STRESS ANALYSIS

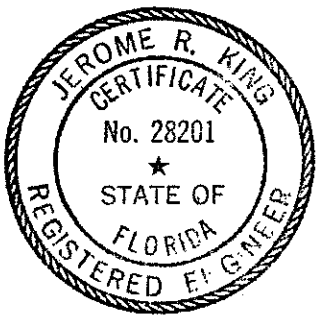
Tower Tech model TTXL-12 & TTXR-12
12' legs & 7' legs

FOR

TOWER TECH, Inc.

BY

J.R. KING ENGINEERING



I HEREBY CERTIFY THAT THESE CALCULATIONS WAS PREPARED BY ME AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF Florida.

SIGNED:

DATE: 12/17/16

REG. NO. 28201

J.R. KING ENGINEERING

10890 NORTHMARK DRIVE
EDEN PRAIRIE, MN 55344
952 944-1391
JRKINGENG@COMCAST.NET

Title:
Fiberglass modular cooling tower – TTXL-12 & TTXR-12
12' legs & 7' legs

Purpose:
Analyze and design the components of the fiberglass cooling tower.

References:

1. AISC, Steel Construction Manual, 8th edition
2. Structural Engineering Handbook, 2ND edition
   By Gaylord & Gaylord, 1973 McGraw-Hill
3. Aluminum Structures, 2nd edition
   By J. Randolph Kissell & Robert Ferry
4. Risa3d – Rapid interactive structural analysis,
   three dimensional, computer software

Specifications:

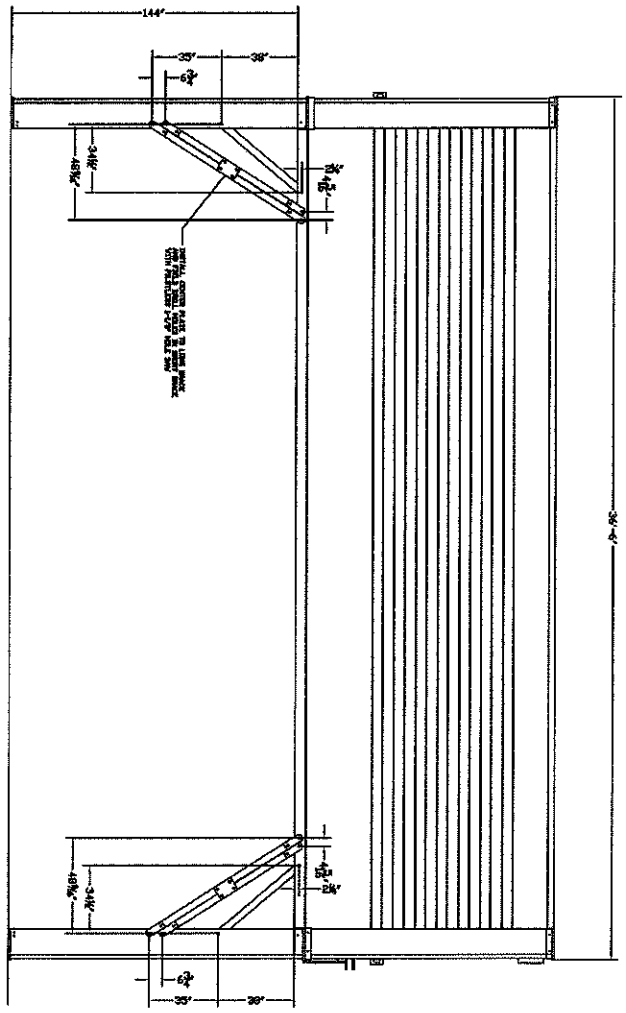
1. Tower Tech tests and material properties data
2. Creative Pultrusions, Inc. material properties data

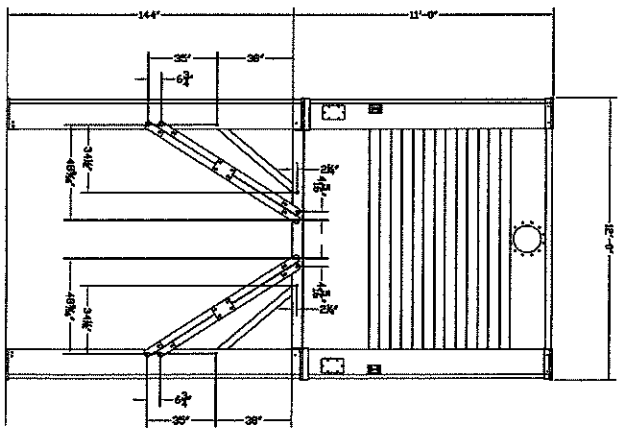
Design Requirements:
The design loads shall be in accordance with the IBC (International Building Code). Wind, seismic and gravity loadings are applied. The illustrated tower shell and substructure is designed to withstand a wind pressure of 91.6 psf. (ASCE7-10 200 mph wind, exposure C) and a seismic force factors: SDC E, Ss = 3, S1 = 2, soil class D.

Procedures:
Procedures are the methodologies indicated in the listed references, as specifically presented within the calculations. To use the AISC equations and built-in sections within risa3d, the fiberglass properties have been put in place of the steel; the printouts that have "Steel" headings are calculated as fiberglass and should be interpreted as such. The properties of the fill material are based on actual in-house tests. Safety factors are calculated and compared to those for steel, aluminum, and wood.

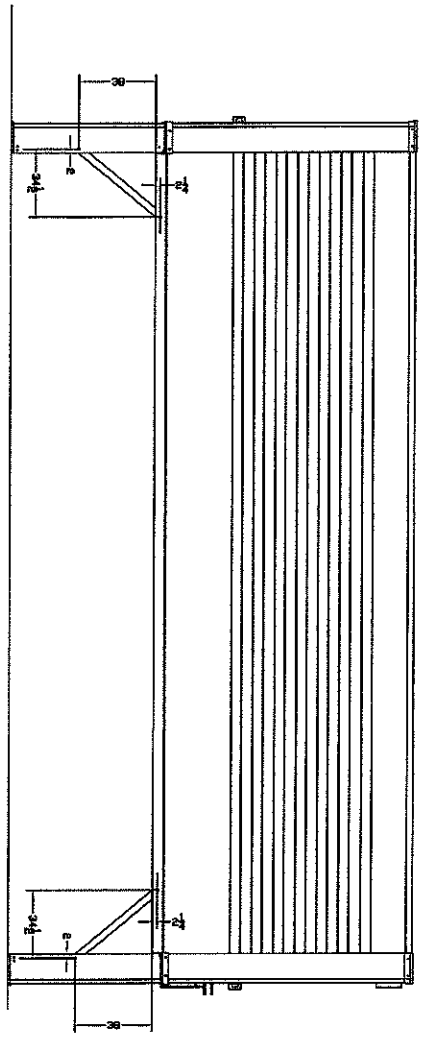
Conclusions:
The analysis and design of the subject cooling tower and their appurtenances have been completed satisfactorily.

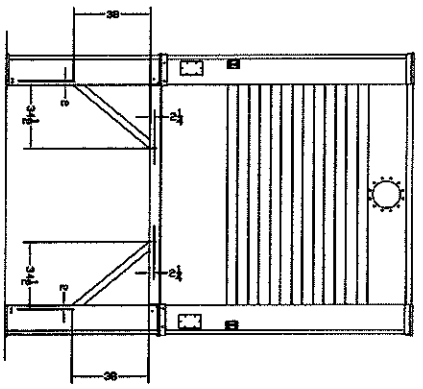
OPTIONAL BRACING UP TO 144 INCH SUBSTRUCTURE





STANDARD BRACING UP TO 84 INCH SUBSTRUCTURE





DATE:	28 Apr 2016
DRAWN/APP:	
PROJECT#:	
DWG TYPE:	SPECIAL
DRAWN BY:	BW
CHECKED BY:	

10

CONSTRUCTION LIBRARY DRAWING

Bracing Scheme for Seismic and Wind Load Applications

TTXL-12 & TTXR-12

Model #

TOWER TECH, Inc.
THE TECHNOLOGY COMPANY
Oklahoma City, Oklahoma

Modular Cooling Tower

LATERAL FORCES

Lateral Wind

200 mph, exposure "C" RISK III OR IV

qz = .00256(200)*2x.9x.9=82.9

Fx=82.9x.85.1.3xAf=91.6Af

Seismic Forces

Largest spectral response accelerations

Ss = 300%g, S1 = 200%g Soil class "D" , Fa = 1.0, Fv = 1.5

Sms = 1 x 3.0 = 3.0 Sds = 2/3 x Sms = 2.0

Sm1 = 1.5 x 2 = 3.0 Sd1 = 2/3 x Sm1 = 2.0

Importance Factor = 1.0

Seismic Design Category = E

Select R = 3.0 Omega = 2 Cd = 2.5 (table 15.4-1)

Elevated tanks, vessels, on symmetrically braced legs (sec 15.7.10)

ASCE/SEI 7-10 (Chapter 15)

Section 15.4 go to Section 12.8

Seismic base shear: V = Cs x W

Operational weight, W= 37,623 lbs

Cs = Sds/(R/I) = 2/3

V=Cs x W = 25,082 lbs

SECTION 1609 WIND LOADS

FIGURE 1609A ULTIMATE DESIGN WIND SPEEDS, V_{alt} FOR RISK CATEGORY II BUILDINGS AND OTHER STRUCTURES

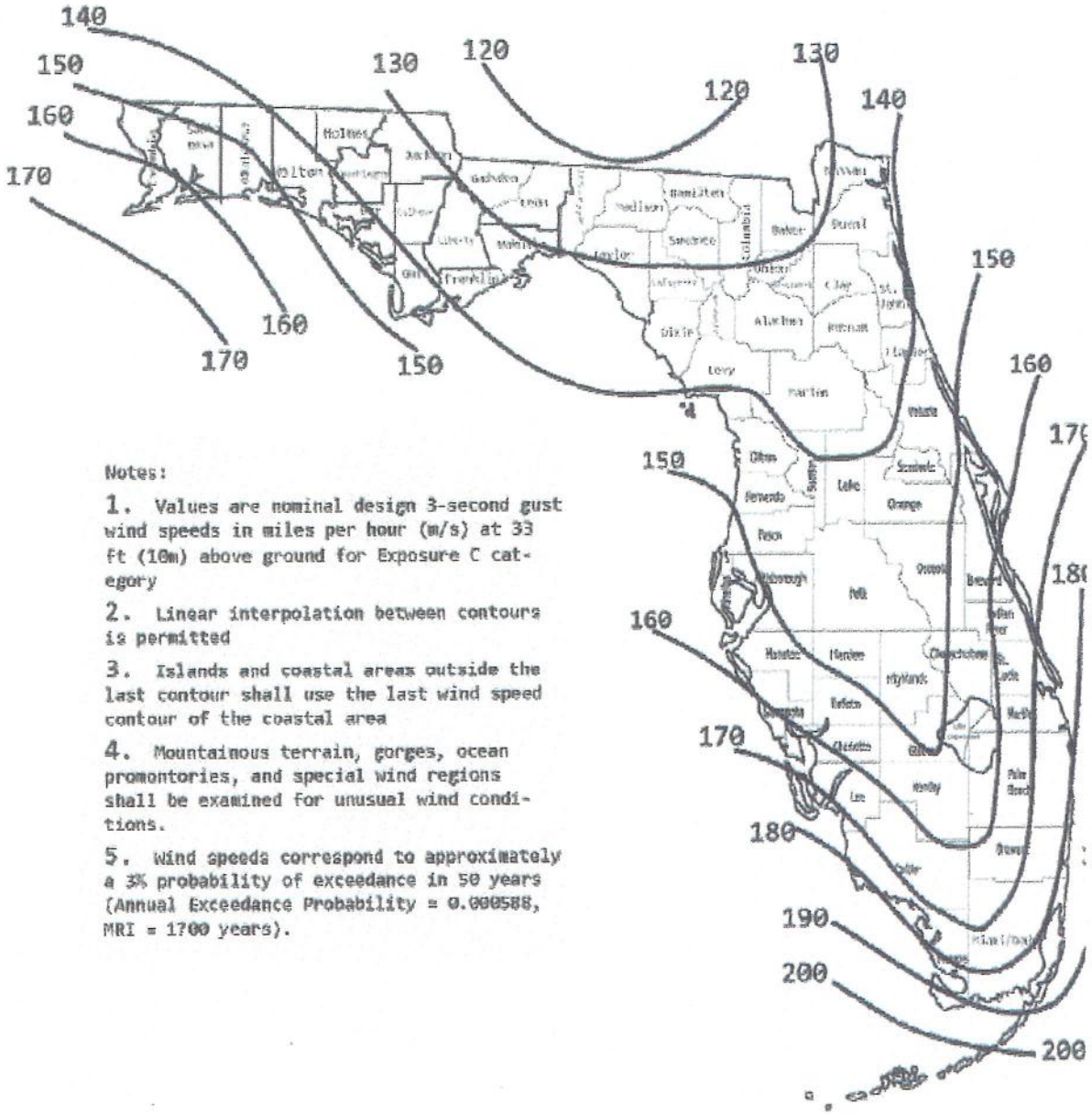
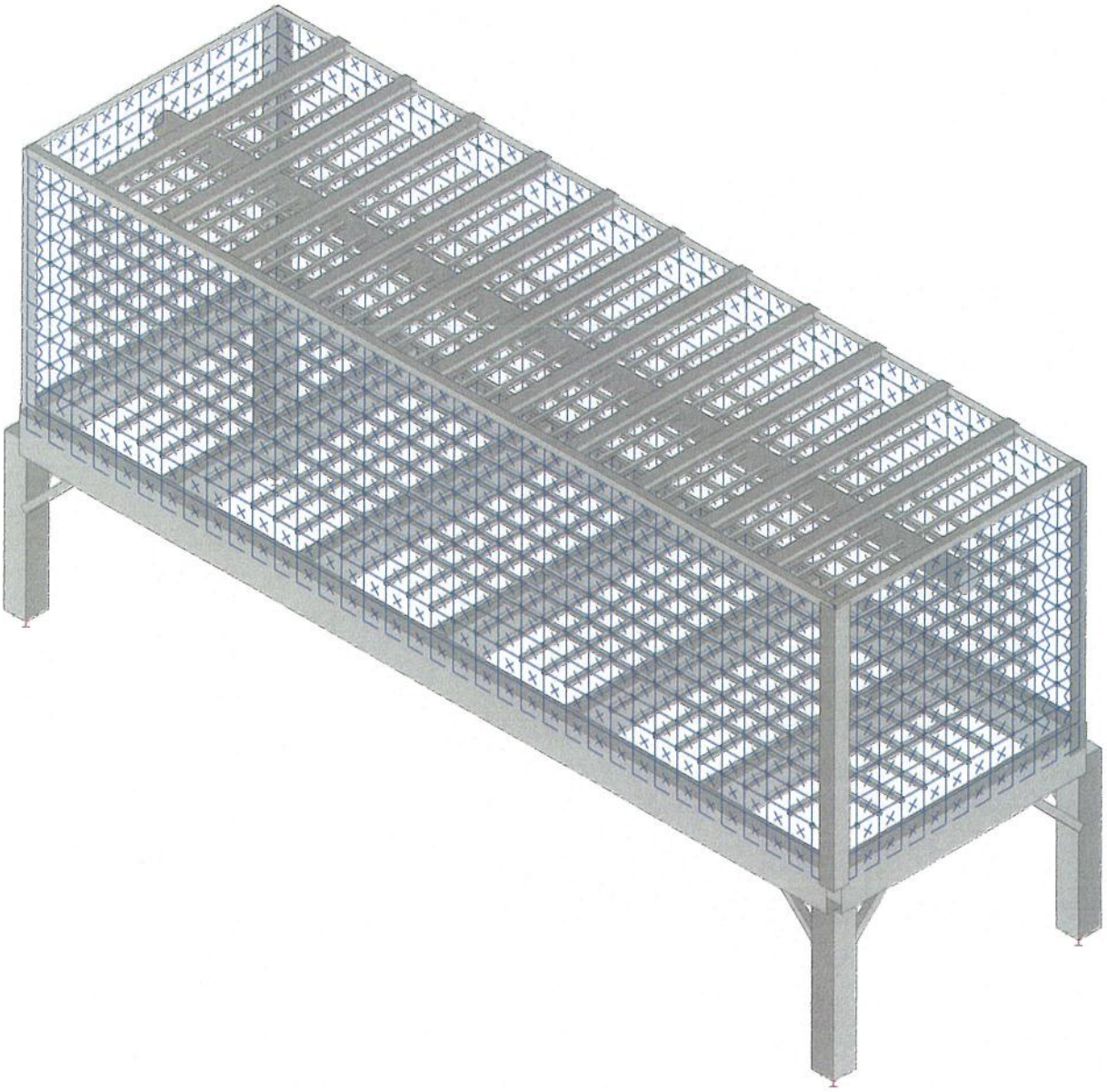


FIGURE 1609B ULTIMATE DESIGN WIND SPEEDS, V_{alt} FOR RISK CATEGORY III AND IV BUILDINGS AND OTHER STRUCTURES



Envelope Only Solution

TOWER TECH		SK - 1
J.R. KING ENGINEERING	TTXL-12, TTXR-12	Dec 17, 2016 at 7:25 AM
	7' OR LESS	TTXL-12.r3d

(Global) Model Settings

Display Sections for Member Calcs	3
Max Internal Sections for Member Calcs	99
Include Shear Deformation?	Yes
Increase Nailing Capacity for Wind?	Yes
Include Warping?	Yes
Trans Load Btwn Intersecting Wood Wall?	Yes
Area Load Mesh (in^2)	144
Merge Tolerance (in)	.12
P-Delta Analysis Tolerance	0.50%
Include P-Delta for Walls?	Yes
Automatically Iterate Stiffness for Walls?	No
Max Iterations for Wall Stiffness	3
Gravity Acceleration (ft/sec^2)	32.2
Wall Mesh Size (in)	12
Eigensolution Convergence Tol. (1.E-)	4
Vertical Axis	Y
Global Member Orientation Plane	XZ
Static Solver	Standard Skyline
Dynamic Solver	Accelerated Solver

Hot Rolled Steel Code	AISC 14th(360-10): ASD
Adjust Stiffness?	Yes(Iterative)
RISAConnection Code	AISC 13th(360-05): ASD
Cold Formed Steel Code	AISI 1999: ASD
Wood Code	AF&PA NDS-97: ASD
Wood Temperature	< 100F
Concrete Code	ACI 318-02
Masonry Code	ACI 530-05: ASD
Aluminum Code	AA ADM1-05: ASD - Building

Number of Shear Regions	4
Region Spacing Increment (in)	4
Biaxial Column Method	PCA Load Contour
Parme Beta Factor (PCA)	.65
Concrete Stress Block	Rectangular
Use Cracked Sections?	Yes
Use Cracked Sections Slab?	Yes
Bad Framing Warnings?	No
Unused Force Warnings?	Yes
Min 1 Bar Diam. Spacing?	No
Concrete Rebar Set	REBAR_SET_ASTMA615
Min % Steel for Column	1
Max % Steel for Column	8

(Global) Model Settings, Continued

Seismic Code	ASCE 7-10
Seismic Base Elevation (ft)	Not Entered
Add Base Weight?	Yes
Ct X	.02
Ct Z	.02
T X (sec)	.29
T Z (sec)	.29
R X	3
R Z	3
Ct Exp. X	.75
Ct Exp. Z	.75
SD1	2
SDS	2
S1	2
TL (sec)	12
Risk Cat	I or II
Drift Cat	Other
Om Z	2
Om X	2
Cd Z	2.5
Cd X	2.5
Rho Z	1
Rho X	1

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1...	Density[k/ft^3]	Yield[ksi]	Ry	Fu[ksi]	Rt
1	fiberglass	2000	500	.12	.44	.11	20	1.2	58	1.1

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]
1	FIBERGLASSPL	2000	500	.12	.44	.11
2	RIGID	1e+5		0	0	0
3	GM3	25	6	.12	.44	0

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design Ru...	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	C-1	HSS12x12x6	Column	Single Angle	fiberglass	Typical	16	357	357	561
2	C-2	L8x8x14	Column	Single Angle	fiberglass	Typical	13.3	79.7	79.7	3.46
3	B-1	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
4	B-2	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
5	B-3	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
6	B-4	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
7	B-5	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
8	B-6	W6x20	Beam	Wide Flange	fiberglass	Typical	5.87	13.3	41.4	.24
9	PIPE	PIPE 10.0	Beam	Pipe	fiberglass	Typical	11.5	151	151	302
10	BR-1	HSS3.5x3.5x4	VBrace	Tube	fiberglass	Typical	2.91	5.04	5.04	8.35
11	COLLECTOR	C8x11.5	Beam	Channel	fiberglass	Typical	3.37	1.31	32.5	.13

General Section Sets

	Label	Shape	Type	Material	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	GEN1	RE4X4	Beam	FIBERGLASSPL	16	21.333	21.333	31.573
2	RIGID		None	RIGID	1e+6	1e+8	1e+8	1e+6
3	FILL	RE2X2	Beam	GM3	4	1.333	1.333	1.973

Load Combinations

	Description	Sol..	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	Fa...	...	...	...	...	BLC	Fact..	BLC	Fact...
1	SIESMIC				SX*...	1	SZ*SF	1																
2	IBC 16-9	Yes			DL	1	LL	1																
3	IBC 16-12 (a) ..	Yes			DL	1	WLX	.6																
4	IBC 16-12 (a) ..	Yes			DL	1	WLZ	.6																
5	IBC 16-13 (a) ..	Yes			DL	1	WLX	.45	LL	.75														
6	IBC 16-13 (a) ..	Yes			DL	1	WLZ	.45	LL	.75														
7	IBC 16-13 (c) ..	Yes			DL	1	WLX	.45	LL	.75														
8	IBC 16-13 (c) ..	Yes			DL	1	WLZ	.45	LL	.75														
9	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
10	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
11	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
12	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
13	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
14	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
15	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
16	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
17	IBC 16-16 (a)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
18	IBC 16-16 (b)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
19	IBC 16-16 (c)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												
20	IBC 16-16 (d)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												

Dynamics Input

Number of Modes	36
Load Combination Number	2 - IBC 16-9
Acceleration of Gravity	32.2 (ft/sec^2)
Convergence Tolerance	0.0001

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu..	Area(Me...	Surface...
1	DEAD	DL		-1						
2	FILL	DL						2		
3	WATER	LL						2		
4	WIND-Z	WLZ								396
5	WIND-X	WLX								121
6	DEFLECTION	None				3				

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	N3	max	1.946	3	9.146	2	5.441	4	0	2	0	2	0	2
2		min	-4.238	19	-7.729	4	-1.571	9	0	2	0	2	0	2
3	N2	max	1.43	3	17.496	6	5.607	4	0	2	0	2	0	2
4		min	-4.652	11	1.528	17	-1.445	17	0	2	0	2	0	2
5	N1	max	1.947	3	17.496	6	5.607	4	0	2	0	2	0	2
6		min	-4.242	17	-2.12	17	-1.162	17	0	2	0	2	0	2
7	N4	max	1.429	3	11.834	13	5.441	4	0	2	0	2	0	2
8		min	-4.648	9	-7.729	4	-1.299	9	0	2	0	2	0	2

Envelope Joint Reactions (Continued)

	Joint		X [k]	LC	Y [k]	LC	Z [k]	LC	MX [k-ft]	LC	MY [k-ft]	LC	MZ [k-ft]	LC
9	Totals:	max	6.752	3	36.612	2	22.097	4						
10		min	-17.254	11	6.186	17	-5.319	17						

Envelope AISC 14th(360-10): ASD Steel Code Checks

	Member	Shape	Code Check	Loc[ft]	LC	Shear..	Loc[..	Dir	LC	Pnc/o...	Pnt/om...	Mnyy/om [k-ft]	Mnzz/om [k...	Cb	Eqn
1	M30	HSS3.5x3...	1.005	1.931	4	.021	0	y	11	18.147	34.85	3.313	3.313	1...	H1-1a
2	M32A	HSS3.5x3...	1.005	1.931	4	.019	4.302	y	17	18.147	34.85	3.313	3.313	1...	H1-1a
3	M17	L4x4x8	.882	0	4	.058	9.99	z	3	1.343	44.91	1.57	2.25	2...	H2-1
4	M31A	HSS3.5x3...	.833	1.931	11	.028	0	y	4	18.147	34.85	3.313	3.313	1...	H1-1a
5	M30A	HSS3.5x3...	.832	1.931	9	.027	4.302	y	4	18.147	34.85	3.313	3.313	1...	H1-1a
6	M18	L4x4x8	.829	0	4	.138	1.908	y	3	1.343	44.91	2.026	2.25	2...	H2-1
7	M16	L4x4x8	.606	2.939	4	.136	20.2...	z	4	24.429	44.91	1.57	3.266	1	H2-1
8	M3	HSS12x1...	.602	3.857	4	.170	3.929	z	4	99.247	191.617	44.088	44.088	1...	H1-1b
9	M4	HSS12x1...	.602	3.857	4	.170	3.929	y	4	99.247	191.617	44.088	44.088	1...	H1-1b
10	M2	HSS12x1...	.570	3.857	9	.165	3.929	y	4	99.247	191.617	44.088	44.088	1...	H1-1b
11	M19	W6x20	.565	0	4	.024	5.5	z	4	7.913	70.299	4.111	4.244	1...	H1-1b
12	M23	W6x20	.565	0	4	.024	5.5	z	4	7.913	70.299	4.111	4.244	1...	H1-1b
13	M1	HSS12x1...	.549	3.929	9	.165	3.929	z	4	99.247	191.617	44.088	44.088	1...	H1-1b
14	M22	W6x20	.520	0	4	.021	5.5	z	4	7.913	70.299	4.111	6.659	1...	H1-1b
15	M20	W6x20	.520	0	4	.021	5.5	z	4	7.913	70.299	4.111	6.658	1...	H1-1b

Envelope Joint Displacements

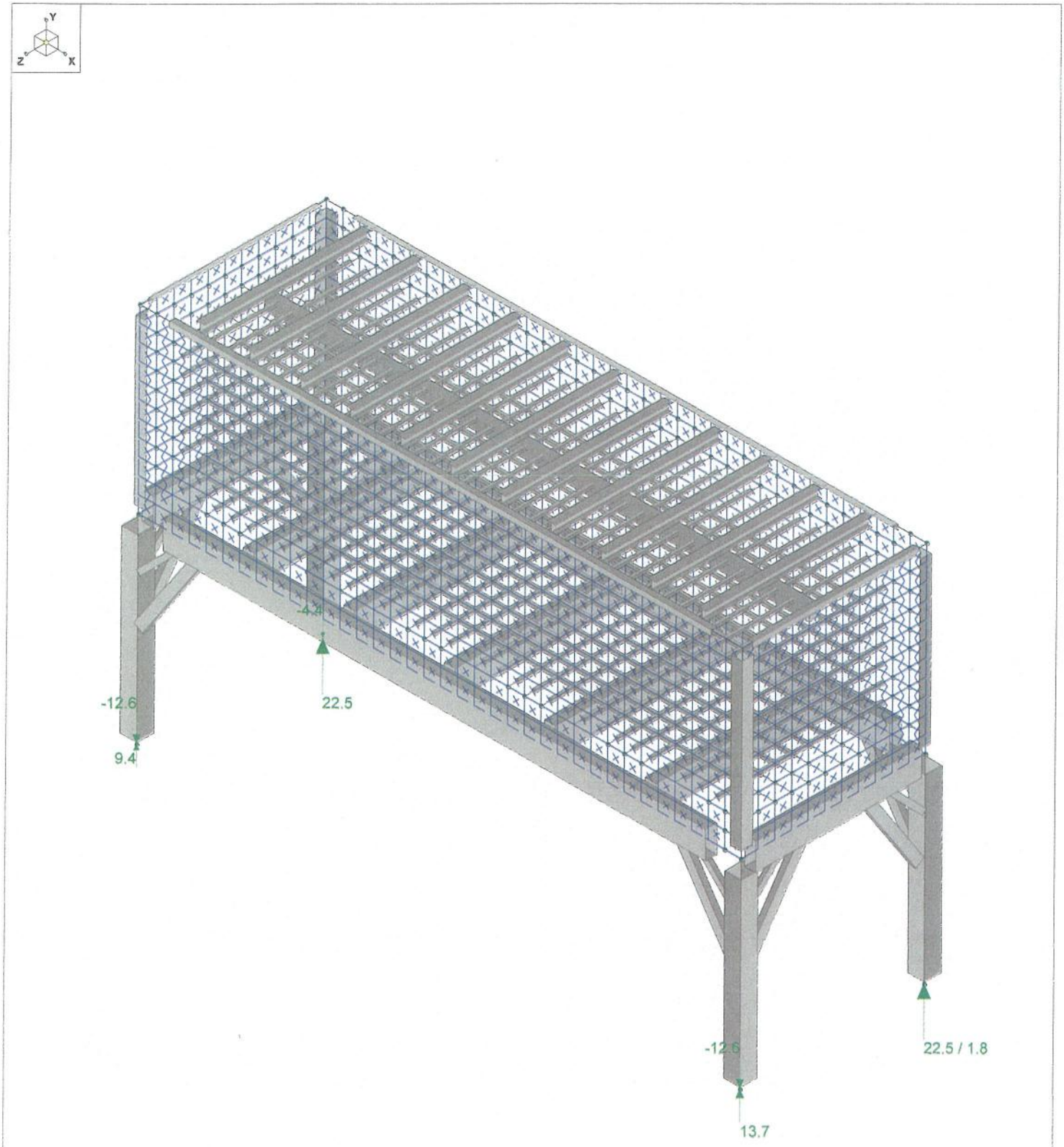
	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
1	N2845	max	1.008	11	-.019	19	.578	17	6.845e-02	4	-8.048e-08	2	2.021e-04	9
2		min	-.478	3	-.174	13	-21.175	4	-2.45e-03	9	-3.39e-04	4	-7.282e-05	3
3	N2898	max	1.063	11	-.022	19	.578	17	1.687e-04	9	6.136e-03	3	2.085e-04	19
4		min	-1.544	3	-.171	13	-21.163	4	-6.65e-04	4	-3.195e-04	17	-8.062e-05	3
5	N2894	max	1.066	9	-.023	19	.578	17	1.602e-04	9	2.144e-03	3	2.101e-04	19
6		min	-1.62	3	-.169	13	-21.158	4	-6.716e-04	4	-1.031e-04	17	-8.171e-05	3
7	N2890	max	1.068	11	-.025	19	.578	17	1.514e-04	9	1.122e-03	3	2.105e-04	19
8		min	-1.658	3	-.168	2	-21.153	4	-6.788e-04	4	-6.402e-05	17	-8.188e-05	3
9	N2886	max	1.069	11	-.027	19	.578	17	1.426e-04	9	3.626e-04	3	2.104e-04	19
10		min	-1.675	3	-.168	2	-21.149	4	-6.862e-04	4	-3.882e-05	17	-8.16e-05	3
11	N2882	max	1.069	11	-.027	17	.578	17	1.374e-04	17	2.806e-05	11	2.099e-04	19
12		min	-1.675	3	-.168	2	-21.146	4	-6.936e-04	4	-3.602e-04	3	-8.108e-05	3
13	N2878	max	1.068	11	-.025	17	.578	17	1.356e-04	17	9.191e-05	11	2.089e-04	19
14		min	-1.658	3	-.168	2	-21.143	4	-7.01e-04	4	-1.117e-03	3	-8.04e-05	3
15	N2874	max	1.065	11	-.023	17	.578	17	1.339e-04	17	1.252e-04	11	2.074e-04	19
16		min	-1.621	3	-.169	15	-21.141	4	-7.08e-04	4	-2.137e-03	3	-7.958e-05	3

Envelope Plate/Shell Principal Stresses

	Plate		Surf...	Sigma1 [ksi]	LC	Sigma2 [ksi]	LC	Tau Max [ksi]	LC	Angle [rad]	LC	Von Mises [ksi]	LC
1	P207	max	T	.959	3	.025	3	4.682	4	2.238	17	9.836	4
2		min		-.886	4	-10.249	4	.077	11	-.492	19	.137	9
3		max	B	10.285	4	.689	4	4.798	4	2.082	19	9.958	4
4		min		-.164	3	-1.028	3	.051	9	-.682	9	.102	9
5	P394	max	T	.366	9	-.16	17	4.682	4	2.344	11	9.836	4
6		min		-.886	4	-10.249	4	.182	5	-.742	19	.369	2
7		max	B	10.285	4	.689	4	4.798	4	2.235	2	9.958	4
8		min		.067	17	-.486	13	.21	2	-.779	13	.369	2
9	P197	max	T	10.075	4	.754	4	4.661	4	2.236	2	9.72	4
10		min		-.045	9	-.269	2	.076	9	-.615	13	.138	11

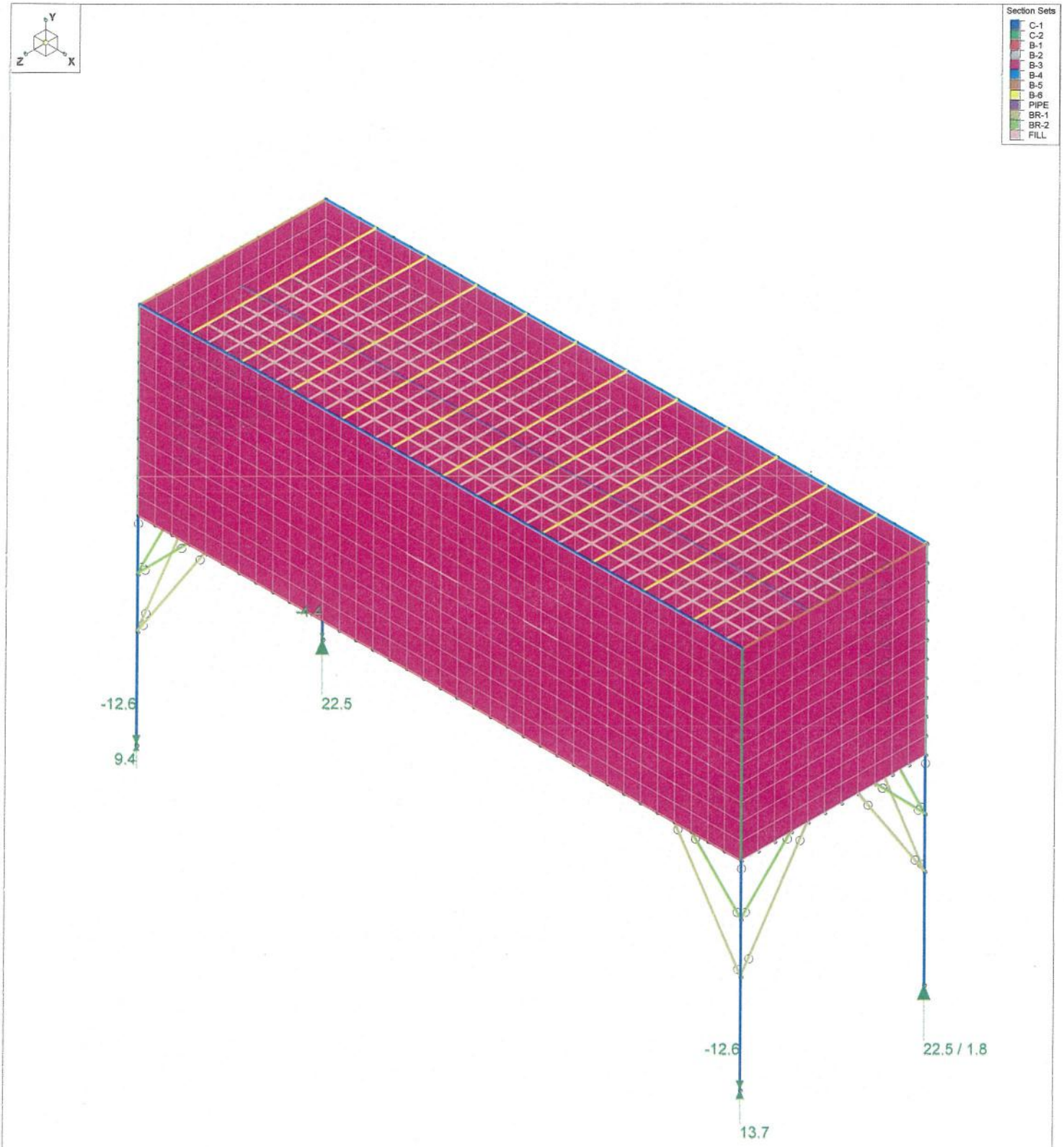
Envelope Plate/Shell Principal Stresses (Continued)

	Plate		Surf...	Sigma1 [ksi]	LC	Sigma2 [ksi]	LC	Tau Max [ksi]	LC	Angle [rad]	LC	Von Mises [ksi]	LC
11		max	B	.288	17	-.019	9	4.664	4	2.236	2	9.752	4
12		min		-.8	4	-10.127	4	.051	11	-.342	5	.102	11
13	P10	max	T	10.075	4	.754	4	4.661	4	1.554	4	9.72	4
14		min		-.104	3	-.501	3	.182	5	.109	3	.369	2
15		max	B	.512	3	.018	3	4.664	4	1.483	3	9.752	4
16		min		-.8	4	-10.127	4	.21	2	.007	4	.369	2
17	P393	max	T	.389	9	-.204	17	4.473	4	2.343	11	9.421	4
18		min		-.887	4	-9.833	4	.174	5	-.734	19	.393	5
19		max	B	9.848	4	.656	4	4.596	4	2.336	13	9.537	4
20		min		.083	17	-.545	13	.229	2	-.751	9	.404	2



Envelope Only Solution
Y-direction Reaction Units are k and k-ft (Enveloped)

J.R. King Engineering	Tower Tech TTXL	SK - 2
Jerry King		Jan 6, 2017 at 8:41 AM
		TTXL-12 12 legs.r3d



Envelope Only Solution
Y-direction Reaction Units are k and k-ft (Enveloped)

J.R. King Engineering	Tower Tech TTXL	SK - 1
Jerry King		Jan 6, 2017 at 8:40 AM
		TTXL-12 12 legs.r3d

Hot Rolled Steel Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1...	Density[k/ft^3]	Yield[ksi]	Ry	Fu[ksi]	Rt
1	fiberglass	2000	500	.12	.44	.11	20	1.2	58	1.1

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]
1	FIBERGLASSPL	2000	500	.12	.44	.11
2	RIGID	1e+5		0	0	0
3	GM3	25	6	.12	.44	0

Hot Rolled Steel Section Sets

	Label	Shape	Type	Design List	Material	Design Ru...	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	C-1	HSS12x12x6	Column	Single Angle	fiberglass	Typical	16	357	357	561
2	C-2	L8x8x14	Column	Single Angle	fiberglass	Typical	13.3	79.7	79.7	3.46
3	B-1	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
4	B-2	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
5	B-3	HSS20x8x10	Beam	Tube	fiberglass	Typical	30.3	338	1440	916
6	B-4	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
7	B-5	L4x4x8	Beam	Single Angle	fiberglass	Typical	3.75	5.52	5.52	.322
8	B-6	W6x20	Beam	Wide Flange	fiberglass	Typical	5.87	13.3	41.4	.24
9	PIPE	PIPE 10.0	Beam	Pipe	fiberglass	Typical	11.5	151	151	302
10	BR-1	HSS7x4x4	VBrace	Tube	fiberglass	Typical	4.77	12.8	30.5	29.3
11	BR-2	HSS4x3x4	VBrace	Tube	fiberglass	Typical	2.91	3.91	6.15	7.96
12	COLLECTOR	C8x11.5	Beam	Channel	fiberglass	Typical	3.37	1.31	32.5	.13

General Section Sets

	Label	Shape	Type	Material	A [in2]	Iyy [in4]	Izz [in4]	J [in4]
1	GEN1	RE4X4	Beam	FIBERGLASSPL	16	21.333	21.333	31.573
2	RIGID		None	RIGID	1e+6	1e+8	1e+8	1e+6
3	FILL	RE2X2	Beam	GM3	4	1.333	1.333	1.973

Load Combinations

	Description	Sol...	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	Fa...	...	...	...	...	BLC	Fact...	BLC	Fact...
1	SIESMIC				SX*...	1	SZ*SF	1																
2	IBC 16-9	Yes			DL	1	LL	1																
3	IBC 16-12 (a) ..	Yes			DL	1	WLX	.6																
4	IBC 16-12 (a) ..	Yes			DL	1	WLZ	.6																
5	IBC 16-13 (a) ..	Yes			DL	1	WLX	.45	LL	.75														
6	IBC 16-13 (a) ..	Yes			DL	1	WLZ	.45	LL	.75														
7	IBC 16-13 (c) ..	Yes			DL	1	WLX	.45	LL	.75														
8	IBC 16-13 (c) ..	Yes			DL	1	WLZ	.45	LL	.75														
9	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
10	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	.21												
11	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
12	IBC 16-12 (b) ..	Yes			DL	1	Sds*DL	.14	SX*SF	.7	SZ*...	-.21												
13	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
14	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	.158	LL	.75										
15	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
16	IBC 16-14 (a) ..	Yes			DL	1	Sds*DL	.105	SX*SF	.525	SZ*...	-.1...	LL	.75										
17	IBC 16-16 (a)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
18	IBC 16-16 (b)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	.21												
19	IBC 16-16 (c)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												

Load Combinations (Continued)

	Description	Sol..	PDelta	SRSS	BLC	Fa...	BLC	Factor	BLC	Fac...	BLC	Fa...	BLC	Fa...	BLC	Fa...	...	...	...	...	BLC	Fact..	BLC	Fact...
20	IBC 16-16 (d)	Yes			DL	.6	Sds*DL	-.14	SX*SF	.7	SZ*...	-.21												

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Z Gravity	Joint	Point	Distribu..	Area(Me...	Surface...
1	DEAD	DL		-1						
2	FILL	DL						2		
3	WATER	LL						2		
4	WIND-Z	WLZ								396
5	WIND-X	WLX								121
6	DEFLECTION	None				3				

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	N3	max	1.878	3	9.405	5	5.448	4	0	2	0	2	0	2
2		min	-4.328	19	-12.64	4	-1.515	9	0	2	0	2	0	2
3	N2	max	1.498	3	22.528	4	5.601	4	0	2	0	2	0	2
4		min	-4.632	11	1.757	17	-1.397	17	0	2	0	2	0	2
5	N1	max	1.879	3	22.528	4	5.601	4	0	2	0	2	0	2
6		min	-4.33	17	-4.366	17	-1.058	17	0	2	0	2	0	2
7	N4	max	1.497	3	13.68	13	5.448	4	0	2	0	2	0	2
8		min	-4.629	9	-12.64	4	-1.184	9	0	2	0	2	0	2
9	Totals:	max	6.752	3	37.054	2	22.097	4						
10		min	-17.551	11	6.328	17	-5.008	17						

Envelope AISC 14th(360-10): ASD Steel Code Checks

	Member	Shape	Code Check	Loc[ft]	LC	Shear..	Loc[..	Dir	LC	Pnc/o...	Pnt/om...	Mnyy/om [k-ft]	Mnzz/om [k...	Cb	Eqn
1	M376	HSS7x4x4	.970	2.823	9	.030	7.281	y	4	17.353	57.126	4.762	8.665	1..	H1-1a
2	M374A	HSS7x4x4	.970	2.823	11	.029	7.281	y	4	17.353	57.126	4.762	8.665	1..	H1-1a
3	M375	HSS7x4x4	.960	2.435	4	.026	6.281	y	11	21.922	57.126	4.762	8.665	1..	H1-1a
4	M376A	HSS7x4x4	.960	2.435	4	.025	6.281	y	17	21.922	57.126	4.762	8.665	1..	H1-1a
5	M3	HSS12x1...	.950	5.878	4	.144	6	z	4	85.839	191.617	44.088	44.088	1..	H1-1a
6	M4	HSS12x1...	.950	5.878	4	.144	6	y	4	85.839	191.617	44.088	44.088	1..	H1-1a
7	M17	L4x4x8	.881	0	4	.058	9.99	z	3	1.343	44.91	1.57	2.25	2..	H2-1
8	M2	HSS12x1...	.846	5.878	9	.139	6	y	4	85.839	191.617	44.088	44.088	1..	H1-1b
9	M18	L4x4x8	.827	0	4	.138	1.908	y	3	1.343	44.91	2.026	2.25	2..	H2-1
10	M1	HSS12x1...	.826	6	9	.139	6	z	4	85.839	191.617	44.088	44.088	1..	H1-1b
11	M16	L4x4x8	.606	2.939	4	.136	20.2...	z	4	24.429	44.91	1.57	3.266	1	H2-1
12	M19	W6x20	.565	0	4	.024	5.5	z	4	7.913	70.299	4.111	4.244	1..	H1-1b
13	M23	W6x20	.565	0	4	.024	5.5	z	4	7.913	70.299	4.111	4.244	1..	H1-1b
14	M6	L8x8x14	.547	0	9	.122	1.01	z	4	19.504	159.281	15.023	18.973	3..	H2-1
15	M22	W6x20	.520	0	4	.021	5.5	z	4	7.913	70.299	4.111	6.659	1..	H1-1b
16	M20	W6x20	.520	0	4	.021	5.5	z	4	7.913	70.299	4.111	6.658	1..	H1-1b
17	M15	L4x4x8	.510	2.939	4	.163	20.9...	y	4	24.429	44.91	2.026	3.266	1	H2-1
18	M5	L8x8x14	.506	.224	11	.138	0	y	4	19.504	159.281	15.023	18.973	4...	H2-1
19	M21	W6x20	.441	0	4	.018	5.5	z	4	7.913	70.299	4.111	7.017	2..	H1-1b
20	M265A	W6x20	.441	0	4	.018	5.5	z	4	7.913	70.299	4.111	7.016	2..	H1-1b
21	M10	HSS20x8...	.438	31.959	17	.045	31.9...	y	11	18.774	362.874	57.185	175.612	4..	H1-1a

Envelope Joint Displacements

	Joint		X [in]	LC	Y [in]	LC	Z [in]	LC	X Rotation [rad]	LC	Y Rotatio...	LC	Z Rotatio...	LC
1	N2845	max	2.386	11	-.013	4	.909	17	6.783e-02	4	-8.056e-08	2	3.428e-04	9
2		min	-1.122	3	-.197	13	-23.186	4	-1.506e-03	9	-3.389e-04	4	-1.274e-04	3
3	N2898	max	2.437	11	-.022	19	.909	17	2.411e-04	9	6.138e-03	3	3.561e-04	19
4		min	-2.189	3	-.191	13	-23.174	4	-1.25e-03	4	-2.949e-04	17	-1.379e-04	3
5	N2894	max	2.44	11	-.024	19	.909	17	2.324e-04	9	2.144e-03	3	3.586e-04	19
6		min	-2.265	3	-.189	13	-23.169	4	-1.256e-03	4	-9.662e-05	17	-1.393e-04	3
7	N2890	max	2.442	11	-.027	19	.909	17	2.239e-04	9	1.122e-03	3	3.59e-04	19
8		min	-2.303	3	-.187	13	-23.164	4	-1.264e-03	4	-5.797e-05	17	-1.395e-04	3
9	N2886	max	2.443	11	-.029	19	.909	17	2.155e-04	9	3.626e-04	3	3.587e-04	19
10		min	-2.32	3	-.186	2	-23.16	4	-1.271e-03	4	-3.194e-05	17	-1.391e-04	3
11	N2882	max	2.443	11	-.029	17	.909	17	2.109e-04	17	1.992e-05	11	3.578e-04	19
12		min	-2.32	3	-.186	2	-23.156	4	-1.279e-03	4	-3.602e-04	3	-1.385e-04	3
13	N2878	max	2.442	11	-.027	17	.909	17	2.094e-04	17	7.153e-05	11	3.562e-04	19
14		min	-2.303	3	-.187	15	-23.154	4	-1.286e-03	4	-1.117e-03	3	-1.375e-04	3
15	N2874	max	2.439	11	-.024	17	.909	17	2.078e-04	17	1.067e-04	11	3.538e-04	19
16		min	-2.266	3	-.193	6	-23.152	4	-1.293e-03	4	-2.137e-03	3	-1.364e-04	3
17	N2870	max	2.436	11	-.022	17	.909	17	2.063e-04	17	2.775e-04	11	3.483e-04	19
18		min	-2.189	3	-.205	6	-23.151	4	-1.299e-03	4	-6.136e-03	3	-1.341e-04	3
19	N2852	max	2.387	11	-.017	17	.909	17	6.724e-02	4	3.088e-05	4	1.995e-04	19
20		min	-1.123	3	-.229	6	-23.15	4	-1.506e-03	9	-5.909e-06	17	-7.681e-05	3
21	N2846	max	2.386	17	-.012	4	.909	17	6.689e-02	4	6.365e-05	9	3.634e-04	9
22		min	-1.123	3	-.193	13	-23.15	4	-1.499e-03	9	-5.604e-03	4	-1.037e-04	3

Envelope Plate/Shell Principal Stresses

	Plate		Surf...	Sigma1 [ksi]	LC	Sigma2 [ksi]	LC	Tau Max [ksi]	LC	Angle [rad]	LC	Von Mises [ksi]	LC
1	P207	max	T	.968	3	.001	3	4.681	4	2.312	17	9.835	4
2		min		-.887	4	-10.248	4	.034	15	-.575	19	.097	13
3		max	B	10.285	4	.687	4	4.799	4	2.224	19	9.959	4
4		min		-.165	3	-1.041	3	.007	13	-.672	9	.053	13
5	P394	max	T	.412	9	-.262	17	4.681	4	2.329	11	9.835	4
6		min		-.887	4	-10.248	4	.171	5	-.779	19	.366	2
7		max	B	10.285	4	.687	4	4.799	4	2.34	13	9.959	4
8		min		.133	17	-.558	9	.209	2	-.766	9	.366	2
9	P197	max	T	10.075	4	.759	4	4.658	4	2.239	2	9.718	4
10		min		-.063	13	-.298	17	.034	13	-.184	13	.097	15
11		max	B	.357	17	-.035	13	4.666	4	2.239	2	9.754	4
12		min		-.795	4	-10.127	4	.006	15	-.368	5	.052	15
13	P10	max	T	10.075	4	.759	4	4.658	4	1.554	4	9.718	4
14		min		-.092	3	-.513	13	.171	5	.032	3	.366	2
15		max	B	.509	3	.038	3	4.666	4	1.543	3	9.754	4
16		min		-.795	4	-10.127	4	.209	2	.007	4	.366	2
17	P393	max	T	.435	9	-.3	2	4.471	4	2.318	11	9.419	4
18		min		-.89	4	-9.832	4	.162	5	-.785	19	.371	5
19		max	B	9.848	4	.653	4	4.598	4	2.35	9	9.538	4
20		min		.147	17	-.624	9	.228	2	-.739	17	.401	2

Properties

	ASTM TEST METHOD	UNITS/ VALUE	SERIES 500/525 SHAPES	SERIES 625 SHAPES	SERIES 500/525 PLATE ⑤ 1/8" 3.175mm	SERIES 500/525 PLATE ⑤ 3/16" - 1/4" 4.76-6.35mm	SERIES 500/525 PLATE ⑤ 3/8" - 1" 9.5-25.4mm	SERIES 625 PLATE ⑤ 1/8" 3.175mm	SERIES 625 PLATE ⑤ 3/16" - 1/4" 4.76-6.35mm	SERIES 625 PLATE ⑤ 3/8" - 1" 9.5-25.4mm
MECHANICAL										
Tensile Stress, LW	D638	psi N/mm²	30,000 207	30,000 207	20,000 138	20,000 138	20,000 138	20,000 138	20,000 138	20,000 138
Tensile Stress, CW	D638	psi N/mm²	7,000 48.3	7,000 48.3	7,500 51.7	10,000 68.9	10,000 68.9	7,500 51.7	10,000 68.9	10,000 68.9
Tensile Modulus, LW	D638	10^6 psi 10^3N/mm²	2.5 17.2	2.6 17.9	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4
Tensile Modulus, CW	D638	10^6 psi 10^3N/mm²	0.8 5.52	0.8 5.52	0.7 4.83	0.9 6.21	1.4 9.65	1.0 6.89	1.0 6.89	1.4 9.65
Compressive Stress, LW	D695	psi N/mm²	30,000 207	30,000 207	24,000 165	24,000 165	24,000 165	24,000 165	24,000 165	24,000 165
Compressive Stress, CW	D695	psi N/mm²	15,000 103	16,000 110	15,500 107	16,500 114	20,000 138	16,500 114	17,500 121	17,500 121
Compressive Modulus, LW	D695	10^6 psi 10^3N/mm²	2.5 17.2	2.6 17.9	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4	1.8 12.4
Compressive Modulus CW	D695	10^6 psi 10^3N/mm²	0.8 6.89	0.8 6.89	0.7 6.89	0.9 6.89	1.4 6.89	1.0 6.89	1.0 6.89	1.4 6.89
Flexural Stress, LW	D790	psi N/mm²	30,000 207	30,000 207	35,000 241	35,000 241	30,000 207	35,000 241	35,000 241	30,000 207
Flexural Stress, CW	D790	psi N/mm²	10,000 68.9	10,000 68.9	13,000 89.6	15,000 103	18,000 124	13,000 89.6	15,000 103	18,000 124
Flexural Modulus, LW	D790	10^6 psi 10^3N/mm²	1.6 11.0	1.6 11.0	1.8 12.4	2 13.8	2 13.8	1.8 12.4	2 13.8	2 13.8
Flexural Modulus, CW	D790	10^6 psi 10^3N/mm²	0.8 5.52	0.8 5.52	0.9 6.21	1.1 7.58	1.4 9.65	1.0 6.89	1.1 7.58	1.4 9.65
Modulus of Elasticity ①	full section	10^6 psi 10^3N/mm²	2.6 17.9	2.8 19.3						
Modulus of Elasticity: W & I shapes > 4" W & I shapes > 102mm	full section	10^6 psi 10^3N/mm²	2.5 17.2	2.5 17.2						
Parallel Compressive Shear Stress, LW ②⑨	D3846	psi N/mm²	3,000 20.7	3,000 20.7						
Shear Modulus, LW ③⑨	—	10^6 psi 10^3N/mm²	0.425 2.93	0.425 2.93						
Short Beam Shear, LW ⑧⑨	D2344	psi N/mm²	4,500 31.0	4,500 31.0						
Bearing Stress, LW	D953	psi N/mm²	30,000 207	30,000 207	32,000 220.6	32,000 221	32,000 221	32,000 221	32,000 221	32,000 221
Poisson's Ratio, LW ⑨	D3039	in/in mm/mm	0.33 .330	0.33 .330	0.31 .310	0.31 .310	0.31 .310	0.32 .320	0.32 .320	0.32 .320
Notched Izod Impact, LW	D256	ft-lbs/in J/mm	25 1.33	25 1.33	15 .801	10 .533	10 .533	15 .801	10 .533	10 .533
Notched Izod Impact, CW	D256	ft-lbs/in J/mm	4 .214	4 .214	5 .267	5 .267	5 .267	5 .267	5 .267	5 .267
PHYSICAL										
Barcol Hardness	D2583	—	45 ④	45 ④	40	40	40	40	40	40
24 hr Water Absorption ⑦	D570	% Max	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Density	D792	lbs/in³ 10^{-3}g/mm³	.062-.070 1.72-1.94	.062-.070 1.72-1.94	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88	.060-.068 1.66-1.88
Coefficient of Thermal Expansion, LW ⑨	D696	10^{-6} in/in/°F 10^{-4} mm/mm/°C	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0	4.4 8.0
Thermal Conductivity ⑨	C177	BTU-in/ft²Hr/°F W(m**K)	4 .58	4 .58						

All values are minimum ultimate properties from coupon tests except as noted.

① This value is determined from full section simple beam bending of EXTREN® structural shapes.

② The shear stress test results will change radically if the notched orientation is altered. The value in this chart represents the test configuration where the notches are machined parallel to the reinforcing mat. For notches machined perpendicular to the reinforcing mat, this value would be two to three times larger.

③ The Shear Modulus value has been determined from tests with full sections of EXTREN® structural shapes. (See Strongwell's Strongwell *Design Manual* for further information.)

④ Value would be 50 if the surfacing veil were not there.

⑤ Plate compressive stress/modulus measured edgewise and flexural stress/modulus measured flatwise.

⑥ Values apply to Series 525 and 625.

⑦ Measured as a percentage maximum by weight.

⑧ Span to depth ratio of 3:1; EXTREN® angles will have a minimum value of 4000 psi and the I/W shapes are tested in the web.

⑨ Typical values because these are shape and composite dependent tests.

LW — Lengthwise
CW — Crosswise
PF — Perpendicular to laminate face
N.T. — Not Tested

Specifications for Wall Sections of Tower Tech, Inc. ("Buyer")

1. Definition of "Products": The terms "Products," as used hereinafter, shall mean finished "Perimeter Basin Wall," finished "Center Basin," finished "Mid Wall," and finished "Top Wall," all manufactured by the pultrusion process.

2. Material Technical Properties: Products to, at a minimum, conform to the following typical properties of pultruded materials:

Mechanical Properties (Coupon Sample, u.n.o.)	ASTM Test Method	Polyester
Properties at 100% at 77°F (90% at or below 100°F, 80% at 100-125°F, 70% at 125-150°F)		
Specific Gravity	ASTM D792	1.75
Density, lb/in cubed	ASTM D792	0.07
Tensile Strength, LW, psi	ASTM D638	33,000
Tensile Strength, CW, psi	ASTM D638	7,500
Tensile Modulus of Elasticity, LW, ksi	ASTM D638	3,000
Tensile Modulus of Elasticity, CW, ksi	ASTM D638	1,000
Compressive Strength, LW, psi	ASTM D695	33,000
Compressive Strength, CW, psi	ASTM D695	17,000
Comp. Modulus of Elasticity, LW, ksi	ASTM D695	3,000
Comp. Modulus of Elasticity, CW, ksi	ASTM D695	1,000
Flexural Strength, LW, psi	ASTM D790	33,000
Flexural Strength, CW, psi	ASTM D790	10,000
Flexural Modulus, LW, ksi	ASTM D790	2,000
Flexural Modulus, CW, ksi	ASTM D790	1,000
Modulus of Elasticity, ksi	Perimeter Basin & Center Basin, Full Section	3,200
Modulus of Elasticity, ksi	Mid Wall & Top Wall, Full Section	2,200
Shear Modulus, ksi	Full Section	420
Shear Strength by Punch, PF, psi	ASTM D732	6,000
Bearing Stress, LW, psi	ASTM D953	30,000
Bearing Stress, CW, psi	ASTM D953	18,000
Izod Impact, Notched, LW, ft-lb/in	ASTM D256	30
Izod Impact, Notched, CW, ft-lb/in	ASTM D256	5
Barcol Hardness	ASTM D2583	45
Possion's Ratio, LW, in/in	ASTM D3039	0.35
Possion's Ratio, CW, in/in	ASTM D3039	0.1+E105

(LW = Lengthwise; CW = Crosswise; PF = Perpendicular to Laminate Face)

Thermal Properties	ASTM Test Method	Polyester
Coef. Of Linear Expansion in/in/F	ASTM D696	?
Thermal Conductivity, BTU/hr/sq ft/F/in	ASTM D C177	?

Flammability	ASTM Test Method	Polyester
Flammability Classification	UL94	94V-O
Flammability Extinguishing	ASTM D635	Self-exinguish.
NBS Smoke Chamber	ASTM E662	650
Flame Resistance (Ignition/Burn), sec	FTMS 406-2023	55/30

Other Properties	ASTM Test Method	Polyester
Water Absorption, % 24 hr.	ASTM D570	0.5 Max
Customer Standard Color	———	Specific Beige
NSF Potable Water Approved	———	———