1	0	4	0	3	0	1	0	1
112			min	0	1	0	2	0	2	0	2	0	1	0	1
113		2	max	0	3	0	1	0	4	0	3	0	4	0	2

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
114			min	0	1	0	2	0	2	0	2	0	2	0	1
115		3	max	0	3	0	1	0	4	0	3	0	4	0	2
116			min	0	1	0	2	0	2	0	2	0	2	0	1
117		4	max	0	3	0	1	0	4	0	3	0	4	0	2
118			min	0	1	0	2	0	2	0	2	0	2	0	1
119		5	max	0	3	0	1	0	4	0	3	0	4	0	2
120			min	0	1	0	2	0	2	0	2	0	2	0	1
121	M15	1	max	0	3	0	1	0	4	0	3	0	1	0	1
122			min	0	1	0	2	0	2	0	2	0	1	0	1
123		2	max	0	3	0	1	0	4	0	3	0	4	0	2
124			min	0	1	0	2	0	2	0	2	0	2	0	1
125		3	max	0	3	0	1	0	4	0	3	0	4	0	2
126			min	0	1	0	2	0	2	0	2	0	2	0	1
127		4	max	0	3	0	1	0	4	0	3	0	4	0	2
128			min	0	1	0	2	0	2	0	2	0	2	0	1
129		5	max	0	3	0	1	0	4	0	3	0	4	0	2
130			min	0	1	0	2	0	2	0	2	0	2	0	1
131	M16	1	max	0	3	0	1	0	4	0	3	0	1	0	1
132			min	0	1	0	2	0	2	0	2	0	1	0	1
133		2	max	0	3	0	1	0	4	0	3	0	4	0	2
134			min	0	1	0	2	0	2	0	2	0	2	0	1
135		3	max	0	3	0	1	0	4	0	3	0	4	0	2
136			min	0	1	0	2	0	2	0	2	0	2	0	1
137		4	max	0	3	0	1	0	4	0	3	0	4	0	2
138			min	0	1	0	2	0	2	0	2	0	2	0	1
139		5	max	0	3	0	1	0	4	0	3	0	4	0	2
140			min	0	1	0	2	0	2	0	2	0	2	0	1
141	M17	1	max	0	2	0	1	0	4	0	3	0	1	0	1
142			min	0	1	0	2	0	3	0	2	0	1	0	1
143		2	max	0	2	0	1	0	4	0	3	0	4	0	2
144			min	0	1	0	2	0	3	0	2	0	3	0	1
145		3	max	0	2	0	1	0	4	0	3	0	4	0	2
146			min	0	1	0	2	0	3	0	2	0	3	0	1
147		4	max	0	2	0	1	0	4	0	3	0	4	0	2
148			min	0	1	0	2	0	3	0	2	0	3	0	1
149		5	max	0	2	0	1	0	4	0	3	0	4	0	2
150			min	0	1	0	2	0	3	0	2	0	3	0	1
151	M18	1	max	0	2	0	1	0	4	0	3	0	1	0	1
152			min	0	1	0	2	0	3	0	2	0	1	0	1
153		2	max	0	2	0	1	0	4	0	3	0	4	0	2
154			min	0	1	0	2	0	3	0	2	0	3	0	1
155		3	max	0	2	0	1	0	4	0	3	0	4	0	2
156			min	0	1	0	2	0	3	0	2	0	3	0	1
157		4	max	0	2	0	1	0	4	0	3	0	4	0	2
158			min	0	1	0	2	0	3	0	2	0	3	0	1
159		5	max	0	2	0	1	0	4	0	3	0	4	0	2
160			min	0	1	0	2	0	3	0	2	0	3	0	1
161	M19	1	max	0	2	0	1	0	1	0	3	0	1	0	1
162			min	0	1	0	2	0	1	0	2	0	1	0	1
163		2	max	0	2	0	1	0	1	0	3	0	4	0	2
164			min	0	1	0	2	0	1	0	2	0	3	0	1
165		3	max	0	2	0	1	0	1	0	3	0	4	0	2
166			min	0	1	0	2	0	1	0	2	0	3	0	1
167		4	max	0	2	0	1	0	1	0	3	0	4	0	2
168			min	0	1	0	2	0	1	0	2	0	3	0	1
169		5	max	0	2	0	1	0	1	0	3	0	4	0	2
170			min	0	1	0	2	0	1	0	2	0	3	0	1

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
171	M32	1	max	0	2	0	1	0	2	0	2	0	3	0	1
172			min	-.004	1	0	2	0	3	0	4	0	2	0	2
173		2	max	0	2	0	1	0	2	0	2	0	3	0	1
174			min	-.004	1	0	2	0	3	0	4	0	4	0	2
175		3	max	0	2	0	1	0	2	0	2	0	3	0	2
176			min	-.004	1	0	2	0	3	0	4	0	4	0	1
177		4	max	0	2	0	1	0	2	0	2	0	3	0	2
178			min	-.004	1	0	2	0	3	0	4	0	4	0	1
179		5	max	0	2	0	1	0	2	0	2	0	3	0	2
180			min	-.004	1	0	2	0	3	0	4	0	4	0	1
181	M33	1	max	0	2	0	1	0	2	0	2	0	3	0	1
182			min	-.006	1	0	2	0	3	0	4	0	4	0	2
183		2	max	0	2	0	1	0	2	0	2	0	3	0	1
184			min	-.006	1	0	2	0	3	0	4	0	4	0	2
185		3	max	0	2	0	1	0	2	0	2	0	3	0	3
186			min	-.006	1	0	2	0	3	0	4	0	4	0	1
187		4	max	0	2	0	1	0	2	0	2	0	3	0	2
188			min	-.006	1	0	2	0	3	0	4	0	4	0	1
189		5	max	0	2	0	1	0	2	0	2	0	1	0	2
190			min	-.006	1	0	2	0	3	0	4	0	4	0	1
191	M34	1	max	0	2	0	1	0	2	0	2	0	3	0	1
192			min	-.006	1	0	2	0	3	0	4	0	4	0	2
193		2	max	0	2	0	1	0	2	0	2	0	3	0	1
194			min	-.006	1	0	2	0	3	0	4	0	4	0	2
195		3	max	0	2	0	1	0	2	0	2	0	3	0	1
196			min	-.006	1	0	2	0	3	0	4	0	4	0	2
197		4	max	0	2	0	1	0	2	0	2	0	3	0	2
198			min	-.006	1	0	2	0	3	0	4	0	4	0	1
199		5	max	0	2	0	1	0	2	0	2	0	1	0	2
200			min	-.006	1	0	2	0	3	0	4	0	4	0	1
201	M35	1	max	0	3	0	1	0	1	0	2	0	3	0	1
202			min	-.006	1	0	2	0	3	0	4	0	4	0	2
203		2	max	0	3	0	1	0	1	0	2	0	3	0	1
204			min	-.006	1	0	2	0	3	0	4	0	4	0	2
205		3	max	0	3	0	1	0	1	0	2	0	3	0	1
206			min	-.006	1	0	2	0	3	0	4	0	4	0	2
207		4	max	0	3	0	1	0	1	0	2	0	3	0	2
208			min	-.006	1	0	2	0	3	0	4	0	4	0	1
209		5	max	0	3	0	1	0	1	0	2	0	1	0	2
210			min	-.006	1	0	2	0	3	0	4	0	4	0	1
211	M36	1	max	0	3	0	1	0	4	0	2	0	3	0	1
212			min	-.005	1	0	2	0	3	0	4	0	4	0	2
213		2	max	0	3	0	1	0	4	0	2	0	3	0	1
214			min	-.005	1	0	2	0	3	0	4	0	4	0	2
215		3	max	0	3	0	1	0	4	0	2	0	3	0	1
216			min	-.005	1	0	2	0	3	0	4	0	4	0	2
217		4	max	0	3	0	1	0	4	0	2	0	1	0	2
218			min	-.005	1	0	2	0	3	0	4	0	4	0	1
219		5	max	0	3	0	1	0	4	0	2	0	1	0	2
220			min	-.005	1	0	2	0	3	0	4	0	2	0	1
221	M37	1	max	0	3	0	1	0	4	0	2	0	3	0	1
222			min	-.003	1	0	2	0	3	0	4	0	4	0	2
223		2	max	0	3	0	1	0	4	0	2	0	3	0	1
224			min	-.003	1	0	2	0	3	0	4	0	4	0	2
225		3	max	0	3	0	1	0	4	0	2	0	3	0	1
226			min	-.003	1	0	2	0	3	0	4	0	4	0	2
227		4	max	0	3	0	1	0	4	0	2	0	1	0	2

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
228			min	-.003	1	0	2	0	3	0	4	0	2	0	1
229		5	max	0	3	0	1	0	4	0	2	0	1	0	2
230			min	-.003	1	0	2	0	3	0	4	0	2	0	1
231	M38	1	max	0	3	0	1	0	4	0	2	0	3	0	1
232			min	-.002	1	0	2	0	3	0	4	0	4	0	2
233		2	max	0	3	0	1	0	4	0	2	0	3	0	1
234			min	-.002	1	0	2	0	3	0	4	0	4	0	2
235		3	max	0	3	0	1	0	4	0	2	0	3	0	1
236			min	-.002	1	0	2	0	3	0	4	0	4	0	2
237		4	max	0	3	0	1	0	4	0	2	0	1	0	2
238			min	-.002	1	0	2	0	3	0	4	0	2	0	1
239		5	max	0	3	0	1	0	4	0	2	0	1	0	2
240			min	-.002	1	0	2	0	3	0	4	0	2	0	1
241	M39	1	max	0	3	0	1	0	4	0	2	0	3	0	1
242			min	-.002	1	0	2	0	3	0	4	0	4	0	2
243		2	max	0	3	0	1	0	4	0	2	0	3	0	1
244			min	-.002	1	0	2	0	3	0	4	0	4	0	2
245		3	max	0	3	0	1	0	4	0	2	0	3	0	1
246			min	-.002	1	0	2	0	3	0	4	0	4	0	3
247		4	max	0	3	0	1	0	4	0	2	0	1	0	2
248			min	-.002	1	0	2	0	3	0	4	0	2	0	1
249		5	max	0	3	0	1	0	4	0	2	0	1	0	2
250			min	-.002	1	0	2	0	3	0	4	0	2	0	1
251	M40	1	max	0	3	0	1	0	4	0	2	0	3	0	1
252			min	0	1	0	2	0	2	0	4	0	4	0	2
253		2	max	0	3	0	1	0	4	0	2	0	3	0	1
254			min	0	1	0	2	0	2	0	4	0	4	0	2
255		3	max	0	3	0	1	0	4	0	2	0	3	0	1
256			min	0	1	0	2	0	2	0	4	0	4	0	3
257		4	max	0	3	0	1	0	4	0	2	0	1	0	2
258			min	0	1	0	2	0	2	0	4	0	2	0	1
259		5	max	0	3	0	1	0	4	0	2	0	1	0	2
260			min	0	1	0	2	0	2	0	4	0	2	0	1
261	M41	1	max	0	3	0	1	0	1	0	2	0	3	0	1
262			min	0	1	0	2	0	2	0	4	0	4	0	2
263		2	max	0	3	0	1	0	1	0	2	0	3	0	1
264			min	0	1	0	2	0	2	0	4	0	4	0	2
265		3	max	0	3	0	1	0	1	0	2	0	3	0	1
266			min	0	1	0	2	0	2	0	4	0	4	0	3
267		4	max	0	3	0	1	0	1	0	2	0	1	0	2
268			min	0	1	0	2	0	2	0	4	0	2	0	1
269		5	max	0	3	0	1	0	1	0	2	0	1	0	2
270			min	0	1	0	2	0	2	0	4	0	2	0	1
271	M42	1	max	0	3	0	1	0	1	0	2	0	3	0	1
272			min	0	1	0	2	0	2	0	4	0	4	0	2
273		2	max	0	3	0	1	0	1	0	2	0	3	0	1
274			min	0	1	0	2	0	2	0	4	0	4	0	2
275		3	max	0	3	0	1	0	1	0	2	0	3	0	1
276			min	0	1	0	2	0	2	0	4	0	4	0	3
277		4	max	0	3	0	1	0	1	0	2	0	1	0	2
278			min	0	1	0	2	0	2	0	4	0	2	0	1
279		5	max	0	3	0	1	0	1	0	2	0	1	0	2
280			min	0	1	0	2	0	2	0	4	0	2	0	1
281	M43	1	max	0	3	0	1	0	1	0	2	0	3	0	1
282			min	0	1	0	2	0	2	0	4	0	4	0	2
283		2	max	0	3	0	1	0	1	0	2	0	3	0	1
284			min	0	1	0	2	0	2	0	4	0	4	0	2

Envelope Member Section Forces (Continued)

	Member	Sec		Axial[k]	LC	y Shear[k]	LC	z Shear[k]	LC	Torque[k...	LC	y-y Mom...	LC	z-z Mom...	LC
285		3	max	0	3	0	1	0	1	0	2	0	3	0	1
286			min	0	1	0	1	0	2	0	4	0	4	0	3
287		4	max	0	3	0	1	0	1	0	2	0	1	0	2
288			min	0	1	0	2	0	2	0	4	0	2	0	1
289		5	max	0	3	0	1	0	1	0	2	0	1	0	2
290			min	0	1	0	2	0	2	0	4	0	2	0	1

Envelope Member Section Deflections

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L...	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
1	M1	1	m..	0	1	0	1	0	1	0	1	NC	1	NC	1
2			m..	0	1	0	1	0	1	0	1	NC	1	NC	1
3		2	m..	0	2	0	1	.029	3	0	1	NC	1	NC	1
4			m..	0	1	0	2	0	1	0	1	NC	1	1439.811	3
5		3	m..	0	2	.003	1	.104	3	0	1	NC	1	NC	1
6			m..	0	1	0	2	0	1	0	1	NC	1	404.773	3
7		4	m..	0	2	.007	1	.206	3	0	1	NC	2	NC	1
8			m..	0	1	0	2	0	1	0	1	6185.172	1	204.203	3
9		5	m..	0	2	.011	1	.317	3	0	1	NC	2	NC	1
10			m..	0	1	0	2	0	1	0	1	3789.08	1	132.568	3
11	M2	1	m..	0	2	.317	3	0	1	1.09...	2	NC	1	NC	1
12			m..	-.011	1	0	1	0	2	0	1	263.269	3	NC	1
13		2	m..	0	2	.37	2	.024	1	1.19...	2	NC	1	NC	2
14			m..	-.011	1	0	1	.001	2	0	1	375.875	3	2486.98	1
15		3	m..	0	2	.423	2	.03	1	1.29...	2	NC	1	NC	2
16			m..	-.011	1	0	1	.002	2	0	1	625.837	3	2017.654	1
17		4	m..	0	2	.444	2	.016	1	1.39...	2	NC	1	NC	2
18			m..	-.011	1	0	1	0	2	0	1	564.278	4	3813.808	1
19		5	m..	0	2	.445	2	0	1	1.49...	2	NC	1	NC	1
20			m..	-.011	1	0	1	0	2	0	1	416.439	4	NC	1
21	M3	1	m..	0	1	.011	1	0	1	2.57...	4	NC	2	NC	1
22			m..	0	2	0	2	-.445	2	-2.18...	3	3781.997	1	94.394	2
23		2	m..	0	1	.007	1	0	1	1.93...	4	NC	2	NC	1
24			m..	0	2	0	2	-.287	2	-1.64...	3	6272.122	1	146.242	2
25		3	m..	0	1	.003	1	0	1	1.28...	4	NC	1	NC	1
26			m..	0	2	0	2	-.144	2	-1.09...	3	NC	1	291.189	2
27		4	m..	0	1	0	1	0	1	6.44...	4	NC	1	NC	1
28			m..	0	2	0	2	-.04	2	-5.46...	3	NC	1	1039.651	2
29		5	m..	0	1	0	1	0	1	0	1	NC	1	NC	1
30			m..	0	1	0	1	0	1	0	1	NC	1	NC	1
31	M4	1	m..	0	2	.445	2	0	1	1.49...	2	NC	1	NC	1
32			m..	-.011	1	0	1	0	2	0	1	817.043	3	NC	1
33		2	m..	0	2	.441	2	.007	1	1.40...	2	NC	1	NC	2
34			m..	-.011	1	0	1	0	3	0	1	1328.109	3	9834.017	1
35		3	m..	0	2	.419	2	.016	1	1.32...	2	NC	1	NC	2
36			m..	-.011	1	0	1	0	2	0	1	1078.273	4	3861.119	1
37		4	m..	0	2	.373	2	.013	1	1.24...	2	NC	1	NC	2
38			m..	-.011	1	0	1	0	2	0	1	1606.673	4	4815.517	1
39		5	m..	0	2	.315	2	0	1	1.16...	2	NC	1	NC	1
40			m..	-.011	1	0	1	0	3	0	1	NC	1	NC	1
41	M5	1	m..	0	1	.011	1	0	1	0	1	NC	2	NC	1
42			m..	0	3	0	2	-.315	2	-3.80...	2	3746.638	1	133.498	2
43		2	m..	0	1	.005	1	0	1	0	1	NC	2	NC	1
44			m..	0	3	0	2	-.197	2	-2.85...	2	7779.578	1	213.42	2
45		3	m..	0	1	.002	1	0	1	0	1	NC	1	NC	1
46			m..	0	3	0	2	-.096	2	-1.90...	2	NC	1	435.781	2

Envelope Member Section Deflections (Continued)

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L..	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
47		4	m...	0	1	0	1	0	1	0	1	NC	1	NC	1
48			m...	0	3	0	2	-.026	2	-9.51...	2	NC	1	1589.347	2
49		5	m...	0	1	0	1	0	1	0	1	NC	1	NC	1
50			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
51	M8	1	m...	0	2	0	2	.281	3	1.07...	2	NC	1	NC	1
52			m...	-.01	1	0	1	0	1	0	1	NC	1	293.689	3
53		2	m...	0	2	-.57	2	.308	2	1.18...	2	105.317	2	NC	1
54			m...	-.01	1	-.573	1	0	1	0	1	104.803	1	418.34	3
55		3	m...	0	2	-.675	2	.352	2	1.29...	2	88.85	2	NC	1
56			m...	-.01	1	-.68	1	0	1	0	1	88.267	1	693.882	3
57		4	m...	0	2	-.317	2	.383	2	1.39...	2	189.472	2	NC	1
58			m...	-.01	1	-.321	1	0	1	0	1	187.163	1	631.664	4
59		5	m...	0	2	0	2	.394	2	1.50...	2	NC	1	NC	1
60			m...	-.01	1	0	1	0	1	0	1	NC	1	463.558	4
61	M9	1	m...	0	2	0	2	.245	3	1.06...	3	NC	1	NC	1
62			m...	-.008	1	0	1	0	1	0	1	NC	1	333.783	3
63		2	m...	0	2	-.57	2	.266	2	1.15...	2	105.315	2	NC	1
64			m...	-.008	1	-.573	1	0	1	0	1	104.796	1	473.732	3
65		3	m...	0	2	-.675	2	.306	2	1.27...	2	88.849	2	NC	1
66			m...	-.008	1	-.68	1	0	1	0	1	88.258	1	781.088	3
67		4	m...	0	2	-.317	2	.333	2	1.38...	2	189.466	2	NC	1
68			m...	-.008	1	-.321	1	0	1	0	1	187.129	1	722.696	4
69		5	m...	0	2	0	2	.343	2	1.5e-...	2	NC	1	NC	1
70			m...	-.008	1	0	1	0	1	0	1	NC	1	525.832	4
71	M10	1	m...	0	2	0	2	.209	3	1.04...	3	NC	1	NC	1
72			m...	-.007	1	0	1	0	1	0	1	NC	1	387.553	3
73		2	m...	0	2	-.57	2	.226	2	1.11...	2	105.316	2	NC	1
74			m...	-.007	1	-.573	1	0	1	0	1	104.815	1	547.292	3
75		3	m...	0	2	-.675	2	.26	2	1.23...	2	88.85	2	NC	1
76			m...	-.007	1	-.68	1	0	1	0	1	88.28	1	895.029	3
77		4	m...	0	2	-.317	2	.284	2	1.35...	2	189.469	2	NC	1
78			m...	-.007	1	-.321	1	0	1	0	1	187.214	1	848.023	4
79		5	m...	0	2	0	2	.292	2	1.46...	2	NC	1	NC	1
80			m...	-.007	1	0	1	0	1	0	1	NC	1	609.491	4
81	M11	1	m...	0	2	0	2	.174	3	1.00...	3	NC	1	NC	1
82			m...	-.006	1	0	1	0	1	0	1	NC	1	461.499	3
83		2	m...	0	2	-.57	2	.187	2	1.05...	2	105.318	2	NC	1
84			m...	-.006	1	-.572	1	0	1	0	1	104.853	1	647.304	3
85		3	m...	0	2	-.675	2	.216	2	1.17...	2	88.852	2	NC	1
86			m...	-.006	1	-.68	1	0	1	0	1	88.323	1	1047.126	3
87		4	m...	0	2	-.317	2	.236	2	1.29...	2	189.477	2	NC	1
88			m...	-.006	1	-.321	1	0	1	0	1	187.385	1	1025.666	4
89		5	m...	0	2	0	2	.243	2	1.41...	2	NC	1	NC	1
90			m...	-.005	1	0	1	0	1	0	1	NC	1	724.658	4
91	M12	1	m...	0	2	0	2	.141	3	9.52...	3	NC	1	NC	1
92			m...	-.004	1	0	1	0	1	0	1	NC	1	566.72	3
93		2	m...	0	2	-.57	2	.15	2	9.85...	2	105.321	2	NC	1
94			m...	-.004	1	-.572	1	0	1	0	1	104.904	1	787.648	3
95		3	m...	0	2	-.675	2	.174	2	1.10...	2	88.855	2	NC	1
96			m...	-.004	1	-.679	1	0	1	0	1	88.381	1	1255.988	3
97		4	m...	0	2	-.317	2	.191	2	1.21...	2	189.491	2	NC	1
98			m...	-.004	1	-.32	1	0	1	0	1	187.613	1	1288.107	4
99		5	m...	0	2	0	2	.196	2	1.33...	2	NC	1	NC	1
100			m...	-.004	1	0	1	0	1	0	1	NC	1	888.629	4
101	M13	1	m...	0	2	0	2	.11	3	8.81...	3	NC	1	NC	1
102			m...	-.003	1	0	1	0	1	0	1	NC	1	723.453	3
103		2	m...	0	2	-.57	2	.116	2	8.99...	2	105.324	2	NC	1

Envelope Member Section Deflections (Continued)

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L...	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
104			m...	-.003	1	-.572	1	0	1	0	1	104.962	1	993.038	3
105		3	m...	0	2	-.675	2	.135	2	1.01...	2	88.859	2	NC	1
106			m...	-.003	1	-.679	1	0	1	0	1	88.447	1	1553.672	3
107		4	m...	0	2	-.317	2	.148	2	1.12...	2	189.507	2	NC	1
108			m...	-.003	1	-.32	1	0	1	0	1	187.875	1	1698.881	4
109		5	m...	0	2	0	2	.153	2	1.23...	2	NC	1	NC	1
110			m...	-.003	1	0	1	0	1	0	1	NC	1	1132.938	4
111	M14	1	m...	0	2	0	2	.081	3	7.92...	3	NC	1	NC	1
112			m...	-.002	1	0	1	0	1	0	1	NC	1	971.908	3
113		2	m...	0	2	-.57	2	.086	2	7.98...	2	105.328	2	NC	1
114			m...	-.002	1	-.571	1	0	1	0	1	105.024	1	1311.088	3
115		3	m...	0	2	-.675	2	.1	2	9.00...	2	88.864	2	NC	1
116			m...	-.002	1	-.678	1	0	1	0	1	88.518	1	1999.489	3
117		4	m...	0	2	-.317	2	.11	2	1.00...	2	189.525	2	NC	1
118			m...	-.002	1	-.319	1	0	1	0	1	188.153	1	2397.027	4
119		5	m...	0	2	0	2	.113	2	1.10...	2	NC	1	NC	1
120			m...	-.002	1	0	1	0	1	0	1	NC	1	1520.231	4
121	M15	1	m...	0	2	0	2	.056	3	6.84...	3	NC	1	NC	1
122			m...	-.002	1	0	1	0	1	0	1	NC	1	NC	1
123		2	m...	0	2	-.57	2	.059	2	6.83...	2	105.333	2	NC	1
124			m...	-.002	1	-.571	1	0	1	0	1	105.087	1	NC	1
125		3	m...	0	2	-.675	2	.069	2	7.73...	2	88.869	2	NC	1
126			m...	-.002	1	-.677	1	0	1	0	1	88.589	1	7018.288	4
127		4	m...	0	2	-.317	2	.075	2	8.63...	2	189.544	2	NC	1
128			m...	-.002	1	-.319	1	0	1	0	1	188.436	1	3740.38	4
129		5	m...	0	2	0	2	.078	2	9.52...	2	NC	1	NC	1
130			m...	-.001	1	0	1	0	1	0	1	NC	1	2190.243	4
131	M16	1	m...	0	2	0	2	.035	3	5.59...	3	NC	1	NC	1
132			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
133		2	m...	0	2	-.57	2	.036	2	5.53...	2	105.337	2	NC	1
134			m...	0	1	-.571	1	0	1	0	1	105.15	1	NC	1
135		3	m...	0	2	-.675	2	.043	2	6.27...	2	88.873	2	NC	1
136			m...	0	1	-.677	1	0	1	0	1	88.66	1	NC	1
137		4	m...	0	2	-.317	2	.047	2	7.02...	2	189.564	2	NC	1
138			m...	0	1	-.318	1	0	1	0	1	188.717	1	6921.976	4
139		5	m...	0	2	0	2	.048	2	7.77...	2	NC	1	NC	1
140			m...	0	1	0	1	0	1	0	1	NC	1	3510.91	4
141	M17	1	m...	0	2	0	2	.018	3	4.16...	3	NC	1	NC	1
142			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
143		2	m...	0	2	-.57	2	.019	2	4.08...	2	105.341	2	NC	1
144			m...	0	1	-.57	1	0	1	0	1	105.211	1	NC	1
145		3	m...	0	2	-.675	2	.022	2	4.64...	2	88.879	2	NC	1
146			m...	0	1	-.676	1	0	1	0	1	88.73	1	NC	1
147		4	m...	0	2	-.316	2	.024	2	5.20...	2	189.584	2	NC	1
148			m...	0	1	-.318	1	0	1	0	1	188.995	1	NC	1
149		5	m...	0	2	0	2	.025	2	5.77...	2	NC	1	NC	1
150			m...	0	1	0	1	0	1	0	1	NC	1	6738.512	4
151	M18	1	m...	0	2	0	2	.006	3	2.55...	3	NC	1	NC	1
152			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
153		2	m...	0	2	-.57	2	.007	2	2.48...	2	105.346	2	NC	1
154			m...	0	1	-.57	1	0	4	0	1	105.271	1	NC	1
155		3	m...	0	2	-.675	2	.008	2	2.83...	2	88.884	2	NC	1
156			m...	0	1	-.676	1	0	4	0	1	88.799	1	NC	1
157		4	m...	0	2	-.316	2	.009	2	3.18...	2	189.605	2	NC	1
158			m...	0	1	-.317	1	0	1	0	1	189.266	1	NC	1
159		5	m...	0	2	0	2	.009	2	3.53...	2	NC	1	NC	1
160			m...	0	1	0	1	0	1	0	1	NC	1	NC	1

Envelope Member Section Deflections (Continued)

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L...	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
161	M19	1	m...	0	2	0	2	0	3	7.63...	3	NC	1	NC	1
162			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
163		2	m...	0	2	-.57	2	0	3	7.36...	2	105.351	2	NC	1
164			m...	0	1	-.57	1	0	4	0	1	105.33	1	NC	1
165		3	m...	0	2	-.675	2	.001	3	8.43...	2	88.889	2	NC	1
166			m...	0	1	-.675	1	0	4	0	1	88.865	1	NC	1
167		4	m...	0	2	-.316	2	0	3	9.49...	2	189.626	2	NC	1
168			m...	0	1	-.317	1	0	4	0	1	189.531	1	NC	1
169		5	m...	0	2	0	2	0	2	1.05...	2	NC	1	NC	1
170			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
171	M32	1	m...	0	2	0	2	.394	2	1.50...	2	NC	1	NC	1
172			m...	-.01	1	0	1	0	1	0	1	NC	1	935.369	3
173		2	m...	0	2	-.189	1	.384	2	1.41...	2	318.994	1	NC	1
174			m...	-.01	1	-.19	2	0	1	0	1	316.253	2	1550.983	3
175		3	m...	0	2	-.338	2	.36	2	1.32...	2	177.736	2	NC	1
176			m...	-.009	1	-.339	1	0	1	0	1	176.994	1	1784.938	4
177		4	m...	0	2	-.19	2	.323	2	1.23...	2	315.643	2	NC	1
178			m...	-.009	1	-.194	1	0	1	0	1	309.533	1	2359.486	4
179		5	m...	0	2	0	3	.275	2	1.14...	2	NC	1	NC	1
180			m...	-.009	1	0	1	0	1	0	1	NC	1	NC	1
181	M33	1	m...	0	2	0	2	.343	2	1.5e-...	2	NC	1	NC	1
182			m...	-.008	1	0	1	0	1	0	1	NC	1	1088.591	3
183		2	m...	0	2	-.188	1	.334	2	1.40...	2	319.665	1	NC	1
184			m...	-.008	1	-.19	2	0	1	0	1	316.298	2	1850.615	3
185		3	m...	0	2	-.338	3	.313	2	1.30...	2	177.766	3	NC	1
186			m...	-.008	1	-.338	1	0	1	0	1	177.49	1	1956.631	4
187		4	m...	0	2	-.19	2	.28	2	1.20...	2	315.737	2	NC	1
188			m...	-.007	1	-.193	1	0	1	0	1	311.179	1	2599.373	4
189		5	m...	0	2	0	3	.237	2	1.10...	2	NC	1	NC	1
190			m...	-.007	1	0	1	0	1	0	1	NC	1	NC	1
191	M34	1	m...	0	2	0	2	.292	2	1.46...	2	NC	1	NC	1
192			m...	-.007	1	0	1	0	1	0	1	NC	1	1291.861	3
193		2	m...	0	2	-.188	1	.285	2	1.36...	2	319.913	1	NC	1
194			m...	-.007	1	-.19	2	0	1	0	1	316.317	2	2267.683	3
195		3	m...	0	2	-.338	3	.267	2	1.26...	2	177.801	1	NC	1
196			m...	-.006	1	-.338	1	0	1	0	1	177.784	2	2164.857	4
197		4	m...	0	2	-.19	2	.239	2	1.16...	2	315.805	2	NC	1
198			m...	-.006	1	-.192	1	0	1	0	1	312.38	1	2889.485	4
199		5	m...	0	2	0	3	.2	2	1.06...	2	NC	1	NC	1
200			m...	-.006	1	0	1	0	1	0	1	NC	1	NC	1
201	M35	1	m...	0	2	0	2	.243	2	1.41...	2	NC	1	NC	1
202			m...	-.005	1	0	1	0	1	0	1	NC	1	1569.716	3
203		2	m...	0	2	-.188	1	.237	2	1.31...	2	319.844	1	NC	1
204			m...	-.005	1	-.19	2	0	1	0	1	316.315	2	2874.029	3
205		3	m...	0	2	-.337	1	.223	2	1.20...	2	177.97	1	NC	1
206			m...	-.005	1	-.338	2	0	1	0	1	177.794	2	2422.665	4
207		4	m...	0	2	-.19	2	.199	2	1.10...	2	315.853	2	NC	1
208			m...	-.005	1	-.192	1	0	1	0	1	313.231	1	3247.734	4
209		5	m...	0	2	0	3	.165	2	1.00...	2	NC	1	NC	1
210			m...	-.004	1	0	1	0	1	0	1	NC	1	NC	1
211	M36	1	m...	0	2	0	2	.196	2	1.33...	2	NC	1	NC	1
212			m...	-.004	1	0	1	0	1	0	1	NC	1	1964.07	3
213		2	m...	0	2	-.188	1	.192	2	1.23...	2	319.562	1	NC	1
214			m...	-.004	1	-.19	2	0	1	0	1	316.299	2	3632.695	4
215		3	m...	0	2	-.337	1	.181	2	1.13...	2	178.041	1	NC	1
216			m...	-.004	1	-.337	2	0	1	0	1	177.797	2	2750.162	4
217		4	m...	0	2	-.19	2	.161	2	1.03...	2	315.888	2	NC	1

Envelope Member Section Deflections (Continued)

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L...	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
218			m...	-.004	1	-.191	1	0	1	0	1	313.83	1	3701.719	4
219		5	m...	0	2	0	3	.132	2	9.32...	2	NC	1	NC	1
220			m...	-.003	1	0	1	0	1	0	1	NC	1	NC	1
221	M37	1	m...	0	2	0	2	.153	2	1.23...	2	NC	1	NC	1
222			m...	-.003	1	0	1	0	1	0	1	NC	1	2551.484	3
223		2	m...	0	2	-.188	1	.15	2	1.13...	2	319.149	1	NC	1
224			m...	-.003	1	-.19	2	0	1	0	1	316.274	2	4185.211	4
225		3	m...	0	2	-.337	1	.142	2	1.04...	2	178.048	1	NC	1
226			m...	-.003	1	-.337	2	0	1	0	1	177.798	2	3180.019	4
227		4	m...	0	2	-.19	2	.126	2	9.43...	2	315.914	2	NC	1
228			m...	-.003	1	-.191	1	0	1	0	1	314.262	1	4296.295	4
229		5	m...	0	2	0	3	.102	2	8.47...	2	NC	1	NC	1
230			m...	-.002	1	0	1	0	1	0	1	NC	1	NC	1
231	M38	1	m...	0	2	0	2	.113	2	1.10...	2	NC	1	NC	1
232			m...	-.002	1	0	1	0	1	0	1	NC	1	3484.459	3
233		2	m...	0	2	-.189	1	.111	2	1.01...	2	318.669	1	NC	1
234			m...	-.002	1	-.19	2	0	1	0	1	316.244	2	4944.156	4
235		3	m...	0	2	-.337	1	.106	2	9.27...	2	178.019	1	NC	1
236			m...	-.002	1	-.337	2	0	1	0	1	177.796	2	3769.121	4
237		4	m...	0	2	-.19	2	.095	2	8.38...	2	315.935	2	NC	1
238			m...	-.002	1	-.191	1	0	1	0	1	314.594	1	5109.555	4
239		5	m...	0	2	0	3	.075	2	7.5e-...	2	NC	1	NC	1
240			m...	-.002	1	0	1	0	1	0	1	NC	1	NC	1
241	M39	1	m...	0	2	0	2	.078	2	9.52...	2	NC	1	NC	1
242			m...	-.001	1	0	1	0	1	0	1	NC	1	5104.35	3
243		2	m...	0	2	-.189	1	.077	2	8.74...	2	318.164	1	NC	1
244			m...	-.001	1	-.19	2	0	1	0	1	316.211	2	6050.28	4
245		3	m...	0	2	-.337	1	.074	2	7.96...	2	177.973	1	NC	1
246			m...	-.001	1	-.337	3	0	1	0	1	177.793	3	4626.078	4
247		4	m...	0	2	-.19	2	.067	2	7.17...	2	315.955	2	NC	1
248			m...	-.001	1	-.191	1	0	1	0	1	314.874	1	6290.609	4
249		5	m...	0	2	0	3	.051	2	6.39...	2	NC	1	NC	1
250			m...	-.001	1	0	1	0	1	0	1	NC	1	NC	1
251	M40	1	m...	0	2	0	2	.048	2	7.77...	2	NC	1	NC	1
252			m...	0	1	0	1	0	1	0	1	NC	1	8313.857	3
253		2	m...	0	2	-.189	1	.048	2	7.11...	2	317.657	1	NC	1
254			m...	0	1	-.19	2	0	1	0	1	316.177	2	7809.997	4
255		3	m...	0	2	-.337	1	.047	2	6.46...	2	177.923	1	NC	1
256			m...	0	1	-.337	3	0	1	0	1	177.79	3	5987.336	4
257		4	m...	0	2	-.19	2	.043	2	5.81...	2	315.976	2	NC	1
258			m...	0	1	-.19	1	0	1	0	1	315.135	1	8164.08	4
259		5	m...	0	2	0	3	.031	2	5.16...	2	NC	1	NC	1
260			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
261	M41	1	m...	0	2	0	2	.025	2	5.77...	2	NC	1	NC	1
262			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
263		2	m...	0	2	-.189	1	.025	2	5.28...	2	317.163	1	NC	1
264			m...	0	1	-.19	2	0	1	0	1	316.142	2	NC	1
265		3	m...	0	2	-.337	1	.026	2	4.78...	2	177.875	1	NC	1
266			m...	0	1	-.337	3	0	3	0	1	177.787	3	8483.654	4
267		4	m...	0	2	-.19	2	.024	2	4.29...	2	315.997	2	NC	1
268			m...	0	1	-.19	1	0	1	0	1	315.394	1	NC	1
269		5	m...	0	2	0	3	.016	2	3.79...	2	NC	1	NC	1
270			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
271	M42	1	m...	0	2	0	2	.009	2	3.53...	2	NC	1	NC	1
272			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
273		2	m...	0	2	-.19	1	.009	2	3.22...	2	316.688	1	NC	1
274			m...	0	1	-.19	2	0	3	0	1	316.107	2	NC	1

Envelope Member Section Deflections (Continued)

	Member	S...		x [in]	LC	y [in]	LC	z [in]	L...	x Rot...	L...	(n) L/y Ratio	LC	(n) L/z Ratio	LC
275		3	m...	0	2	-.337	1	.01	2	2.92...	2	177.832	1	NC	1
276			m...	0	1	-.337	3	0	3	0	1	177.785	3	NC	1
277		4	m...	0	2	-.19	2	.01	2	2.61...	2	316.021	2	NC	1
278			m...	0	1	-.19	1	0	1	0	1	315.662	1	NC	1
279		5	m...	0	2	0	3	.006	2	2.30...	2	NC	1	NC	1
280			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
281	M43	1	m...	0	2	0	2	0	2	1.05...	2	NC	1	NC	1
282			m...	0	1	0	1	0	1	0	1	NC	1	NC	1
283		2	m...	0	2	-.19	1	.001	4	9.62...	2	316.233	1	NC	1
284			m...	0	1	-.19	2	0	3	0	1	316.072	2	NC	1
285		3	m...	0	2	-.337	1	.002	2	8.68...	2	177.795	1	NC	1
286			m...	0	1	-.337	3	0	3	0	1	177.783	3	NC	1
287		4	m...	0	2	-.19	2	.002	2	7.75...	2	316.047	2	NC	1
288			m...	0	1	-.19	1	0	3	0	1	315.942	1	NC	1
289		5	m...	0	2	0	3	0	2	6.82...	2	NC	1	NC	1
290			m...	0	1	0	1	0	1	0	1	NC	1	NC	1

Envelope AA ADM1-10: ASD - Building Aluminum Code Checks

Member	Shape	Code C...	Loc[ft]	LC	Shear ...	Loc[ft]	Dir	LC	Pnc/O...	Pnt/Om...	Mny/O...	Mnz/O...	Vny/O...	Vnz/O...	Cb	Eqn
No Data to Print ...																

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PROJECT NO. ______ SHEET 2000 OF ______

PROJECT NAME ______ DESIGNED BY AF DATE ______

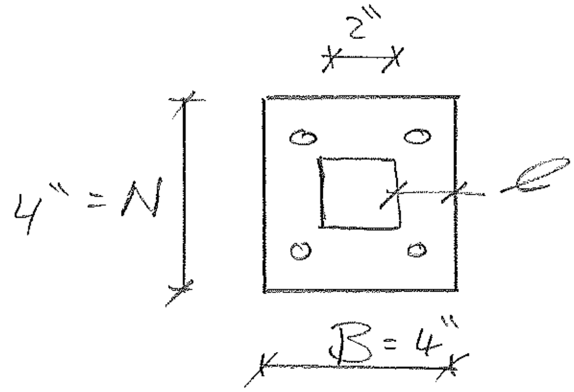
SUBJECT ______ CHECKED BY ______ DATE ______

Base plate Design

$$t \geq e \sqrt{\frac{2P_u}{0.9BNF_y}}$$

$t = 0.315''$

$e = \frac{4'' - 2''}{2} = 1''$



$P_u = 329$ lb (page

$F_y = 42$ Ksi (316 SS)

$$\therefore 0.315 \geq 1 \sqrt{\frac{2 * 329/1000}{0.9 * 4 * 4 * 42}} = 0.03'' \quad (OK)$$

use [4" * 4" * 0.35", 316 SS]

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PROJECT NO. ______ SHEET 2001 OF ______

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Base plate to Concrete

Use ITW Red head Trubolt wedge

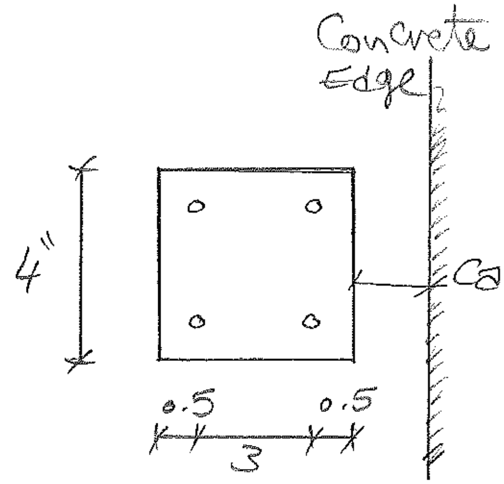
Anchor strength based on ESR-2427

$f'_c = 2500$ psi

bolt spacing = 3"

bolt size = $\frac{3}{8}$" ϕ

Edge distance = 2.25"



* for Concrete breakout strength =

$N_{cb} = [A_{cg}/A_{Nco}]\,\phi_{ed,N}\,\phi_{c,N}\,\phi_{cp,N}\,N_b$

$A_{ncg} = (C_{a1} + S_1 + 1.5h_{ef})(1.5h_{ef} * 2 + S_2)$

$= (2.25 + 3.0 + 1.5*4)(2*1.5*4 + 3) = 168.87\ in^2$

$A_{Nco} = 9h_{ef}^2 = 9 * 4^2 = 144\ in^2$

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$\psi_{cp,N} = max\left(\frac{1.5}{4''} \text{ or } 1.5 * 4''/4''\right) = 1.5$

$N_b = 24\, \lambda_a \sqrt{f'_c} * h_{ef}^{1.5}$

$= 24 * 1 \sqrt{2500}\ (4)^{1.5} = 9600\ lb$

$N_{cbg} = \left(\frac{168.87}{144}\right) * 1.0 * 1.0 * 1.5 * 9600^{lb} = 16,887^{lb}$

$\leq 2 * 4200$

2 bolts

bolt tensile strength

ESR-2427 table 3

$N_{cbg} = 2 * 4200^{lb} = 8400^{lb}$ (2 bolts capacity)

Allowable tension load $= 0.65 * 8400^{lb} / 1.6 = 3,412\ lb$
(T_S)

check shear strength - Concrete breakout strength in shear: check for edge distance 3"

$V_{cb} = A_{vc}/A_{co}\ (\psi_{ed},\ V\psi_c,\ V\psi_h,\ V\ V_b)$

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A_{VC} = width * depth = $((2 * 1.5 * C_{a1}) + S_1)(1.5 C_{a1})$

$= (2 * 1.5 * 3'' + 3)(1.5 * 3'') = 54.0 \text{ in}^2$

$A_{VCo} = 4.5\, C_{a1}^2 = 4.5 * 3^2 = 40.5 \text{ in}^2$

$\phi_{CV} = 1.0$ (Cracked Concrete)

$\phi_{h,V} = \sqrt{1.5 (C_{a1}/h_a)} = \sqrt{1.5 \left(\frac{3}{4}\right)} = 1.06$

$V_b = \left(7 \left(\frac{l_e}{d_a}\right)^{0.2} \sqrt{d_a}\right) \lambda_a \sqrt{f'_c} * C_{a1}^{1.5}$

$= \left[7 * \left(\frac{1.625}{3/8}\right)^{0.2} \sqrt{3/8}\right] * 1.0 * \sqrt{2500} * 3^{1.5}$

$= 1493 \text{ lb}$

$V_{cb} = \frac{54.0}{40.5} * 1.0 * 1.0 * 1.06 * 1493 = 2110 \text{ lb}$

Steel shear strength = 1880 lb * 2 (2 bolts) = 3600 lb

ESR-2427 Table-4

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PROJECT NAME ________ DESIGNED BY AF DATE ________
SUBJECT ________ CHECKED BY ________ DATE ________

Allowable shear strength = $\phi V_N / 1.6$

$\phi V_N / 1.6 = 0.7 * 2110^{lb} / 1.6 = 923.3$ lb

Shear load = $\frac{50^{lb/ft} * 5}{923.3} = 0.27 > 0.2$

Tension load = $\frac{\text{Applied Tension}}{\text{Allowable Tension}}$

Applied Tension = $\frac{50^{lb/ft} * 5^{ft} * 42''}{3.5''} = 3000$ lb

Tension load = $\frac{3000^{lb}}{3412^{lb}} = 0.879 > 0.2$

∴ $\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2$ (shear-tension interaction)

∴ $0.879 + 0.27 = 1.14 < 1.2$ (OK)

Use [4 - $\frac{3}{8}''\phi$ Redhead ITW or LDT
w/min 4" Embed & 3" edge distance
f'_c ≮ 2500 psi]

2005

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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

ITW RED HEAD

700 HIGH GROVE BOULEVARD
GLENDALE HEIGHTS, ILLINOIS 60139

EVALUATION SUBJECT:

ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHORS, STAINLESS STEEL TRUBOLT+ WEDGE ANCHORS AND CARBON STEEL OVERHEAD TRUBOLT+ WEDGE ANCHORS FOR CRACKED AND UNCRACKED CONCRETE

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ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHORS, STAINLESS STEEL TRUBOLT+ WEDGE ANCHORS AND CARBON STEEL OVERHEAD TRUBOLT+ WEDGE ANCHORS FOR CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2015, 2012, 2009, and 2006 *International Building Code®* (IBC)
- 2015, 2012, 2009, and 2006 *International Residential Code®* (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

Property evaluated:

Structural

2.0 USES

The carbon steel and stainless steel Trubolt+ Wedge Anchors and $^3/_8$-inch-diameter (9.5 mm) carbon steel OVERHEAD Trubolt+ Wedge Anchor are used to resist static, wind, and seismic tension and shear loads (Seismic Design Categories A thru F) in cracked and uncracked normal-weight and lightweight concrete having a specified compressive strength, f'_c, ranging from 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

The carbon steel Trubolt+ Wedge Anchors with diameters of $^3/_8$ inch (9.5 mm), $^1/_2$ inch (12.7 mm) and $^5/_8$-inch (15.9 mm) and the carbon steel OVERHEAD $^3/_8$-inch-diameter (9.5 mm) are used to resist static, wind, and seismic tension and shear loads in cracked and uncracked normal-weight or sand-lightweight concrete over steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa) [minimum of 24MPa is required under ADIBC Appendix L, Section 5.1.1].

The Trubolt+ Wedge anchors comply with anchors as described in Section 1901.3 of the 2015 IBC, Section 1909 of the 2012 IBC, and Section 1912 of the 2009 and 2006 IBC. The anchors are alternatives to cast-in-place anchors described in Section 1908 of the 2012 IBC, and Section 1911 of the 2009 and 2006 IBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

3.0 DESCRIPTION

3.1 RED HEAD Carbon Steel Trubolt+ Wedge Anchor:

The RED HEAD Trubolt+ Wedge Anchor is a torque-controlled, wedge-type mechanical expansion anchor, available in $^3/_8$-inch (9.5 mm), $^1/_2$-inch (12.7 mm), $^5/_8$-inch (15.9 mm) and $^3/_4$-inch (19.1 mm) diameters. The Trubolt+ Wedge Anchor consists of a high-strength threaded anchor body, expansion clip, hex nut and washer. The anchor body is cold-formed from low carbon steel materials conforming to AISI 1015 or AISI 1018 with mechanical properties (yield and ultimate strengths) as described in Tables 3 and 4 of this report. The zinc plating on the anchor body complies with ASTM B633 SC1, Type III, with a minimum 0.0002-inch (5 μm) thickness. The expansion clip is fabricated from low carbon steel materials conforming to AISI 1020. The standard hexagonal steel nut conforms to ANSI B18.2.2-65 and the washer conforms to ANSI/ASME B18.22.1 1965 (R1981). The Trubolt+ Wedge anchor body consists of a threaded section throughout the majority of its length and a wedge section at the far end. The expansion clip is formed around the anchor, just above the wedge. The expansion clip consists of a split cylindrical ring with undercutting grooves at the bottom end. During torquing of the anchor, the grooves in the expansion clip are designed to cut into the walls of the concrete hole as the wedge portion of the stud is forced upward against the interior of the clip (U.S. patent nos. 7,744,320 and 7,811,037). The Trubolt+ Wedge anchor is illustrated in Figure 1 of this report.

3.2 RED HEAD Stainless Steel Trubolt+ Wedge Anchor:

The RED HEAD Trubolt+ Wedge Anchor is a torque-controlled, wedge-type mechanical expansion anchor, available in $^1/_2$-inch (12.7 mm) and $^5/_8$-inch (15.9 mm) diameters. The Trubolt+ Wedge Anchor consists of a high-strength threaded anchor body, expansion clip, hex nut and washer. The anchor body is cold-formed from AISI Type 316 stainless steel materials with mechanical properties (yield and ultimate strengths) as described in Tables 5 and 6 of this report. The expansion clip is fabricated from Type 316 stainless steel materials. The Type 316 stainless steel hexagonal steel nut conforms to ANSI B18.2.2-65 and the AISI Type 316 stainless steel washer conforms to ANSI/ASME B18.22.1 1965 (R1981). The Trubolt+ Wedge anchor body consists of a threaded section throughout the majority of its length and a wedge section at the far end. The expansion clip is formed around the anchor, just above the wedge. The expansion clip consists of a split cylindrical ring with undercutting grooves at the bottom end. During torquing of the anchor, the grooves in the expansion clip are designed to cut into the walls of the concrete hole as the wedge portion of the stud is forced upward against the interior of the clip. The Trubolt+ Wedge anchor is illustrated in Figure 1 of this report.

3.3 OVERHEAD Trubolt+ Wedge Anchor:

The OVERHEAD Trubolt+ Wedge Anchor is a torque-controlled, wedge-type mechanical expansion anchor, available in $^3/_8$-inch (9.5 mm) diameter. The OVERHEAD Trubolt+ Wedge Anchor consists of a high-strength threaded anchor body, expansion clip, coupling nut and washer. The anchor body is cold-formed from low carbon steel materials with the mechanical properties (yield and ultimate strengths) as described in Tables 3 and 4 of this report. The zinc plating on the anchor body complies with ASTM B633 SC1, Type III, with a minimum 0.0002 inch (5 μm) thickness. The expansion clip is fabricated from low carbon steel materials. The coupling nut consists of Grade 2 steel with $^3/_8$" -16 threads throughout the length of the nut. The washer complies with ANSI/ASME B18.22.1 1965 (R1981). The OVERHEAD Trubolt+ Wedge anchor body consists of a threaded section throughout the majority of its length and a wedge section at the far end. The expansion clip is formed around the anchor, just above the wedge. The expansion clip consists of a split cylindrical ring with undercutting grooves at the bottom end. During torquing of the anchor (using coupling nut), the grooves in the expansion clip are designed to cut into the walls of the concrete hole as the wedge portion of the anchor body is forced upward against the interior of the clip (U.S. patent nos. 7,744,320 and 7,811,037). The OVERHEAD Trubolt+ Wedge anchor is illustrated in Figure 2 of this report.

3.4 Concrete:

Normal-weight and lightweight concrete must comply with Sections 1903 and 1905 of the IBC.

3.5 Steel Deck Panels:

Steel deck panels must comply with ASTM A653, SS Grade 40 (minimum), and must have a minimum 0.034-inch (0.864 mm) base-metal thickness (No. 20 gage).

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strength of anchors complying with the 2015 IBC, as well as Section R301.1.3 of the 2015 IRC must be determined in accordance with ACI 318-14 Chapter 17 and this report.

Design strength of anchors in accordance with the 2012 IBC, as well as Section R301.1.3 of the 2012 IRC, must be determined in accordance with ACI 318-11 Appendix D and this report.

Design strength of anchors in accordance with the 2009 IBC and Section R301.1.3 of the 2009 IRC must be in accordance with ACI 318-08 Appendix D and this report.

Design strength of anchors in accordance with the 2006 IBC and Section R301.1.3 of the 2006 IRC must be in accordance with ACI 318-05 Appendix D and this report.

Design parameters are based on the 2015 IBC (ACI 318-14) and 2012 IBC (ACI 318-11) unless noted otherwise in Sections 4.1.1 through 4.1.12 of this report.

The strength design of anchors must comply with ACI 318-14 17.3.1 or ACI 318-11 D.4.1, as applicable, except as required in ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable. Strength reduction factors, ϕ, as given in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, must be used for load combinations calculated in accordance with Section 1605.2 of the IBC and Section 5.3 of ACI 318-14 or Section 9.2 of ACI 318-11, as applicable. Strength reduction factors, ϕ, as given in ACI 318-11 D.4.4 must be used for load combinations calculated in accordance with ACI 318-11 Appendix C.

The value of f'_c used in calculations must be limited to 8,000 psi (55.2 MPa), maximum, in accordance with ACI 318-14 17.2.7 or ACI 318-11 D.3.7, as applicable. An example calculation in accordance with 2015 and 2012 IBC is provided in Table 7.

4.1.2 Requirements for Static Steel Strength in Tension, N_{sa}: The nominal static steel strength of a single anchor in tension, N_{sa}, calculated in accordance with ACI 318-14 17.4.1.2 or ACI 318-11 Section D.5.1.2, as applicable, is given in Tables 3 or 5 of this report. Strength reduction factors, ϕ, corresponding to ductile steel elements may be used for tension.

4.1.3 Requirements for Static Concrete Breakout Strength in Tension, N_{cb}, N_{cbg}: The nominal concrete breakout strength of a single anchor or a group of anchors in tension, N_{cb} or N_{cbg} respectively, must be calculated in accordance with ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, with modifications as described in this section. The basic concrete breakout strength of a single anchor in tension, N_b, must be calculated in accordance with ACI 318-14 17.4.2.2 or ACI 318-11 D.5.2.2, as applicable, using the values of h_{ef} and k_{cr} as given in Tables 3 or 5 of this report. The nominal concrete breakout strength in tension in regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.2.6 or ACI 318-11 D.5.2.6, as applicable, must be calculated with $\psi_{c,N}$ = 1.0 and using the value of k_{uncr} as given in Tables 3 or 5 of this report.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete-filled steel deck floor and roof assemblies, as shown in Figure 7, calculation of the concrete breakout strength in accordance with ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, is not required.

4.1.4 Requirements for Static Pullout Strength in Tension, N_{pn}: The nominal pullout strength of a single anchor in tension in accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ or $N_{p,uncr}$, respectively, is given in Tables 3 or 5 of this report. For all design cases, $\psi_{c,P}$ = 1.0. In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the nominal pullout strength in tension must be calculated according to Eq-1.

$$N_{p,f'c} = N_{p,cr}\sqrt{\frac{f'_c}{2,500}} \text{ (lb, psi)} \qquad \text{(Eq-1)}$$

$$N_{p,f'c} = N_{p,cr}\sqrt{\frac{f'_c}{17.2}} \text{ (N, MPa)}$$

In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension must be calculated according to Eq-2:

$$N_{p,f'c} = N_{p,uncr}\sqrt{\frac{f'_c}{2,500}} \text{ (lb, psi)} \qquad \text{(Eq-2)}$$

$$N_{p,f'c} = N_{p,uncr}\sqrt{\frac{f'_c}{17.2}} \text{ (N, MPa)}$$

where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Tables 3 or 5 of this report, the pullout strength in tension need not be evaluated.

The nominal pullout strength in tension of the anchors installed in the soffit of sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 7 of this report, is given in Table 9. In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the nominal pullout strength in cracked concrete must be calculated according to Eq-1, whereby the value of $N_{p,deck,cr}$ must be substituted for $N_{p,cr}$ and the value 3,000 psi or 20.7 MPa must be substituted for 2,500 psi or 17.2 MPa. In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension must be calculated according to Eq-2, whereby the value of $N_{p,deck,uncr}$ must be substituted for $N_{p,uncr}$ and the value 3,000 psi or 20.7 MPa must be substituted for 2,500 psi or 17.2 MPa.

4.1.5 Requirements for Static Steel in Shear, V_{sa}: The values of V_{sa} for a single anchor given in Tables 4 or 6 of this report must be used in lieu of the values of V_{sa} derived by calculation according to ACI 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable. Strength reduction factors, ϕ, corresponding to ductile steel elements may be used except for the carbon steel $^3/_8$-inch-diameter (9.5 mm) anchors loaded in shear, which have a strength reduction factor corresponding to brittle steel elements.

The shear strength, $V_{sa,deck}$, of anchors installed in the soffit of sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 7 of this report, is given in Table 9 of this report.

4.1.6 Requirements for Static Concrete Breakout Strength in Shear, V_{cb} or V_{cbg}: The nominal static concrete breakout strength in shear of a single anchor or a group of anchors, V_{cb} or V_{cbg}, must be calculated in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable. The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, must be calculated in accordance with ACI 318-14 17.5.2.2 or ACI 318-11 D.6.2.2, as applicable, using the value of d_a, given in Table 2 of this report, and the value l_e, given in Tables 4 or 6, must be taken no greater than h_{ef}. In no cases must l_e exceed $8d_a$.

For anchors installed in the soffit of sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 7, calculation of the concrete breakout strength in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable, is not required.

4.1.7 Requirements for Static Concrete Pryout Strength of Anchor in Shear, V_{cp} or V_{cpg}: The nominal static concrete pryout strength in shear of a single anchor or groups of anchors, V_{cp} or V_{cpg}, must be calculated in accordance with ACI 318-14 17.5.3 or ACI 318-11 D.6.3, as applicable, modified by using the value of k_{cp} provided in Tables 4 and 6 of this report and the value of N_{cb} or N_{cbg} as calculated in Section 4.1.3 of this report.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 7 of this report, calculation of the concrete pryout strength in accordance with ACI 318-14 17.5.3 or ACI 318-11 D.6.3 is not required.

4.1.8 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: Values of s_{min} and c_{min} as given in Table 2 of this report must be used in lieu of ACI 318-14 17.7.1 and 17.7.3 or ACI 318-11 D.8.1 and D.8.3, respectively, as applicable. Minimum member thicknesses, h_{min}, as given in Tables 2 through 6 of this report, must be used in lieu of ACI 318-14 17.7.5 or ACI 318-11 D.8.5, as applicable.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete on steel deck floor and roof assemblies, the anchors must be installed in accordance with Figure 7 of this report and the minimum anchor spacing along the flute must be the greater of $3h_{ef}$ or 1.5 times the flute width.

4.1.9 Requirements for Critical Edge Distance and Splitting: In applications where $c < c_{ac}$ and supplemental reinforcement to control splitting of the concrete is not present, the concrete breakout strength in tension for uncracked concrete, calculated according to ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, must be further multiplied by the factor $\Psi_{cp,N}$ given by Eq-3:

$$\Psi_{cp,N} = c / c_{ac} \qquad \text{(Eq-3)}$$

whereby the factor $\Psi_{cp,N}$ need not be taken as less than $1.5h_{ef} / c_{ac}$. For all other cases $\Psi_{cp,N}$ = 1.0. Values for the critical edge distance c_{ac} must be taken from Tables 3 or 5 of this report.

4.1.10 Requirements for Seismic Design:

4.1.10.1 General: For load combinations including earthquake, the design must be performed according to ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable. Modifications to ACI 318-14 17.2.3 shall be applied under Section 1905.1.8 of the 2015 IBC. For the 2012 IBC, Section 1905.1.9 is omitted. Modifications to ACI 318 (-08, -05) D.3.3 must be applied under Section 1908.1.9 of the 2009 IBC or Section 1908.1.16 of the 2006 IBC, as applicable.

The carbon steel $^1/_2$-inch- $^5/_8$-inch- and $^3/_4$-inch-diameter (12.7, 15.9 and 19.1 mm), stainless steel $^1/_2$-inch (12.7 mm) and $^5/_8$-inch (15.9 mm) anchors loaded in tension and shear, along with the $^3/_8$-inch-diameter (9.5 mm) anchor loaded in tension only, comply with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, as ductile steel elements and must be designed in accordance with ACI 318-14, 17.2.3.4, 17.2.3.5, 17.2.3.6 or 17.2.3.7; ACI 318-11 D.3.3.4, D.3.3.5, D.3.3.6, or D.3.3.7; ACI 318-08 D.3.3.4, D.3.3.5, or D.3.3.6; or ACI 318-05 D.3.3.4 or D.3.3.5, as applicable.

The carbon steel $^3/_8$-inch-diameter (9.5 mm) anchor loaded in shear must be designed in accordance with ACI 318-14 17.2.3.5.3, ACI 318-11 D.3.3.5.3, ACI 318-08 D.3.3.5 or D.3.3.6, or ACI 318-05 D.3.3.6 as brittle steel elements, as applicable.

4.1.10.2 Seismic Tension: The nominal steel strength and nominal concrete breakout strength for anchors in tension must be calculated according to ACI 318-14 17.4.1 and 17.4.2 or ACI 318-11 D.5.1 and D.5.2, respectively, as applicable, as described in Sections 4.1.2 and 4.1.3 of this report. In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the value for nominal pullout strength tension for seismic loads, N_{eq} or $N_{p,deck,cr}$, given in Table 3, 5 or 9 of this report, must be used in lieu of N_p. The values of N_{eq} must be adjusted for the concrete strength in accordance with Eq-4:

$$N_{eq,f'c} = N_{eq}\sqrt{\frac{f'_c}{2{,}500}} \text{ (lb, psi)} \qquad \text{(Eq-4)}$$

$$N_{eq,f'c} = N_{eq}\sqrt{\frac{f'_c}{17.2}} \text{ (N, MPa)}$$

The value of $N_{p,deck,cr}$ must be calculated according to Eq-4, whereby the value 3,000 psi or 20.7 MPa must be substituted for 2,500 psi or 17.2 MPa.

If no values for N_{eq} are given in Tables 3 or 5, the static design strength values govern. Section 4.1.4 provides additional requirements.

4.1.10.3 Seismic Shear: The nominal concrete breakout strength and pryout strength for anchors in shear must be calculated according to ACI 318-14 17.5.2 and 17.5.3 or ACI 318-11 D.6.2 and D.6.3, respectively, as applicable, as described in Sections 4.1.6 and 4.1.7 of this report. In accordance with ACI 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable, the value for nominal steel strength in shear for seismic loads, V_{eq}, or $V_{sa,deck}$, given in Tables 4, 6 or 9 of this report, must be used in lieu of V_{sa}.

4.1.11 Interaction of Tensile and Shear Forces: For designs that include combined tension and shear, the interaction of tension and shear loads must be calculated in accordance with ACI 318-14 17.6 or ACI 318-11 D.7, as applicable.

4.1.12 Lightweight Concrete: For the use of anchors in lightweight concrete, the modification factor λ_a equal to 0.8λ is applied to all values of $\sqrt{f'_c}$ affecting N_n and V_n.

For ACI 318-14 (2015 IBC), ACI 318-11 (2012 IBC) and ACI 318-08 (2009 IBC), λ shall be determined in accordance with the corresponding version of ACI 318.

For ACI 318-05 (2006 IBC), λ shall be taken as 0.75 for all lightweight concrete and 0.85 for sand-lightweight concrete. Linear interpolation shall be permitted if partial sand replacement is used. In addition, the pullout strengths $N_{p,cr}$, $N_{p,uncr}$, and N_{eq} shall be multiplied by the modification factor, λ_a, as applicable.

For anchors installed in the soffit of sand-lightweight concrete-filled steel deck and floor and roof assemblies, further reduction of the pullout values provided in this report is not required.

4.2 Allowable Stress Design (ASD):

4.2.1 General: For anchors designed using load combinations in accordance with IBC Section 1605.3, allowable loads must be established using Eq-5 and Eq-6:

$$T_{allowable,ASD} = \phi N_n / \alpha \qquad \text{(Eq-5)}$$

and

$$V_{allowable,ASD} = \phi V_n / \alpha \qquad \text{(Eq-6)}$$

where

$T_{allowable,ASD}$ = Allowable tension load (lbf or kN).

$V_{allowable,ASD}$ = Allowable shear load (lbf or kN).

ϕN_n = Lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D and 2009 IBC Section 1908.1.9 and ACI 318-05 Appendix D and 2006 IBC Section 1908.1.16, and Section 4.1 of this report, as applicable.

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D and 2009 IBC Section 1908.1.9, ACI 318-05 Appendix D and 2006 IBC Section 1908.1.16, and Section 4.1 of this report, as applicable.

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α must include all applicable factors to account for nonductile failure modes and required over-strength.

An example of allowable stress design values for illustrative purposes is shown in Table 7 of this report.

4.2.2 Interaction of Tensile and Shear Forces: In lieu of ACI 318-14 17.6.1, 17.6.2 and 17.6.3 or ACI 318 (-11, -08, -05) D.7.1, D.7.2 and D.7.3, interaction must be calculated as follows:

For shear loads $V \le 0.2\ V_{allowable,\ ASD}$, the full allowable load in tension, $T_{allowable,\ ASD}$, may be taken.

For tension loads $T \le 0.2\ T_{allowable,\ ASD}$, the full allowable load in shear, $V_{allowable,\ ASD}$, may be taken.

For all other cases, Eq-7 applies:

$$T/T_{allowable,\ ASD} + V/V_{allowable,\ ASD} \le 1.2 \qquad \text{(Eq-7)}$$

For the OVERHEAD Trubolt+ Wedge Anchor, the influence of bending on the tension capacity when loaded in shear must be considered.

4.3 Installation:

Installation parameters are provided in Tables 2 and 8 and Figures 4, 5, and 6 of this report. Anchor locations must comply with this report and the plans and specifications approved by the code official. The Trubolt+ Wedge Anchors must be installed according to ITW's published instructions and this report. Holes must be predrilled in concrete with a compressive strength from 2,500 to 8,500 psi (17.2 to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1] at time of installation, using carbide-tipped masonry drill bits manufactured within the range of the maximum and minimum drill tip dimensions of ANSI Standard B212.15-1994. The nominal drill bit diameter must be equal to that of the anchor size. The minimum drilled hole depth, h_o, must comply with Table 2 of this report. Embedment, spacing, edge distance, and minimum concrete thickness must comply with Table 2. The predrilled holes must be cleaned to remove loose particles, using pressurized air or a vacuum. For the RED HEAD Trubolt+ Wedge Anchor, the hex nut and washer must be assembled on the end of the anchor, leaving the nut flush with the end of the anchor. For the OVERHEAD Trubolt+ Wedge Anchor, the coupling nut and washer must be assembled on the end of the anchor to obtain at least $^1/_2$ inch (12.7 mm) thread engagement on the anchor). The anchors must be hammered into the predrilled hole to the required embedment depth in concrete. Where a fixture is installed, the anchors must be hammered through the fixture into the predrilled hole to the required embedment depth into the concrete. The nut must be tightened against the washer until the specified torque values listed in Table 2 are achieved.

For installation in the soffit of sand-lightweight or normal-weight concrete on steel deck floor and roof assemblies, the hole diameter in the steel deck must not exceed the diameter of the hole in the concrete by more than $^1/_8$ inch (3.2 mm) and concrete must have a minimum compressive strength of 3,000 psi (20.7 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1] at time of installation. For member thickness, edge distance, spacing restrictions, and installations torque values for installation into the soffit of sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, see Figure 7, Table 8, and Section 4.1.8 of this report.

4.4 Special Inspection:

Periodic special inspection is required, in accordance with Section 1705.1.1 and Table 1705.3 of the 2015 IBC and 2012 IBC; Section 1704.15 and Table 1704.4 of the 2009 IBC; or Section 1704.13 of the 2006 IBC, as applicable. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, drill bit type, hole dimensions, hole cleaning procedures, edge distance, anchor spacing, concrete member thickness, anchor embedment, tightening torque, and adherence to the manufacturer's published installation instructions. The special inspector must be present as often as required in accordance with the statement of special inspection. Under the IBC, additional requirements as set forth in Sections 1705, 1706, and 1707 must be observed, where applicable.

5.0 CONDITIONS OF USE

The Trubolt+ Wedge Anchors described in this report comply with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions.

5.1 The anchors must be installed in accordance with ITW's published instructions and this report. In case of conflicts, this report governs.

5.2 Anchor sizes, dimensions, and installation parameters are as set forth in this report.

5.3 The anchors are limited to installation in cracked and uncracked, normal-weight or lightweight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1]. The anchors may also be installed in cracked and uncracked normal-weight or sand-lightweight concrete over profile steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

5.4 The values of f'_c used for calculation purposes must not exceed 8,000 psi (55.0 MPa).

5.5 Strength design values must be established in accordance with Section 4.1 of this report.

5.6 Allowable design values must be established in accordance with Section 4.2 of this report.

5.7 Anchor spacing, edge distance, and minimum member thickness must comply with Tables 2 and 8 and Figures 4, 5, and 6 of this report.

5.8 Prior to installation, calculations and details justifying that the applied loads comply with this report must be submitted to the code official for approval. The calculations and details must be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.9 Since an ICC-ES acceptance criteria for evaluating data to determine the performance of expansion anchors subjected to fatigue or shock loading is unavailable at this time, the use of these anchors under such conditions is beyond the scope of this report.

5.10 Anchors may be installed in regions of concrete where cracking has occurred or where analysis indicates cracking may occur ($f_t > f_r$), subject to the conditions of this report.

5.11 Anchors may be used to resist short-term loading due to wind or seismic forces, subject to the conditions of this report.

5.12 Where not otherwise prohibited in the code, Trubolt+ Wedge Anchors are permitted for use with fire-resistance-rated construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only.
- Anchors that support a fire-resistance-rated envelope or a fire-resistance-rated membrane are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Anchors are used to support nonstructural elements.

5.13 Use of the zinc plated, carbon steel anchors is limited to dry, interior locations.

5.14 Special inspections are provided in accordance with Section 4.4 of this report.

5.15 The anchors are manufactured in the USA; under a quality-control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data complying with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated October 2015, for use in cracked and uncracked concrete, including optional tests for seismic tension and shear; profile steel deck soffit tests; and quality control documentation.

7.0 IDENTIFICATION

The anchors are identified by their dimensional characteristics and the anchor size, and by a length identification marking stamped on the anchor, as indicated in Table 1 of this report. The anchors have the length identification marking underlined on the anchor head, as illustrated in Figure 3 of this report, and this is visible after installation for verification. Packages are identified with the anchor name, material (carbon or stainless) type and size; the manufacturer's name (ITW Red Head, ITW Brands, or ITW Buildex) and address; and the evaluation report number (ESR-2427).

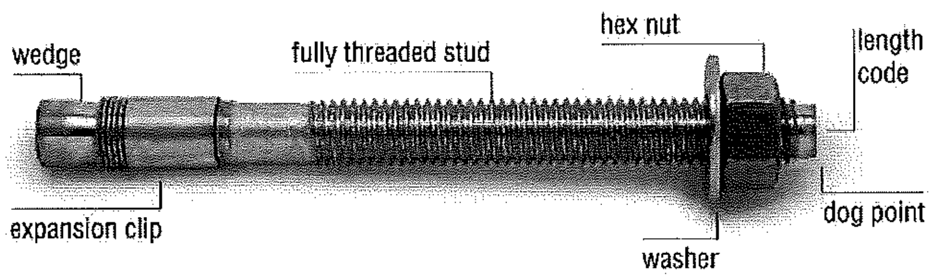


FIGURE 1—ITW RED HEAD TRUBOLT+ WEDGE ANCHOR (Carbon and Stainless Steel)

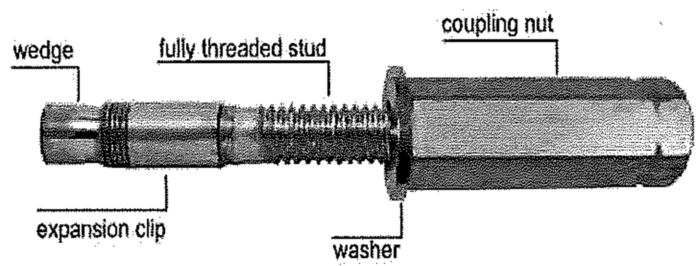


FIGURE 2—OVERHEAD TRUBOLT+ WEDGE ANCHOR

TABLE 1—LENGTH IDENTIFICATION MARKINGS[1]

LENGTH (inches)	ID MARKING ON ANCHOR HEAD												
	C	D	E	F	G	H	I	J	K	L	M	N	O
From	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7	$7^1/_2$	8	$8^1/_2$
Up to, but not including	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7	$7^1/_2$	8	$8^1/_2$	9

For **SI:** 1 inch = 25.4 mm.

[1]Figure 3 shows a typical marking.

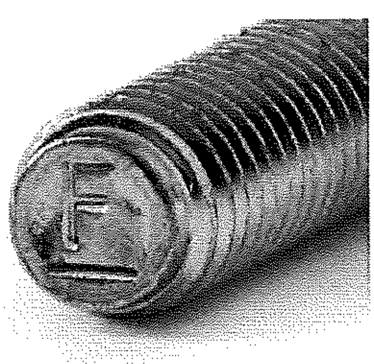


FIGURE 3—TRUBOLT+ WEDGE ANCHOR LENGTH IDENTIFICATION MARKING

TABLE 2—ITW RED HEAD TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR INSTALLATION INFORMATION (CARBON STEEL AND STAINLESS STEEL)[1]

PARAMETER	NOTATION	UNITS	NOMINAL ANCHOR DIAMETER (inch)									
			3/8		1/2				5/8		3/4	
Anchor outer diameter	d_a[d_o][3]	inches	0.361		0.5				0.615		0.7482	
Nominal carbide bit diameter	d_{bit}	inches	3/8		1/2				5/8		3/4	
Effective embedment depth	h_{ef}	inches	1 5/8		2		3 1/4		2 3/4	4 1/4	3 3/4	
Minimum anchor embedment depth	h_{nom}	inches	2		2 1/2		3 3/4		3 1/4	4 3/4	4 3/8	
Minimum hole depth[1]	h_o	inches	2 1/4		2 3/4		4		3 1/2	5	4 5/8	
Minimum concrete member thickness[1]	h_{min}	inches	4	5	4	6	6	8	6	6 1/4	7	8
Critical edge distance[1]	c_{ac}	In.	5	3	6	6	7 1/2	6	7 1/2	6½	12	10
Minimum anchor spacing[1]	s_{min}	In.	3 1/2	2 1/2	6	5 3/4	4	5 3/4	8	6	6	6
Minimum edge distance[2]	c_{min}	In.	3		6				7 1/2	5	7 1/2	7 1/2
Minimum overall anchor length	l_{anchor}	inches	2 1/2		3 3/4		4 1/2		4 1/4	6	5 1/2	
Installation torque	T_{inst}	ft-lb	30		45				90		110	
Minimum diameter of hole in fastened part	d_h	inches	1/2		5/8				3/4		7/8	

For **SI:** 1 inch = 25.4 mm, 1 ft-lb = 1.356 N-m.

[1]Stainless steel anchors are available in 1/2-inch and 5/8-inch-diameters. The OVERHEAD version is available in a carbon steel 3/8-inch-diameter.
[2]For installation of the carbon steel anchors in the soffit of concrete on steel deck floor or roof assemblies, see Figure 7. Anchors in the lower and in the upper flute may be installed with a maximum 1-inch offset in either direction from the center of the flute. In addition, anchors must have an axial spacing along the flute equal to the greater of $3h_{ef}$ or 1.5 times the flute width.
[3]The notation in brackets is for the 2006 IBC.

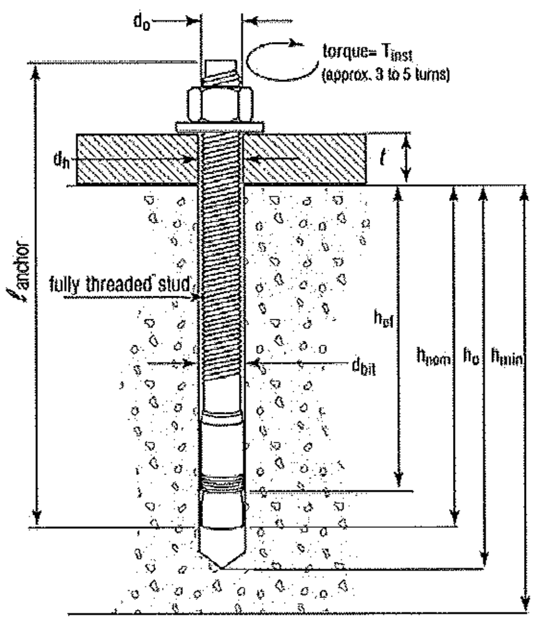


FIGURE 4—ITW RED HEAD TRUBOLT+ WEDGE ANCHOR (INSTALLED)

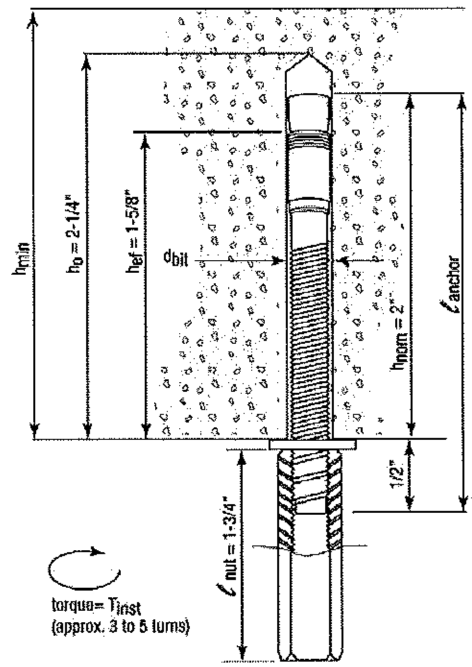
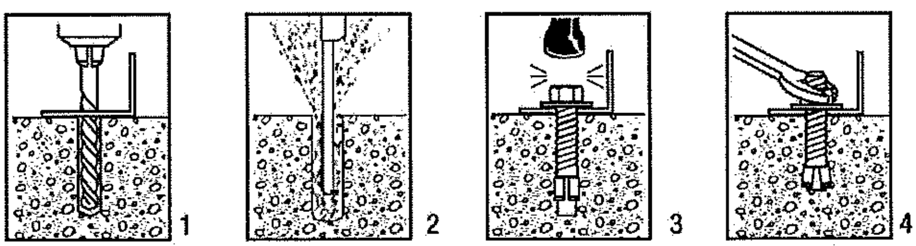


FIGURE 5—OVERHEAD TRUBOLT+ WEDGE ANCHOR (INSTALLED), $^3/_8$ INCH NOMINAL ANCHOR DIAMETER (d_o)



1. Select a carbide drill bit with a diameter equal to the anchor diameter. Drill hole 1/4" deeper than anchor embedment.
2. Clean hole with pressurized air or vacuum to remove any excess dust/debris.
3. Using the washer and nut provided, assemble the anchor, leaving nut one half turn from the end of anchor to protect threads. Drive anchor through fixture to be fastened until washer is flush to surface of fixture.
4. Expand anchor by tightening nut to the specified setting torque (approx 3-5 turns).

FIGURE 6—INSTALLATION INSTRUCTIONS

TABLE 3—ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR TENSION DESIGN INFORMATION[1,2,3,9]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)[6]									
			$^{3}/_{8}$		$^{1}/_{2}$				$^{5}/_{8}$		$^{3}/_{4}$	
Anchor category	1, 2 or 3	—	1		1				1		1	
Minimum effective embedment depth	h_{ef}	In.	$1^{5}/_{8}$		2		$3^{1}/_{4}$		$2^{3}/_{4}$	$4^{1}/_{4}$	$3^{3}/_{4}$	
Minimum concrete member thickness	h_{min}	In.	4	5	4	6	6	8	6	$6^{1}/_{4}$	7	8
Critical edge distance	c_{ac}	In.	5	3	6	6	$7^{1}/_{2}$	6	$7^{1}/_{2}$	$6^{1}/_{2}$	12	10
Data for Steel Strengths – Tension												
Minimum specified yield strength	f_y	psi	60,000		55,000				55,000		55,000	
Minimum specified ultimate strength	f_{uta}	psi	75,000		75,000				75,000		75,000	
Effective tensile stress area (neck)	$A_{se,N}$ $[A_{se}]^{8}$	in^2	0.056		0.119				0.183		0.266	
Steel strength in tension	N_{sa}	lbf	4,200		8,925				13,725		19,950	
Strength reduction factor ϕ for tension, steel failure modes[4]	ϕ	—	0.75		0.75				0.75		0.75	
Data for Concrete Breakout Strengths In Tension												
Effectiveness factor - uncracked concrete	k_{uncr}	—	24		24				24		24	
Effectiveness factor - cracked concrete	k_{cr}	—	17		17				17		17	
Modification factor for cracked and uncracked concrete[5]	$\Psi_{c,N}$	—	1.0		1.0				1.0		1.0	
Strength reduction factor ϕ for tension, concrete failure modes, Condition B[4]	ϕ	—	0.65		0.65				0.65		0.65	
Data for Pullout Strengths												
Pullout strength, uncracked concrete	$N_{p,uncr}$	lbf	See Footnote 7		See Footnote 7		6,540		5,430	8,900	See Footnote 7	
Pullout strength, cracked concrete	$N_{p,cr}$	lbf	See Footnote 7		See Footnote 7				See Footnote 7		See Footnote 7	
Pullout strength for seismic loads	N_{eq}	lbf	See Footnote 7		See Footnote 7				See Footnote 7	6,715	See Footnote 7	
Strength reduction factor ϕ for tension, pullout failure modes, Condition B[4]	ϕ	—	See Footnote 7		0.65				0.65		See Footnote 7	
Additional Anchor Data												
Axial stiffness in service load range in uncracked concrete	β_{uncr}	lbf /in	100,000		250,000				250,000		250,000	
Axial stiffness in service load range in cracked concrete	β_{cr}	lbf /in	40,000		20,000				20,000		20,000	

For **SI:** 1 inch = 25.4 mm, 1 in^2 = 645.16 mm^2, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa, 1 lbf · 10^2/in = 17,500 N/m.

[1]The data in this table is intended to be used with the design provisions of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable; for anchors resisting seismic load combinations, the additional requirements of ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable, shall apply.
[2]Installation must comply with the manufacturers printed installation instructions and details.
[3]The $^{3}/_{8}$-, $^{1}/_{2}$-, $^{5}/_{8}$-, and $^{3}/_{4}$-inch diameter Trubolt + Wedge Anchors are ductile steel elements under tension loading as defined by ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.
[4]All values of ϕ apply to the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable. If the load combinations of ACI 318-11 Appendix C are used, then the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For installations where reinforcement that complies with ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable, requirements for Condition A is present, the appropriate ϕ factor must be determined in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable.
[5]For all design cases $\Psi_{c,N}$ = 1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) must be used.
[6]The actual diameter for the $^{3}/_{8}$-inch diameter anchor is 0.361 inch, for the $^{5}/_{8}$-inch diameter anchor is 0.615-inch, and for the $^{3}/_{4}$-inch diameter anchor is 0.7482-inch.
[7]Anchor pullout strength does not control anchor design. Determine steel and concrete capacities only.
[8]The notation in brackets is for the 2006 IBC.
[9]The OVERHEAD version is available in a carbon steel $^{3}/_{8}$-inch-diameter only.

TABLE 4—ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR SHEAR DESIGN INFORMATION[1,2,3,8]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)[5]									
			3/8		1/2				5/8		3/4	
Anchor category	1, 2 or 3	—	1		1				1		1	
Minimum effective embedment depth	h_{ef}	In.	1 5/8		2		3 1/4		2 3/4	4 1/4	3 3/4	
Minimum concrete member thickness	h_{min}	In.	4	5	4	6	6	8	6	6 1/4	7	8
Critical edge distance	c_{ac}	In.	5	3	6	6	7 1/2	6	7 1/2	6 1/2	12	10
Data for Steel Strengths – Shear												
Minimum specified yield strength	f_y	psi	60,000		55,000				55,000		55,000	
Minimum specified ultimate strength	f_{uta}	psi	75,000		75,000				75,000		75,000	
Effective shear stress area (thread)	$A_{se,V}$ $[A_{se}]$[7]	in^2	0.075		0.142				0.217		0.332	
Steel strength in shear, uncracked or cracked concrete[6]	V_{sa}	lbf	1,830		5,175				8,955		14,970	
Steel strength in shear - seismic loads	V_{eq}	lbf	1,545		5,175				8,955		11,775	
Strength reduction factor ϕ for shear, steel failure modes[4]	ϕ	—	0.60		0.65				0.65		0.65	
Data for Concrete Breakout and Concrete Pryout Strengths – Shear												
Coefficient for pryout strength	k_{cp}	—	1.0		1.0		2.0		2.0		2.0	
Load-bearing length of anchor	l_e	in	1 5/8		2		3 1/4		2 3/4	4 1/4	3 3/4	
Strength reduction factor ϕ for shear, concrete failure modes, Condition B[4]	ϕ	—	0.70		0.70				0.70		0.70	

For **SI:** 1 inch = 25.4 mm, 1 in^2 = 645.16 mm^2, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa, 1 lbf · 10^2/in = 17,500 N/m.

[1]The data in this table is intended to be used with the design provisions of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable; for anchors resisting seismic load combinations, the additional requirements of ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable, shall apply.
[2]Installation must comply with the manufacturers printed installation instructions and details.
[3]The 1/2-, 5/8-, and 3/4-inch diameter Trubolt + Wedge Anchors are ductile steel elements under shear loading as defined by ACI 318-14 2.3 or ACI 318-11 D.1. The 3/8" diameter Trubolt + is considered brittle under shear loading.
[4]All values of ϕ apply to the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 Section 9.2, as applicable. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For installations where reinforcement that complies with ACI 318-14 Chapter 17 or ACI 318-11 Appendix D requirements for Condition A is present, the appropriate ϕ factor must be determined in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable.
[5]The actual diameter for the 3/8" diameter anchor is 0.361-inch, for the 5/8" diameter anchor is 0.615-inch, and for the 3/4" diameter anchor is 0.7482".
[6]Steel strength in shear values are based on test results per ACI 355.2, Section 9.4 and must be used for design.
[7]The notation in brackets is for the 2006 IBC.
[8]The OVERHEAD version is available in a carbon steel 3/8-inch-diameter only.

TABLE 5—ITW RED HEAD STAINLESS STEEL TRUBOLT+ WEDGE ANCHOR TENSION DESIGN INFORMATION[1,2,3]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)[6]					
			$\frac{1}{2}$				$\frac{5}{8}$	
Anchor category	1, 2 or 3	—	1				1	
Minimum effective embedment depth	h_{ef}	In.	2		$3\frac{1}{4}$		$2\frac{3}{4}$	$4\frac{1}{4}$
Minimum concrete member thickness	h_{min}	In.	4	6	6	8	6	$6\frac{1}{4}$
Critical edge distance	c_{ac}	In.	6	6	$7\frac{1}{2}$	6	$7\frac{1}{2}$	$6\frac{1}{2}$
Data for Steel Strengths – Tension								
Minimum specified yield strength	f_y	psi	65,000				65,000	
Minimum specified ultimate strength	f_{uta}	psi	100,000				100,000	
Effective tensile stress area (neck)	$A_{se,N}$ $[A_{se}]$[8]	in^2	0.119				0.183	
Steel strength in tension	N_{sa}	lbf	11,900				18,300	
Strength reduction factor ϕ for tension, steel failure modes[4]	ϕ	—	0.75				0.75	
Data for Concrete Breakout Strengths in Tension								
Effectiveness factor - uncracked concrete	k_{uncr}	—	24				24	
Effectiveness factor - cracked concrete	k_{cr}	—	17				17	
Modification factor for cracked and uncracked concrete[5]	$\Psi_{c,N}$	—	1.0				1.0	
Strength reduction factor ϕ for tension, concrete failure modes, Condition B[4]	ϕ	—	0.65				0.65	
Data for Pullout Strengths								
Pullout strength, uncracked concrete	$N_{p,uncr}$	lbf	See Footnote 7		6,540		5,430	8,900
Pullout strength, cracked concrete	$N_{p,cr}$	lbf	See Footnote 7				See Footnote 7	
Pullout strength for seismic loads	N_{eq}	lbf	2,345		See Footnote 7		See Footnote 7	
Strength reduction factor ϕ for tension, pullout failure modes, Condition B[4]	ϕ	—	0.65				0.65	
Additional Anchor Data								
Axial stiffness in service load range in uncracked concrete	β_{uncr}	lbf /in	250,000				250,000	
Axial stiffness in service load range in cracked concrete	β_{cr}	lbf /in	20,000				20,000	

For **SI:** 1 inch = 25.4 mm, 1 in^2 = 645.16 mm^2, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa, 1 lbf · 10^2/in = 17,500 N/m.

[1]The data in this table is intended to be used with the design provisions of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable; for anchors resisting seismic load combinations, the additional requirements of ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable, shall apply.
[2]Installation must comply with the manufacturers printed installation instructions and details.
[3]The $\frac{1}{2}$- and $\frac{5}{8}$-,inch diameter Trubolt + Wedge Anchors are ductile steel elements as defined by ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.
[4]All values of ϕ apply to the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For installations where reinforcement that complies with ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable, requirements for Condition A is present, the appropriate ϕ factor must be determined in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable.
[5]For all design cases $\Psi_{c,N}$ = 1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) must be used.
[6]The actual diameter for the $\frac{5}{8}$-inch diameter anchor is 0.615-inch.
[7]Anchor pullout strength does not control anchor design. Determine steel and concrete capacities only.
[8]The notation in brackets is for the 2006 IBC.

TABLE 6—ITW RED HEAD STAINLESS STEEL TRUBOLT+ WEDGE ANCHOR SHEAR DESIGN INFORMATION[1,2,3]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)[5]					
			$^1/_2$				$^5/_8$	
Anchor category	1, 2 or 3	—	1				1	
Minimum effective embedment depth	h_{ef}	In.	2		$3^1/_4$		$2^3/_4$	$4^1/_4$
Minimum concrete member thickness	h_{min}	In.	4	6	6	8	6	$6^1/_4$
Critical edge distance	c_{ac}	In.	6	6	$7^1/_2$	6	$7^1/_2$	$6^1/_2$
Data for Steel Strengths - Shear								
Minimum specified yield strength	f_y	psi	65,000				65,000	
Minimum specified ultimate strength	f_{uta}	psi	100,000				100,000	
Effective shear stress area (thread)	$A_{se,V}$ $[A_{se}]$[7]	in^2	0.142				0.217	
Steel strength in shear, uncracked or cracked concrete[6]	V_{sa}	lbf	7,265				10,215	
Steel strength in shear - seismic loads	V_{eq}	lbf	5,805				8,105	
Strength reduction factor ϕ for shear, steel failure modes[4]	ϕ	—	0.65				0.65	
Data for Concrete Breakout and Concrete Pryout Strengths - Shear								
Coefficient for pryout strength	k_{cp}	—	1.0		2.0		2.0	
Load-bearing length of anchor	l_e	in	2		$3^1/_4$		$2^3/_4$	$4^1/_4$
Strength reduction factor ϕ for shear, concrete failure modes, Condition B[4]	ϕ	—	0.70				0.70	

For **SI:** 1 inch = 25.4 mm, 1 in^2 = 645.16 mm^2, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa, 1 lbf · 10^2/in = 17,500 N/m.

[1]The data in this table is intended to be used with the design provisions of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable; for anchors resisting seismic load combinations, the additional requirements of ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable, shall apply.

[2]Installation must comply with the manufacturers printed installation instructions and details.

[3]The $^1/_2$- and $^5/_8$-inch diameter Trubolt + Wedge Anchors are ductile steel elements as defined by ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.

[4]All values of ϕ apply to the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For installations where reinforcement that complies with ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable, requirements for Condition A is present, the appropriate ϕ factor must be determined in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable.

[5]The actual diameter for the $^5/_8$" diameter anchor is 0.615-inch.

[6]Steel strength in shear values are based on test results per ACI 355.2, Section 9.4 and must be used for design.

[7]The notation in brackets is for the 2006 IBC.

TABLE 7—EXAMPLE ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR ALLOWABLE STRESS DESIGN (ASD) VALUES FOR ILLUSTRATIVE PURPOSES[1,2,3,4,5,6,7,8,9,10]

ANCHOR NOTATION	ANCHOR EMBEDMENT DEPTH (inches), h_{nom}	EFFECTIVE EMBEDMENT DEPTH (inches), h_{ef}	ALLOWABLE TENSION LOAD (lbs)
$^3/_8$	2	$1^5/_8$	1,090
$^1/_2$	$2^1/_2$	2	1,490
	$3^3/_4$	$3^1/_4$	2,870
$^5/_8$	$3^1/_4$	$2^3/_4$	2,385
	$4^3/_4$	$4^1/_4$	3,910
$^3/_4$	$4^3/_8$	$3^3/_4$	3,825

For **SI:** 1 inch = 25.4 mm, 1 lbf = 4.45 N.

Design assumptions:

[1]Single anchor with static tension load only.
[2]Concrete determined to remain uncracked for the life of the anchorage.
[3]Load combinations are in accordance with ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable, and no seismic loading.
[4]30 percent dead load and 70 percent live load, controlling load combination 1.2*D* + 1.6*L*.
[5]Calculation of weighted average for α: 1.2*D* + 1.6*L* = 1.2(0.3) + 1.6(0.7) = 1.48.
[6]f'_c = 2,500 psi (normal-weight concrete).
[7]$c_{a1} = c_{a2} > = c_{ac}$.
[8]$h \geq h_{min}$.
[9]Values are for Condition B where supplementary reinforcement in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, is not provided.
[10]The Overhead Trubolt+ Wedge version is available in a carbon steel $^3/_8$-inch-diameter only.

Illustrative Procedure to Calculate Allowable Stress Design Tension Value:

RED HEAD Carbon Steel Trubolt+ Wedge Anchor $^1/_2$ inch diameter using an effective embedment of $3^1/_4$ inches, assuming the given conditions in Table 3, in accordance with ACI 318-14 Chapter 17, ACI 318-11 Appendix D and this report.

	PROCEDURE		CALCULATION
Step 1	Calculate steel strength of a single anchor in tension per ACI 318-14 17.4.1.2, ACI 318-11 D 5.1.2, Table 3 of this report	ϕN_{sa}	$= \phi N_{sa}$ =0.75*8,925 **=6,694 lbs steel strength**
Step 2	Calculate concrete breakout strength of a single anchor in tension per ACI 318-14 17.4.2.1, ACI 318-11 D 5.2.1, Table 3 of this report	N_b	$= k_{uncr} * \lambda_a * \sqrt{f'_c} * h_{ef}^{1.5}$ $= 24 * 1.0 * \sqrt{2{,}500} * 3.25^{1.5}$ = 7,031 lbs
		ϕN_{cb}	$= \phi A_{NC}/A_{NC0}\ \psi_{ed,N}\ \psi_{c,N}\ \psi_{cp,N}\ N_b$ = 0.65*(95/95)/1.0*1.0*1.0*7,031 = 0.65*7,031 **= 4,570 lbs concrete breakout strength**
Step 3	Calculate pullout strength in tension per ACI 318-14 17.4.3.2, ACI 318-11 D 5.3.2, Table 3 of this report	ϕN_{pn}	$= \phi N_{p,uncr}\ \psi_{c,P}\ (f'_{c,act}/2{,}500)^n$ $= 0.65*6{,}540*1.0*1.0^{0.5}$ **= 4,251 lbs pullout strength**
Step 4	Determine controlling resistance strength in tension per ACI 318-14 17.3.1.1, ACI 318-11 D 4.1.1		**= 4,251 lbs controlling resistance**
Step 5	Calculate allowable stress design conversion factor for loading condition per ACI 318-14 Section 5.3, ACI 318-11 Section 9.2	α	=1.2*D* + 1.6*L* =1.2(0.3) + 1.6(0.7) **=1.48**
Step 6	Calculate allowable stress design value per Section 4.2 of this report	$T_{allowable,ASD}$	$= \phi N_n / \alpha$ = 4,251 / 1.48 **= 2,870 lbs allowable stress design**

TABLE 8—ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR INSTALLATION INFORMATION FOR ANCHORS LOCATED IN THE SOFFIT OF CONCRETE FILL ON METAL DECK FLOOR AND ROOF ASSEMBLIES[1,3]

PARAMETER	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)				
			$^{3}/_{8}$	$^{1}/_{2}$		$^{5}/_{8}$	
Anchor outer diameter	$d_a[d_o]^2$	inches	0.361	0.5		0.615	
Nominal carbide bit diameter	d_{bit}	inches	$^{3}/_{8}$	$^{1}/_{2}$		$^{5}/_{8}$	
Location of Installation	-	-	upper and lower flute	upper and lower flute	lower flute	lower flute	
Minimum effective embedment depth	h_{ef}	Inches	$1^{5}/_{8}$	2	$3^{1}/_{4}$	$2^{3}/_{4}$	$4^{1}/_{4}$
Anchor embedment depth	h_{nom}	Inches	2	$2^{1}/_{2}$	$3^{3}/_{4}$	$3^{1}/_{4}$	$4^{3}/_{4}$
Minimum hole depth	h_o	Inches	$2^{1}/_{4}$	$2^{3}/_{4}$	4	$3^{1}/_{2}$	5
Minimum overall anchor length	l_{anchor}	Inches	$2^{1}/_{2}$	$3^{3}/_{4}$	$4^{1}/_{2}$	$4^{1}/_{4}$	6
Installation torque	T_{inst}	ft-lb	30	45		90	
Minimum diameter of hole in fastened part	d_h	inches	$^{1}/_{2}$	$^{5}/_{8}$		$^{3}/_{4}$	

For **SI**: 1 inch = 25.4 mm, 1 ft-lb = 1.356 N-m.

[1]Anchors in the lower and upper flute may be installed with a maximum 1-inch offset in either direction from the center of the flute. In addition, anchors must have an axial spacing along the flute equal to the greater of $3h_{ef}$ or 1.5 times the flute width.
[2]The notation in brackets is for the 2006 IBC.
[3]The Overhead Trubolt+ Wedge version is available in a carbon steel $^{3}/_{8}$-inch-diameter only.

TABLE 9—ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD TRUBOLT+ WEDGE ANCHOR DESIGN INFORMATION FOR ANCHORS LOCATED IN THE SOFFIT OF CONCRETE FILL ON METAL DECK FLOOR AND ROOF ASSEMBLIES[1,2]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)				
			$^{3}/_{8}$	$^{1}/_{2}$		$^{5}/_{8}$	
Location of Installation	-	-	upper and lower flute	upper and lower flute	lower flute	lower flute	
Minimum effective embedment depth	h_{ef}	inches	$1^{5}/_{8}$	2	$3^{1}/_{4}$	$2^{3}/_{4}$	$4^{1}/_{4}$
Characteristic pullout strength, uncracked concrete over metal deck	$N_{p,\ deck,\ uncr}{}^{1}$	lbf	2,170	2,515	5,285	3,365	6,005
Characteristic pullout strength, cracked concrete over metal deck	$N_{p,\ deck,\ cr}{}^{1}$	lbf	1,650	1,780	4,025	2,405	5,025
Characteristic shear strength, concrete over metal deck	$V_{sa,\ deck}{}^{1}$	lbf	1,640[3]	2,200	3,790	2,890	6,560
Reduction factor for pullout strength in tension, Condition B	ϕ	-	0.65	0.65		0.65	
Reduction factor for steel strength in shear, Condition B	ϕ	-	0.60	0.65		0.65	

For **SI**: 1 inch = 25.4 mm, 1 lbf = 4.45 N.

[1]Values for $N_{p,deck}$ and $V_{sa,deck}$ apply to sand-lightweight concrete having a minimum concrete compressive strength, f'_c, of 3,000 psi [minimum of 24 MPa is requiredunder ADIBC Appendix L, Section 5.1.1].
[2]All values of ϕ apply to the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4. For installations where reinforcement that complies with ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable, requirements for Condition A is present, the appropriate ϕ factor must be determined in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable.
[3]For seismic applications according to Section 4.10.3 of this report multiply the value of $V_{sa,deck}$ by 0.84.

2020

ICC-ES Evaluation Report

ESR-2427 FBC Supplement

Reissued November 2016

This report is subject to renewal November 2017.

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DIVISION: 03 00 00—CONCRETE
Section: 03 16 00—Concrete Anchors

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-installed Concrete Anchors

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EVALUATION SUBJECT:

ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHORS, STAINLESS STEEL TRUBOLT+ WEDGE ANCHORS AND CARBON STEEL OVERHEAD TRUBOLT+ WEDGE ANCHORS FOR CRACKED AND UNCRACKED CONCRETE

1.0 REPORT PURPOSE AND SCOPE

Purpose:

The purpose of this evaluation report supplement is to indicate that ITW Red Head Trubolt+ Wedge Anchors and OVERHEAD Trubolt+ Wedge Anchors for Cracked and Uncracked Concrete, recognized in ICC-ES master evaluation report ESR-2427, have also been evaluated for compliance with the codes noted below.

Applicable code editions:

- 2014 and 2010 *Florida Building Code—Building*
- 2014 and 2010 *Florida Building Code—Residential*

2.0 CONCLUSIONS

The ITW Red Head Trubolt+ Wedge Anchors and OVERHEAD Trubolt+ Wedge Anchors for Cracked and Uncracked Concrete, described in Sections 2.0 through 7.0 of the master evaluation report ESR-2427, comply with the 2014 and 2010 *Florida Building Code—Building* and the 2014 and 2010 *Florida Building Code—Residential*, provided the design and installation are in accordance with the 2012 *International Building Code®* provisions noted in the master report and the following provisions apply:

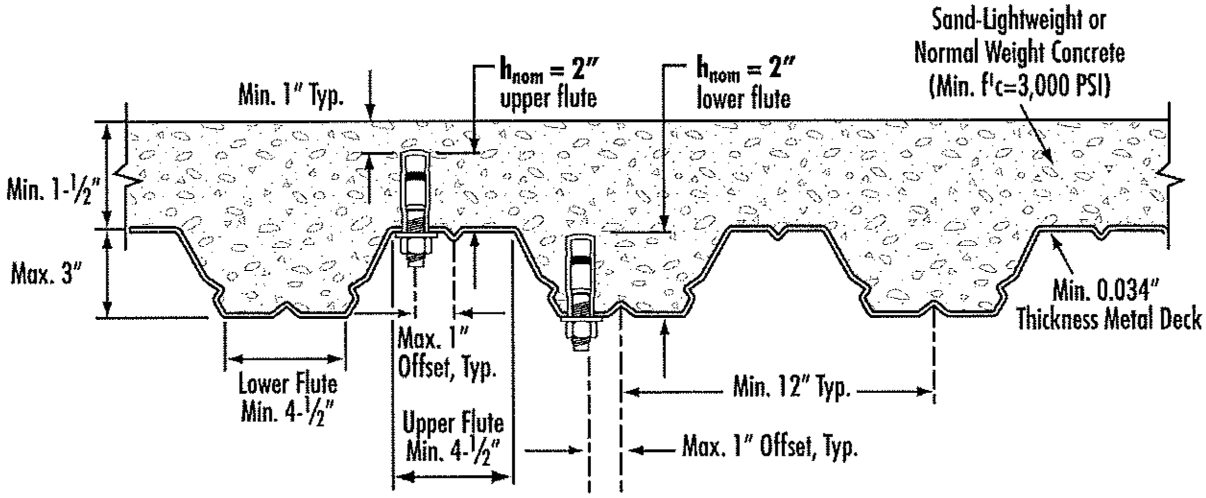
- Design wind loads must be based on Section 1609 of the 2014 and 2010 *Florida Building Code—Building* or Section 301.2.1.1 of the 2014 and 2010 *Florida Building Code—Residential*, as applicable.
- Load combinations must be in accordance with Section 1605.2 or Section 1605.3 of the 2014 and 2010 *Florida Building Code—Building*, as applicable.

Use of the ITW Red Head Trubolt+ Wedge Anchors and OVERHEAD Trubolt+ Wedge Anchors for Cracked and Uncracked Concrete for compliance with the High-Velocity Hurricane Zone provisions of the 2014 and 2010 *Florida Building Code—Building* and the 2014 and 2010 *Florida Building Code—Residential* has not been evaluated, and is outside the scope of this supplemental report.

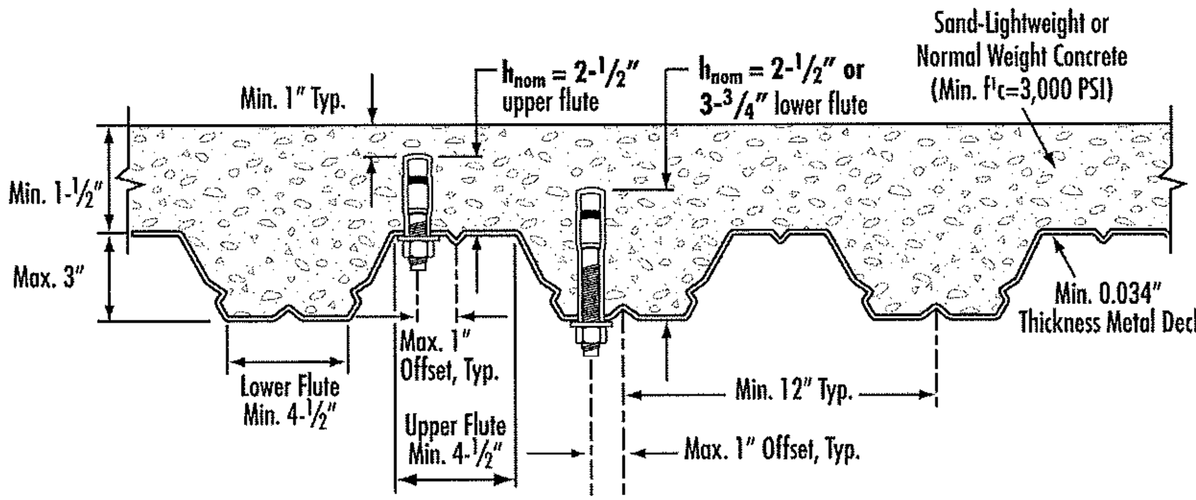
For products falling under Florida Rule 9N-3, verification that the report holder's quality-assurance program is audited by a quality-assurance entity approved by the Florida Building Commission for the type of inspections being conducted is the responsibility of an approved validation entity (or the code official when the report holder does not possess an approval by the Commission).

This supplement expires concurrently with the master report, reissued November 2016.

Nominal Anchor Diameter = 3/8"



Nominal Anchor Diameter = 1/2"



Nominal Anchor Diameter = 5/8"

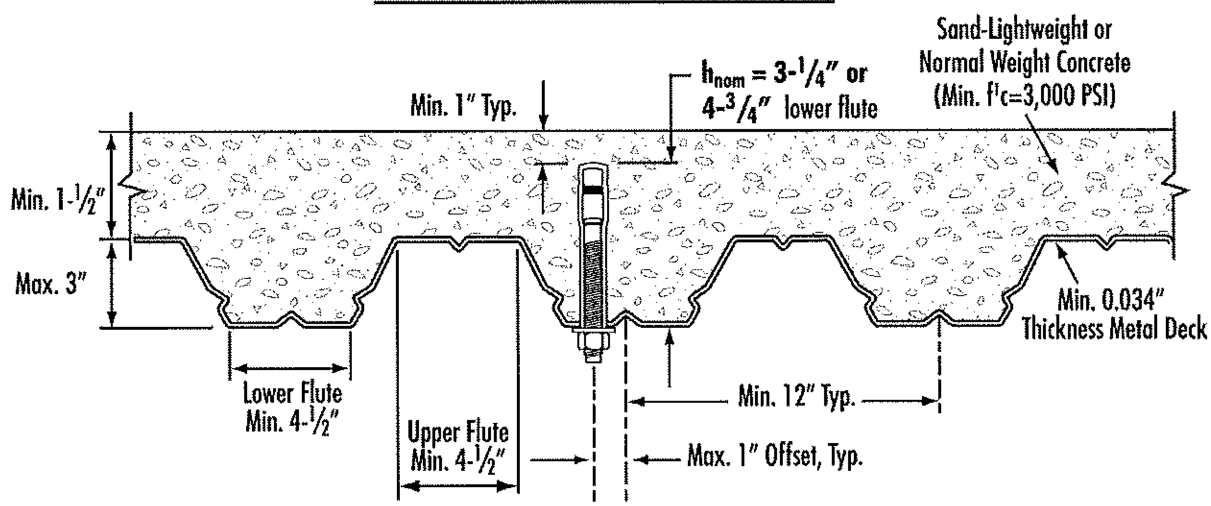


FIGURE 7—ITW RED HEAD CARBON STEEL TRUBOLT+ WEDGE ANCHOR AND OVERHEAD` TRUBOLT+ WEDGE ANCHOR LOCATED IN THE SOFFIT OF CONCRETE OVER STEEL DECK FLOOR AND ROOF ASSEMBLIES (1 inch = 25.4 mm)

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PROJECT NO. ____ SHEET 2022 OF ____

PROJECT NAME ____ DESIGNED BY AF DATE ____

SUBJECT ____ CHECKED BY ____ DATE ____

Base plate to wood

wood Specific weight = 0.43

Tension: $\frac{M}{d} = \frac{50^{lb/f} * 5' * 42''}{3.5''} = 3{,}000$ lb

Adjustment for wood bearing

$C_b = (4'' + 0.375)/4'' = 1.093$

$a = \frac{3000}{1.093 * 625_{psi} * 4''} = 1.093$

Tension = $T = \frac{50^{lb/f} * 5' * 42''}{(3.5 - \frac{1.09}{2})} = 3553$ lb

$\frac{3}{8}''$ ϕ lag screw w/8" min Embed tension

Capacity = $243^{lb} * 8'' = 1944^{lb}$ (Page

2-lag screws capacity = 2*1944 = 3888 lb > 3553^{lb}

USE [4 - $\frac{3}{8}''$ lag screws w/8" min Embed]

2023

Table 12.2A Lag Screw Reference Withdrawal Design Values, W[1]

Tabulated withdrawal design values (W) are in pounds per inch of thread penetration into side grain of wood member. Length of thread penetration in main member shall not include the length of the tapered tip (see 12.2.1.1).

Specific Gravity, G[2]	Lag Screw Diameter, D										
	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"	1-1/8"	1-1/4"
0.73	397	469	538	604	668	789	905	1016	1123	1226	1327
0.71	381	450	516	579	640	757	868	974	1077	1176	1273
0.68	357	422	484	543	600	709	813	913	1009	1103	1193
0.67	349	413	473	531	587	694	796	893	987	1078	1167
0.58	281	332	381	428	473	559	641	719	795	869	940
0.55	260	307	352	395	437	516	592	664	734	802	868
0.51	232	274	314	353	390	461	528	593	656	716	775
0.50	225	266	305	342	378	447	513	576	636	695	752
0.49	218	258	296	332	367	434	498	559	617	674	730
0.47	205	242	278	312	345	408	467	525	580	634	686
0.46	199	235	269	302	334	395	453	508	562	613	664
0.44	186	220	252	283	312	369	423	475	525	574	621
0.43	179	212	243	273	302	357	409	459	508	554	600
0.42	173	205	235	264	291	344	395	443	490	535	579
0.41	167	198	226	254	281	332	381	428	473	516	559
0.40	161	190	218	245	271	320	367	412	455	497	538
0.39	155	183	210	236	261	308	353	397	438	479	518
0.38	149	176	202	227	251	296	340	381	422	461	498
0.37	143	169	194	218	241	285	326	367	405	443	479
0.36	137	163	186	209	231	273	313	352	389	425	460
0.35	132	156	179	200	222	262	300	337	373	407	441
0.31	110	130	149	167	185	218	250	281	311	339	367

1. Tabulated withdrawal design values, W, for lag screw connections shall be multiplied by all applicable adjustment factors (see Table 11.3.1).
2. Specific gravity, G, shall be determined in accordance with Table 12.3.3A.

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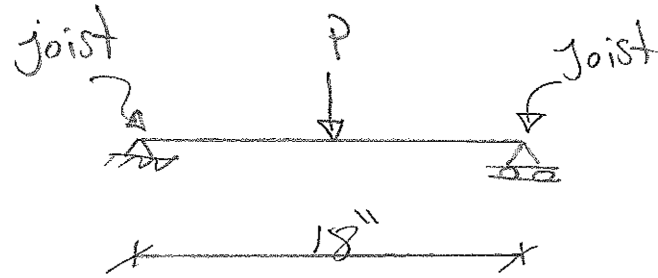
PROJECT NO. ______ SHEET 2024 OF ______

PROJECT NAME ______ DESIGNED BY AF DATE ______

SUBJECT ______ CHECKED BY ______ DATE ______

Base plate to wood

$P = 3000$ lb



Use blocking [3-2x6 w/ 4-$\frac{3}{8}$"ϕ thru-bolt]

2025

WoodWorks® SOFTWARE FOR WOOD DESIGN	COMPANY Dec. 5, 2016 16:51	PROJECT Stainless cable & Railing 216-2 AF Wood Block wood block.wwb

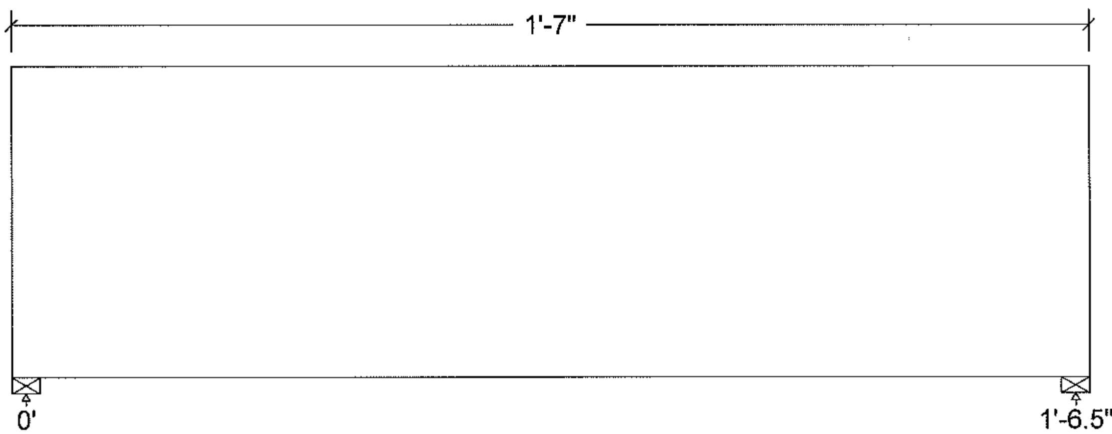
Design Check Calculation Sheet

WoodWorks Sizer 10.42

Loads:

Load	Type	Distribution	Pat-tern	Location [ft] Start	Location [ft] End	Magnitude Start	Magnitude End	Unit
Load1	Dead	Point		0.75		-3000		lbs
Self-weight	Dead	Full UDL				6.2		plf

Maximum Reactions (lbs), Bearing Capacities (lbs) and Bearing Lengths (in) :



	0'		1'-6.5"
Unfactored:			
Dead	5		5
Factored:			
Uplift	1576		1414
Total	5		5
Bearing:			
Capacity			
Beam	1114		1114
Support	1836		1836
Anal/Des			
Beam	0.00		0.00
Support	0.00		0.00
Load comb	#1		#1
Length	0.50*		0.50*
Min req'd	0.50*		0.50*
Cb	1.00		1.00
Cb min	1.00		1.00
Cb support	1.07		1.07
Fcp sup	625		625

*Minimum bearing length setting used: 1/2" for end supports

Timber-soft, Hem-Fir, No.2, 6x6 (5-1/2"x5-1/2")

Supports: All - Timber-soft Beam, D.Fir-L No.2

Total length: 1'-7.0"; volume = 0.3 cu.ft.; Post and timber;

Lateral support: top= at supports, bottom= at supports;

Analysis vs. Allowable Stress and Deflection using NDS 2012 :

Criterion	Analysis Value	Design Value	Unit	Analysis/Design
Shear	fv = 78	Fv' = 126	psi	fv/Fv' = 0.62
Bending(-)	fb = 498	Fb' = 517	psi	fb/Fb' = 0.96
Live Defl'n	negligible			
Total Defl'n	-0.01 = <L/999	0.08 = L/240	in	0.09

Additional Data:

FACTORS:	F/E(psi)	CD	CM	Ct	CL	CF	Cfu	Cr	Cfrt	Ci	Cn	LC#
Fv'	140	0.90	1.00	1.00	-	-	-	-	1.00	1.00	1.00	1
Fb'-	575	0.90	1.00	1.00	1.000	1.000	1.00	1.00	1.00	1.00	-	1
Fcp'	405	-	1.00	1.00	-	-	-	-	1.00	1.00	-	-
E'	1.1 million		1.00	1.00	-	-	-	-	1.00	1.00	-	1

CRITICAL LOAD COMBINATIONS:

Shear : LC #1 = D only, V = 1581, V design = 1581 lbs
Bending(-): LC #1 = D only, M = 1151 lbs-ft
Deflection: LC #1 = D only (total)
D=dead L=live S=snow W=wind I=impact Lr=roof live Lc=concentrated E=earthquake
All LC's are listed in the Analysis output
Load combinations: ASCE 7-10 / IBC 2012

CALCULATIONS:

Deflection: EI = 83.9e06 lb-in2
"Live" deflection = Deflection from all non-dead loads (live, wind, snow…)
Total Deflection = 1.50(Dead Load Deflection) + Live Load Deflection.

Design Notes:

1. WoodWorks analysis and design are in accordance with the ICC International Building Code (IBC 2012), the National Design Specification (NDS 2012), and NDS Design Supplement.
2. Please verify that the default deflection limits are appropriate for your application.
3. Sawn lumber bending members shall be laterally supported according to the provisions of NDS Clause 4.4.1.