STEEL PYLON DESIGN FOR A CURVED CABLE-STAYED BRIDGE LOCATED IN A HIGH SEISMIC ZONE

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A WORK IN PROGRESS

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Existing Bridges

- Project Location - Tacoma, Washington
- Replace old concrete viaducts and steel truss
- Heavy truck traffic route (Port to I-5 & downtown)

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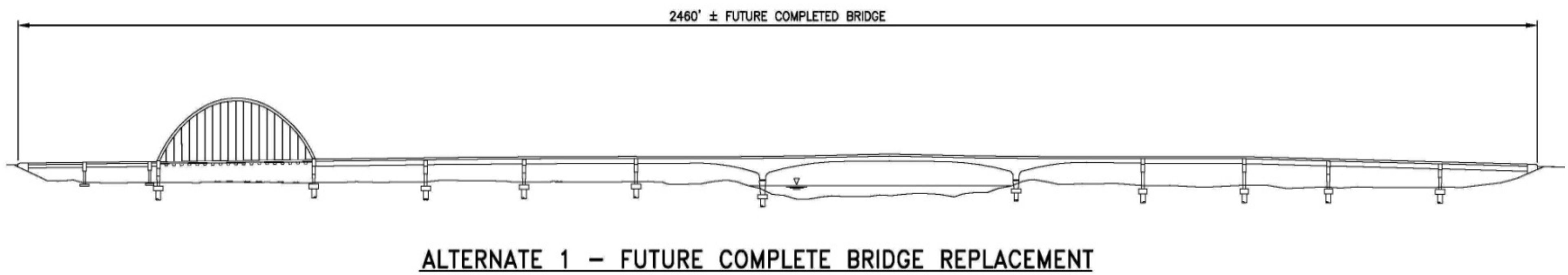
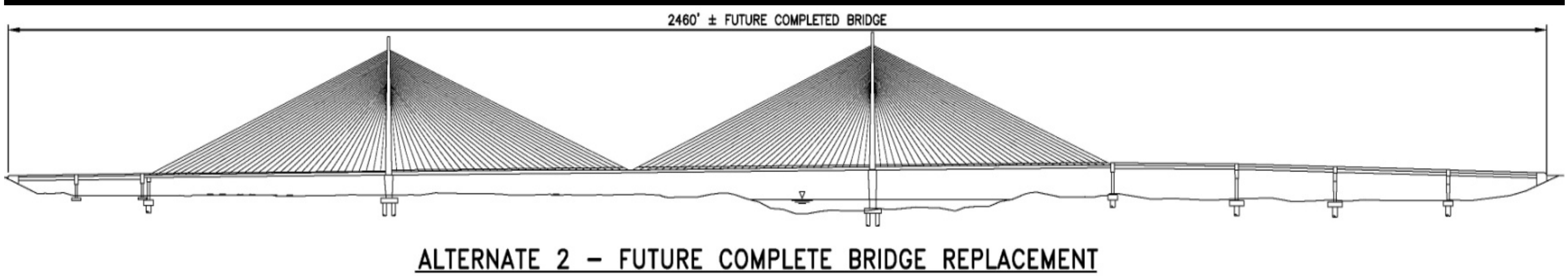
Bridge Type Options



Alternate 1 - Arch with Viaduct



Alternate 2 - Cable Stay

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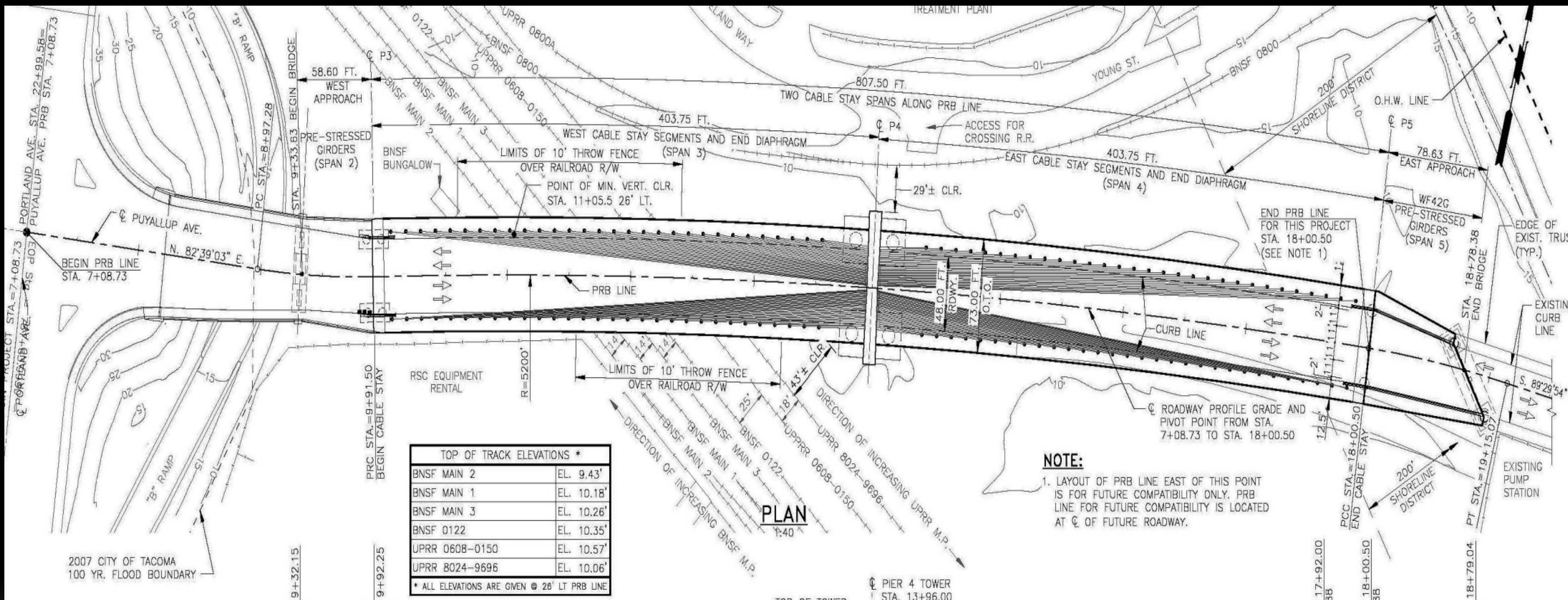
Design Issues 1



- Connect existing misaligned bridges
- Spans 6 railroad tracks at 45 degree skew
- 3 lanes to 4 lanes plus bike access

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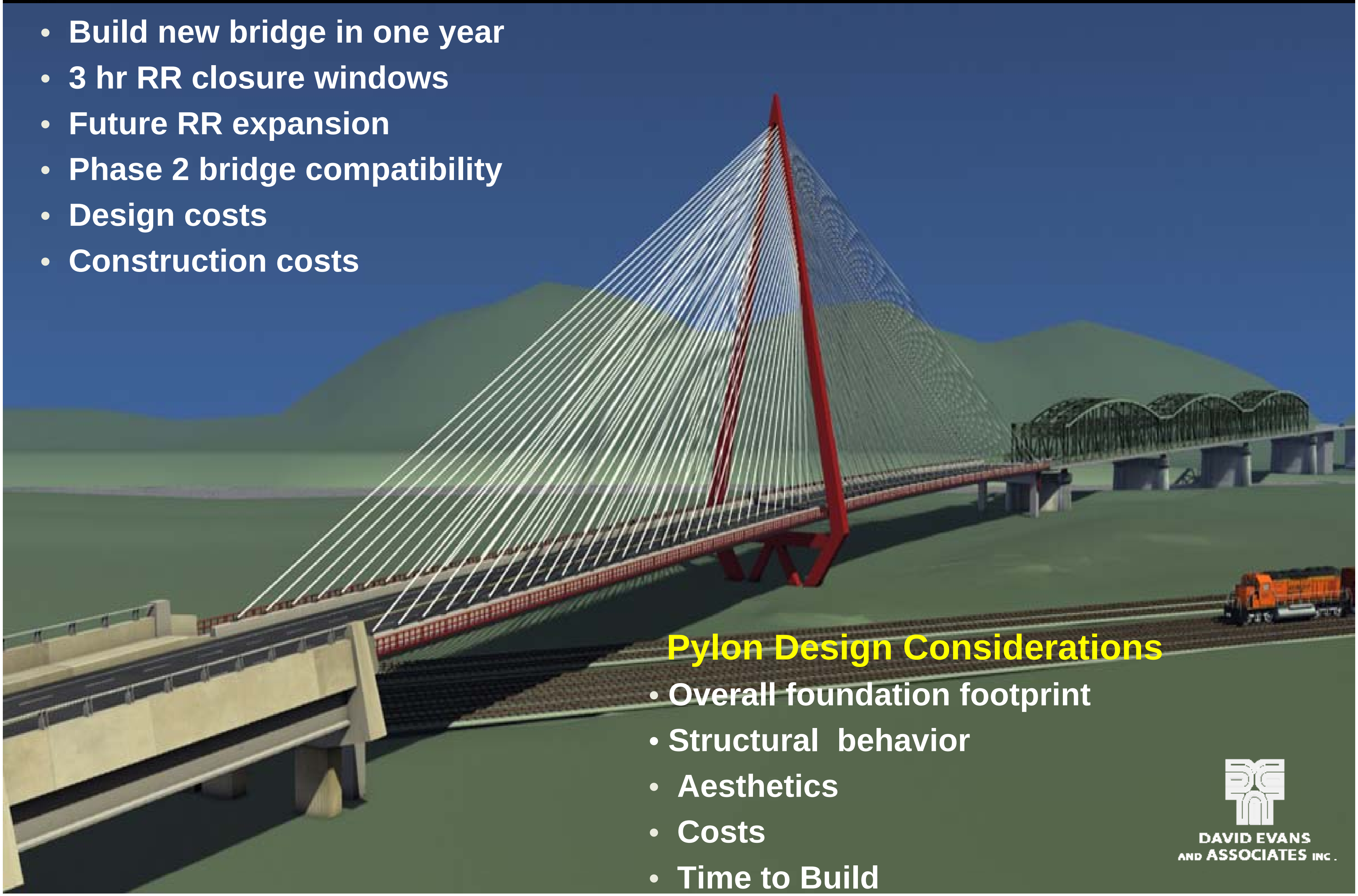
Design Issues 2

- Build new bridge in one year
- 3 hr RR closure windows
- Future RR expansion
- Phase 2 bridge compatibility
- Design costs
- Construction costs



Pylon Design Considerations

- Overall foundation footprint
- Structural behavior
- Aesthetics
- Costs
- Time to Build

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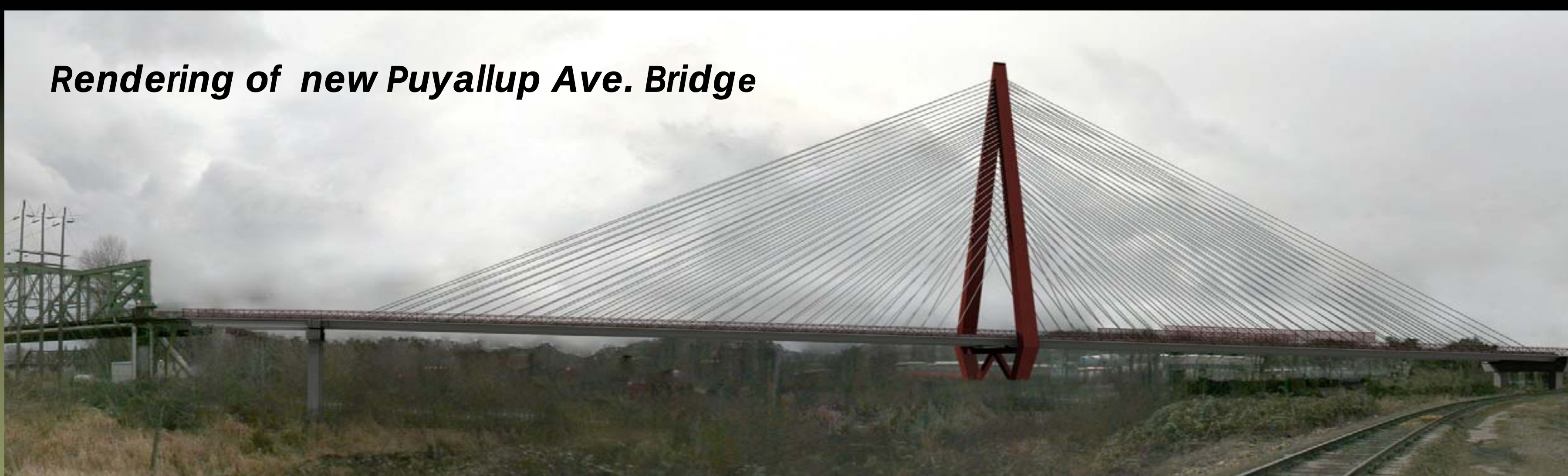
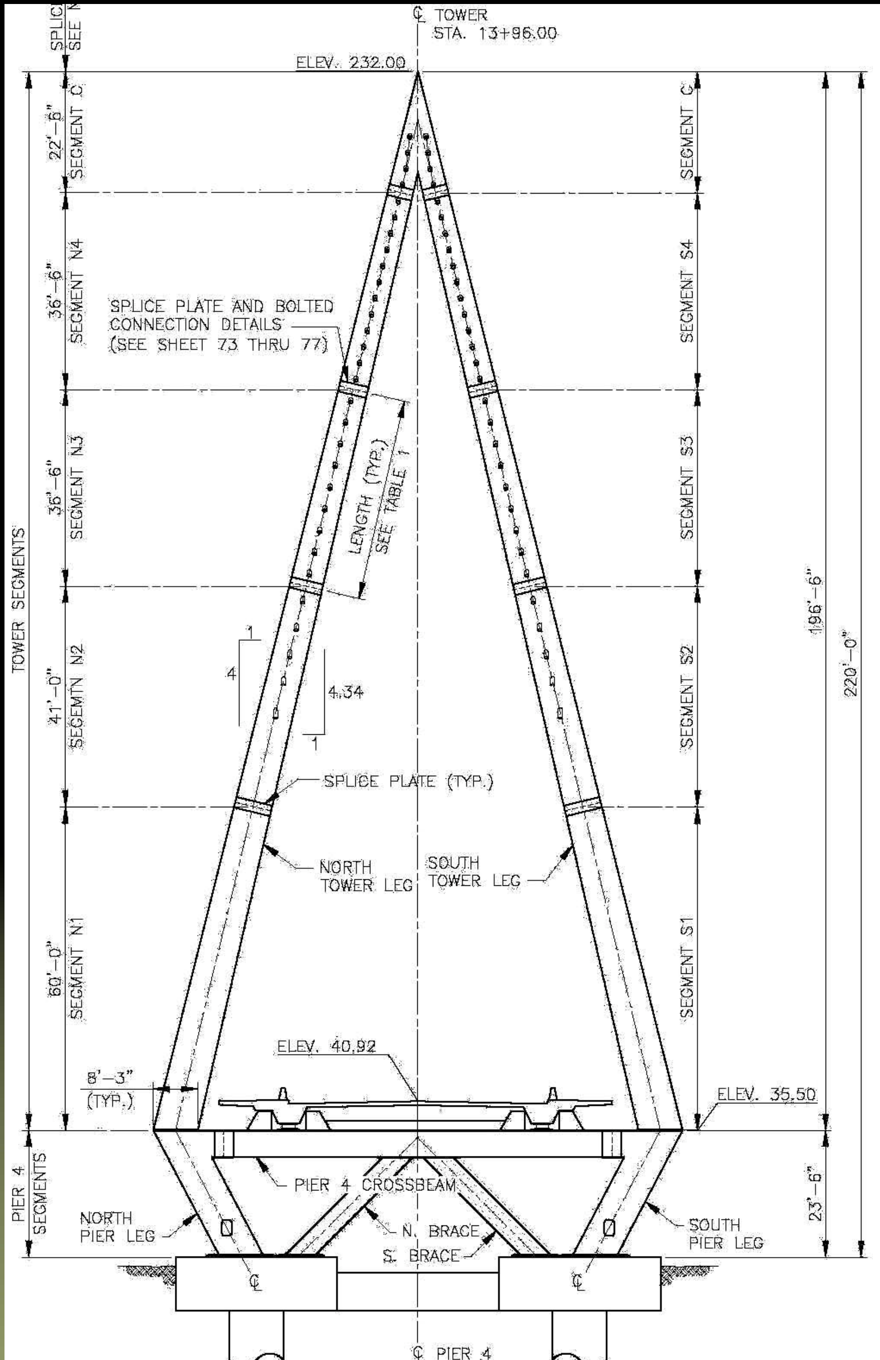
Steel vs. Concrete Pylon

Foss Waterway Cable Stay, Tacoma, WA



Rendering of new Puyallup Ave. Bridge



A-Frame Pylon

- Stable - construction & final stages
- Resists lateral response from wind
- Resists lateral response from EQ
- Suits Steel Construction
- Strong and logical structural form

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Principal Drivers Affecting Steel Pylon Costs

- **Weight of steel**
- **Fabrication**
- **Constructability**

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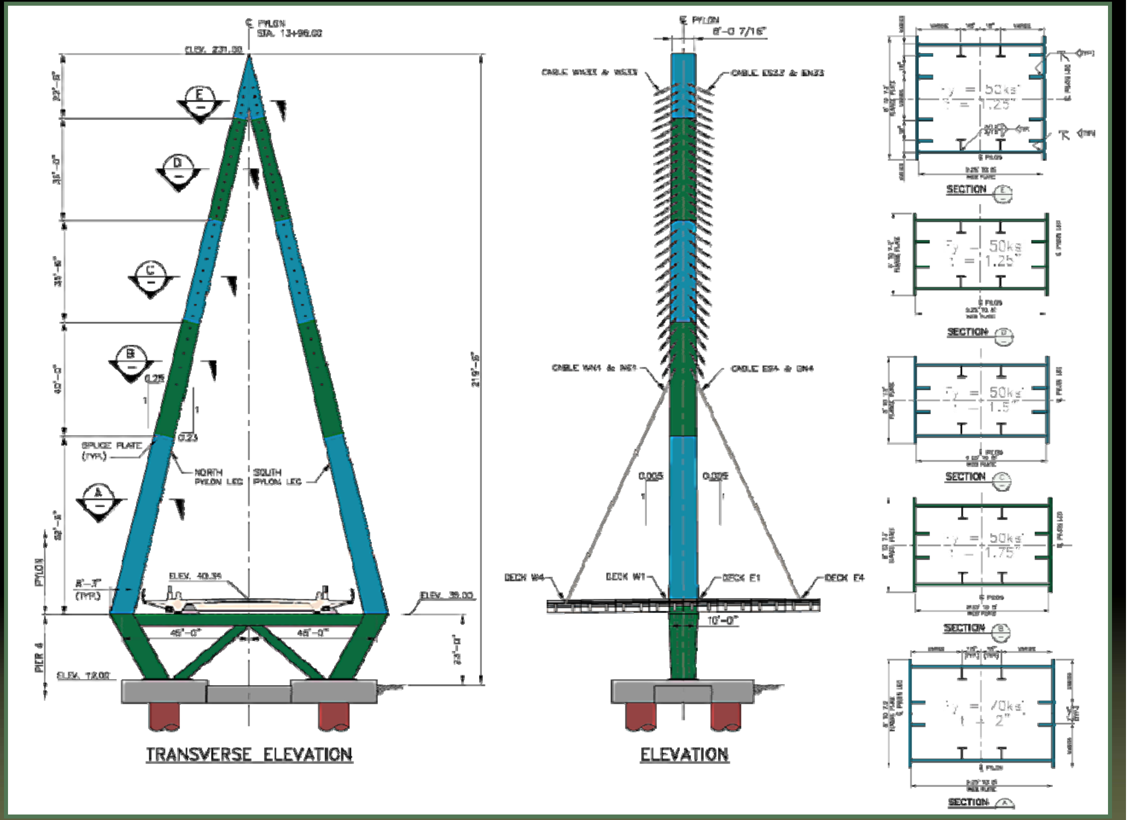
Cost Drivers:

Weight
- Height
- Section
- Plate Thickness

Fabrication
- Simplicity
- Repetition
- Thinner Plates

Constructability
- Simplicity
- Repetition
- Segmentation



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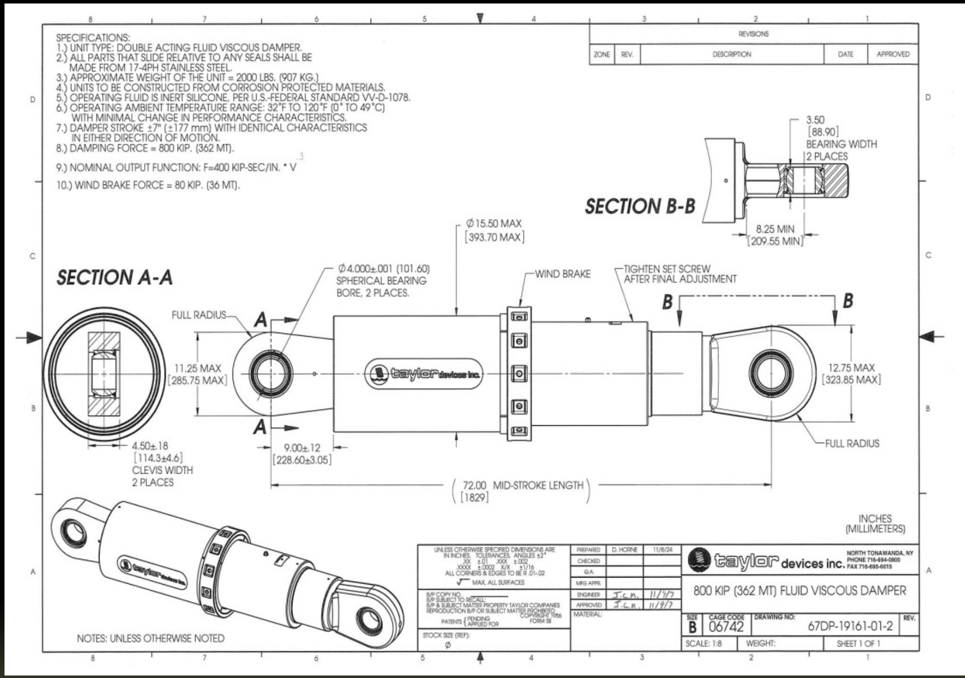
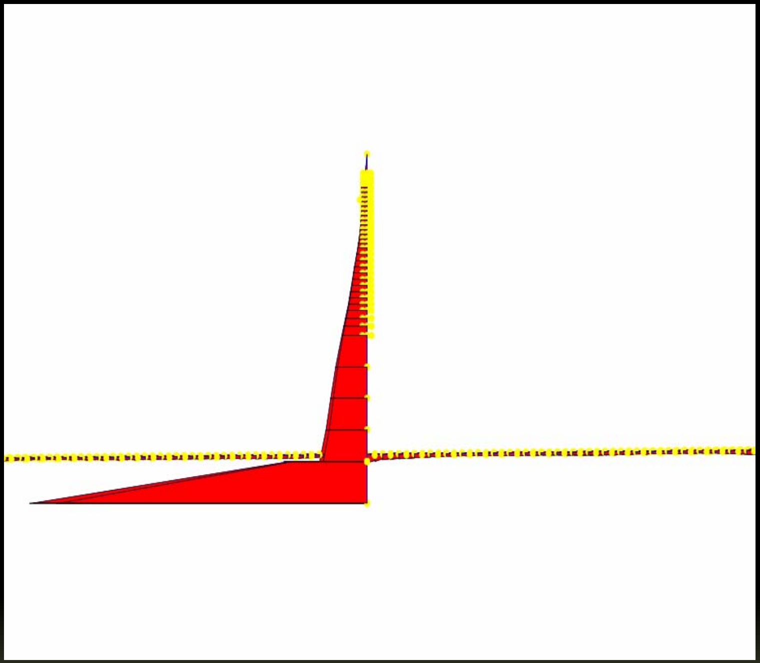
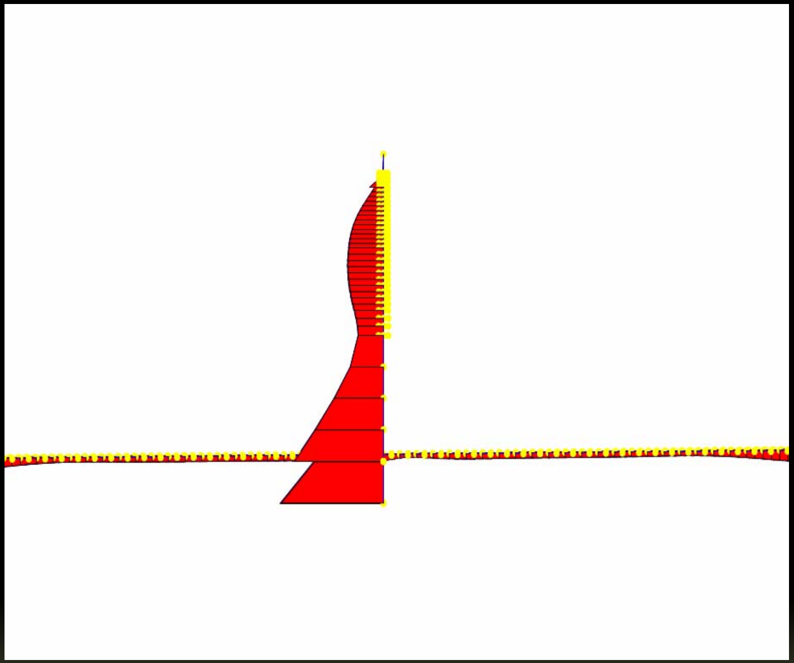
Pylon Dampers



800 k Viscous Dampers – Deck to Piers



Tower moments without dampers



Tower moments with dampers

Reducing Design Forces

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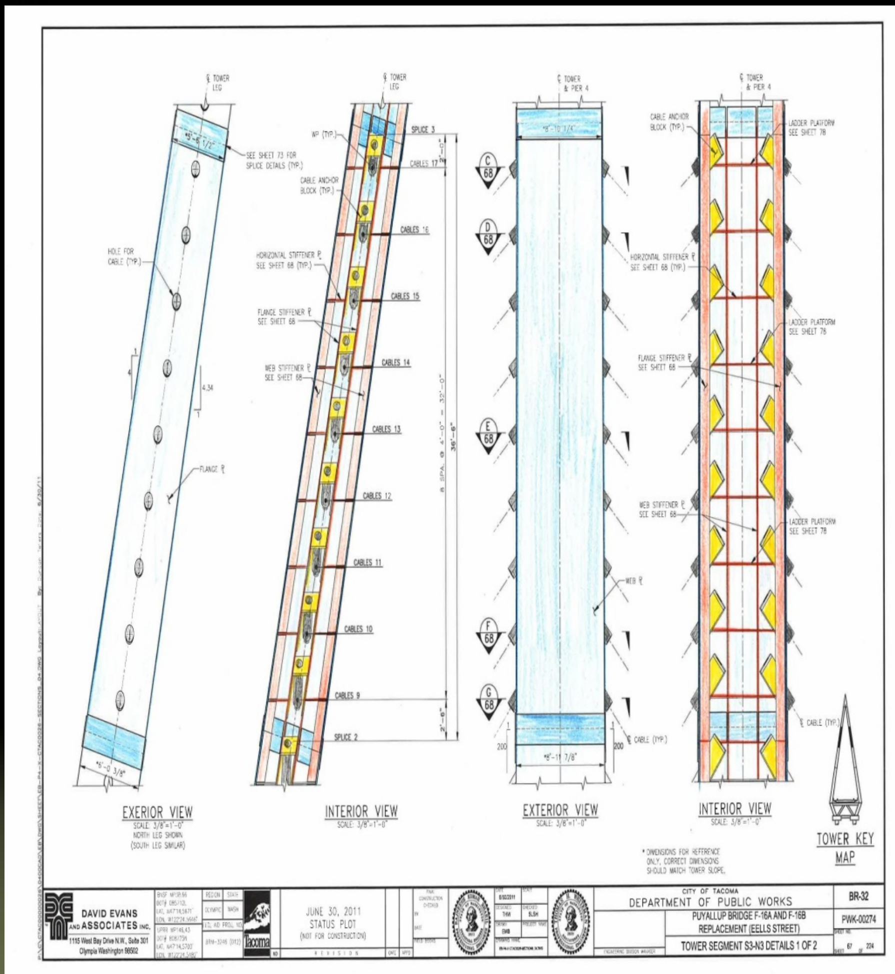
Plate Thickness = F(stiffeners)



$$\left(\frac{L}{r}\right)_{eq} = \frac{a}{r_e}$$

$$\frac{L}{r_{eq}} = \sqrt{6(1-\nu^2)}\,\frac{b}{t}\sqrt{\frac{1+(A_s/bt)}{1+\sqrt{(EI_e/bD)+1}}}$$

where

$b = Nd =$ overall width of longitudinally stiffened panel

$N =$ number of panels into which the longitudinal stiffeners divide the plate

$I_e =$ moment of inertia of section consisting of the stiffener plus a width of plate equal to d

$A_s =$ cross-sectional area of stiffener

$$D = \frac{Et^3}{12(1-\nu^2)}$$

$$\sigma_c = \frac{\pi^2 E\left[1+(a/\psi b)^4\right]}{(a/r_x)^2}$$

***Guide to Stability Design Criteria for Metal Structures*, 5th Ed.**

- **Anchor Support**
- **Tension diaphragm**

Vertical and horizontal buckling

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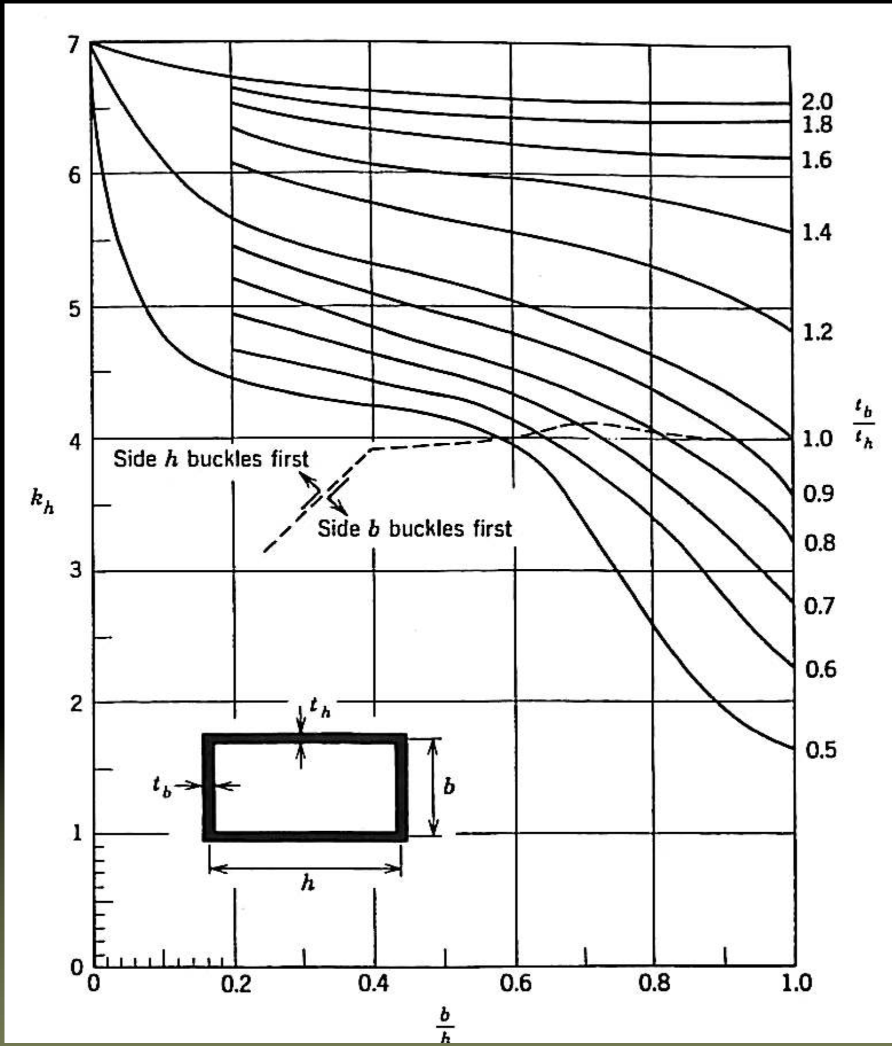
Pylon Section

- KL/r ratio
- K value - longitudinal direction
- K value - transverse direction

$$\frac{KL_{tower}}{r_{tower}} < \frac{KL_{plate}}{r_{plate}}$$



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Cost Drivers:

Weight
- Height
- Section
- Plate Thickness

Fabrication
- Simplicity
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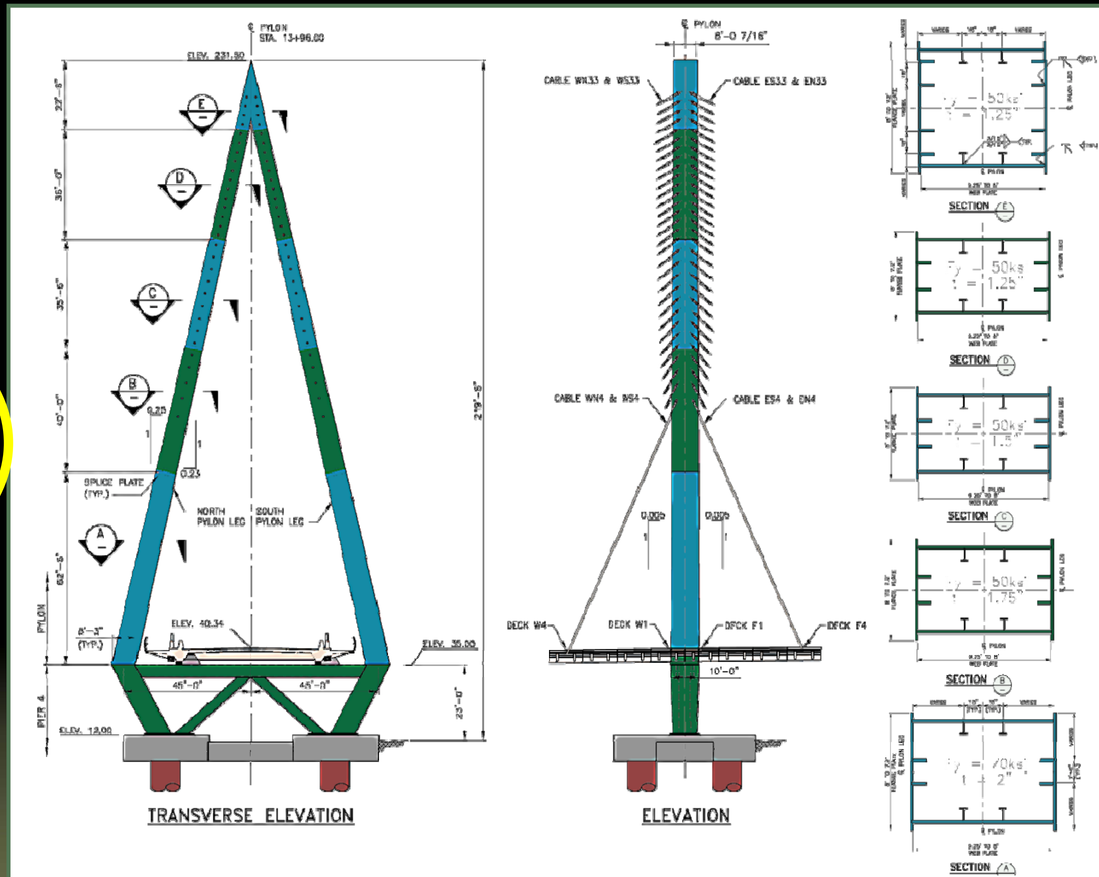
Constructability
- Simplicity
- Repetition
- Segmentation



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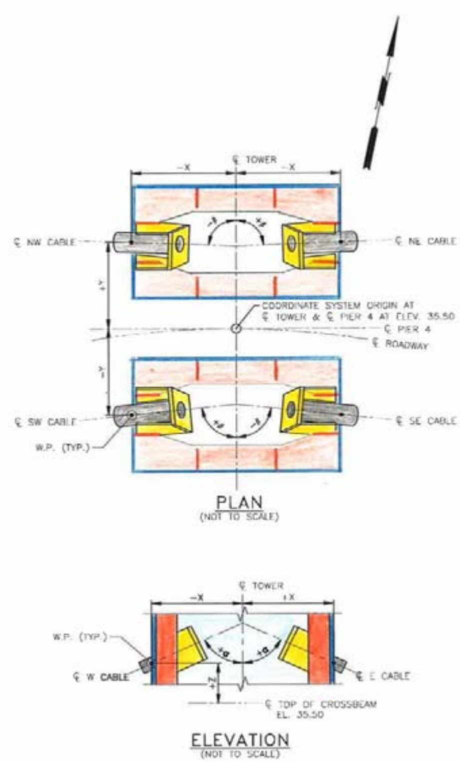
Fabrication

(simple, repetitive)

CABLE W.P. AT TOWER – NW FACE							
CABLE NO.	ANCHOR TYPE (STRANDS)	X FT.	Y FT.	Z FT.	VERT. ANGLE "α" DEGREES	HORZ. ANGLE "ψ" DEGREES	PLATE DIM "B" IN.
4NW	12	−4.6125	26.415	113.00	63.08	−2.77	13.87
5NW	12	−4.5825	24.976	119.00	58.18	−3.66	14.15
6NW	12	−4.5575	23.777	124.00	54.05	−3.93	14.24
7NW	12	−4.5325	22.578	129.00	50.71	−4.10	14.29
8NW	12	−4.5075	21.379	134.00	47.97	−4.21	14.32
9NW	12	−4.4825	20.180	139.00	45.70	−4.27	14.34
10NW	12	−4.4625	19.221	143.00	43.52	−4.17	14.31
11NW	12	−4.4425	18.261	147.00	41.65	−4.09	14.29
12NW	12	−4.4225	17.302	151.00	40.04	−4.00	14.26
13NW	12	−4.4025	16.343	155.00	38.62	−3.92	14.23
14NW	12	−4.3825	15.384	159.00	37.38	−3.84	14.21
15NW	12	−4.3525	14.424	163.00	36.28	−3.76	14.18
16NW	12	−4.3425	13.465	167.00	35.30	−3.69	14.16
17NW	12	−4.3225	12.506	171.00	34.42	−3.61	14.14
18NW	12	−4.3025	11.547	175.00	33.63	−3.54	14.11
19NW	12	−4.2875	10.827	178.00	32.73	−3.41	14.07
20NW	12	−4.2725	10.108	181.00	31.91	−3.28	14.03
21NW	12	−4.2575	9.388	184.00	31.16	−3.15	13.99
22NW	12	−4.2425	8.669	187.00	30.47	−3.04	13.96
23NW	12	−4.2275	7.950	190.00	29.83	−2.93	13.92
24NW	12	−4.2125	7.230	193.00	29.24	−2.82	13.89
25NW	12	−4.1975	6.511	196.00	28.70	−2.71	13.85
26NW	12	−4.1825	5.791	199.00	28.19	−2.61	13.82
27NW	12	−4.1675	5.072	202.00	27.72	−2.51	13.79
28NW	12	−4.1525	4.353	205.00	27.27	−2.42	13.76
29NW	12	−4.1375	3.633	208.00	26.86	−2.32	13.73
30NW	12	−4.1225	2.914	211.00	26.47	−2.23	13.70
31NW	12	−4.1075	2.250	214.00	26.10	−2.13	13.67
32NW	12	−4.0925	1.875	217.00	25.76	−1.99	13.62
33NW	12	−4.0775	1.500	220.00	25.44	−1.85	13.58

CABLE W.P. AT TOWER – SW FACE							
CABLE NO.	ANCHOR TYPE (STRANDS)	X FT.	Y FT.	Z FT.	VERT. ANGLE "α" DEGREES	HORZ. ANGLE "ψ" DEGREES	PLATE DIM "B" IN.
4SW	12	−4.612	−26.415	113.00	63.37	1.73	13.54
5SW	12	−4.582	−24.976	119.00	58.49	3.15	13.99
6SW	12	−4.557	−23.777	124.00	54.36	3.79	14.19
7SW	12	−4.533	−22.578	129.00	51.02	4.25	14.34
8SW	12	−4.507	−21.379	134.00	48.27	4.60	14.45
9SW	12	−4.483	−20.180	139.00	45.99	4.87	14.53
10SW	12	−4.463	−19.221	143.00	43.80	4.97	14.57
11SW	12	−4.443	−18.261	147.00	41.93	5.07	14.60
12SW	12	−4.422	−17.302	151.00	40.30	5.16	14.62
13SW	12	−4.402	−16.343	155.00	38.88	5.24	14.65
14SW	12	−4.382	−15.384	159.00	37.62	5.32	14.68
15SW	12	−4.362	−14.424	163.00	36.52	5.40	14.70
16SW	12	−4.342	−13.465	167.00	35.53	5.48	14.73
17SW	12	−4.322	−12.506	171.00	34.64	5.55	14.75
18SW	12	−4.303	−11.547	175.00	33.84	5.63	14.77
19SW	12	−4.287	−10.827	178.00	32.93	5.64	14.78
20SW	12	−4.273	−10.108	181.00	32.11	5.65	14.78
21SW	12	−4.257	−9.388	184.00	31.35	5.67	14.79
22SW	12	−4.243	−8.669	187.00	30.65	5.70	14.80
23SW	12	−4.227	−7.950	190.00	30.01	5.73	14.80
24SW	12	−4.213	−7.230	193.00	29.41	5.76	14.81
25SW	12	−4.197	−6.511	196.00	28.86	5.79	14.83
26SW	12	−4.182	−5.791	199.00	28.34	5.83	14.84
27SW	12	−4.168	−5.072	202.00	27.87	5.87	14.85
28SW	12	−4.152	−4.353	205.00	27.42	5.91	14.86
29SW	12	−4.138	−3.633	208.00	27.00	5.95	14.88
30SW	12	−4.122	−2.914	211.00	26.60	5.99	14.89
31SW	12	−4.108	−2.250	214.00	26.24	6.03	14.90
32SW	12	−4.092	−1.875	217.00	25.89	6.02	14.90
33SW	12	−4.078	−1.500	220.00	25.56	6.02	14.90



NOTE:
THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS SHOWN PRIOR TO FABRICATION

CABLE W.P. AT TOWER – NE FACE							
CABLE NO.	ANCHOR TYPE (STRANDS)	X FT.	Y FT.	Z FT.	VERT. ANGLE "α" DEGREES	HORZ. ANGLE "ψ" DEGREES	PLATE DIM "H" IN.
4NE	12	4.612	26.415	113.00	62.81	2.76	13.87
5NE	12	4.582	24.976	119.00	57.83	3.66	14.15
6NE	12	4.557	23.777	124.00	53.62	3.93	14.24
7NE	12	4.533	22.578	129.00	50.21	4.10	14.29
8NE	12	4.507	21.379	134.00	47.43	4.20	14.32
9NE	12	4.483	20.180	139.00	45.11	4.26	14.34
10NE	12	4.463	19.221	143.00	42.89	4.17	14.31
11NE	12	4.443	18.261	147.00	40.99	4.08	14.29
12NE	12	4.422	17.302	151.00	39.34	4.00	14.26
13NE	12	4.402	16.343	155.00	37.90	3.92	14.23
14NE	12	4.382	15.384	159.00	36.63	3.84	14.21
15NE	12	4.362	14.424	163.00	35.51	3.76	14.18
16NE	12	4.342	13.465	167.00	34.51	3.69	14.16
17NE	12	4.322	12.506	171.00	33.62	3.61	14.14
18NE	12	4.303	11.547	175.00	32.82	3.54	14.11
19NE	12	4.287	10.827	178.00	31.90	3.40	14.07
20NE	12	4.273	10.108	181.00	31.07	3.28	14.03
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22NE	12	4.243	8.669	187.00	29.60	3.04	13.96
23NE	12	4.227	7.950	190.00	28.95	2.93	13.92
24NE	12	4.213	7.230	193.00	28.35	2.82	13.89
25NE	12	4.197	6.511	196.00	27.80	2.71	13.85
26NE	12	4.182	5.791	199.00	27.28	2.61	13.82
27NE	12	4.168	5.072	202.00	26.80	2.51	13.79
28NE	12	4.152	4.353	205.00	26.35	2.42	13.76
29NE	12	4.138	3.633	208.00	25.93	2.32	13.73
30NE	12	4.122	2.914	211.00	25.53	2.23	13.70
31NE	12	4.108	2.250	214.00	25.16	2.13	13.67
32ME	12	4.092	1.875	217.00	24.82	1.99	13.62
33NE	12	4.078	1.500	220.00	24.49	1.85	13.58

CABLE W.P. AT TOWER – SE FACE							
CABLE NO.	ANCHOR TYPE (STRANDS)	X FT.	Y FT.	Z FT.	VERT. ANGLE "α" DEGREES	HORZ. ANGLE "ψ" DEGREES	PLATE DIM "B" IN.
4SE	12	4.612	−26.415	113.00	63.11	−1.73	13.54
5SE	12	4.582	−24.976	119.00	58.15	−3.15	13.99
6SE	12	4.557	−23.777	124.00	53.94	−3.79	14.19
7SE	12	4.533	−22.578	129.00	50.53	−4.25	14.34
8SE	12	4.507	−21.379	134.00	47.73	−4.60	14.45
9SE	12	4.483	−20.180	139.00	45.41	−4.87	14.53
10SE	12	4.463	−19.221	143.00	43.18	−4.97	14.57
11SE	12	4.443	−18.261	147.00	41.26	−5.07	14.60
12SE	12	4.422	−17.302	151.00	39.61	−5.16	14.62
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19SE	12	4.287	−10.827	178.00	32.11	−5.64	14.78
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26SE	12	4.182	−5.791	199.00	27.44	−5.83	14.84
27SE	12	4.168	−5.072	202.00	26.96	−5.87	14.85
28SE	12	4.152	−4.353	205.00	26.50	−5.91	14.86
29SE	12	4.138	−3.633	208.00	26.07	−5.95	14.88
30SE	12	4.122	−2.914	211.00	25.68	−5.99	14.89
31SE	12	4.108	−2.250	214.00	25.30	−6.03	14.90
32SE	12	4.092	−1.875	217.00	24.95	−6.02	14.90
33SE	12	4.078	−1.500	220.00	24.62	−6.02	14.90

DAVID EVANS AND ASSOCIATES INC.
1115 West Bay Drive N.W., Suite 301
Olympia Washington 98502

JUNE 30, 2011
STATUS PLOT
(NOT FOR CONSTRUCTION)

CITY OF TACOMA
DEPARTMENT OF PUBLIC WORKS
PUYALLUP BRIDGE F-16A AND F-16B REPLACEMENT (EELLS STREET)
PIER 4 TOWER ANCHOR BLOCK 2
BR-46
PWK-00274

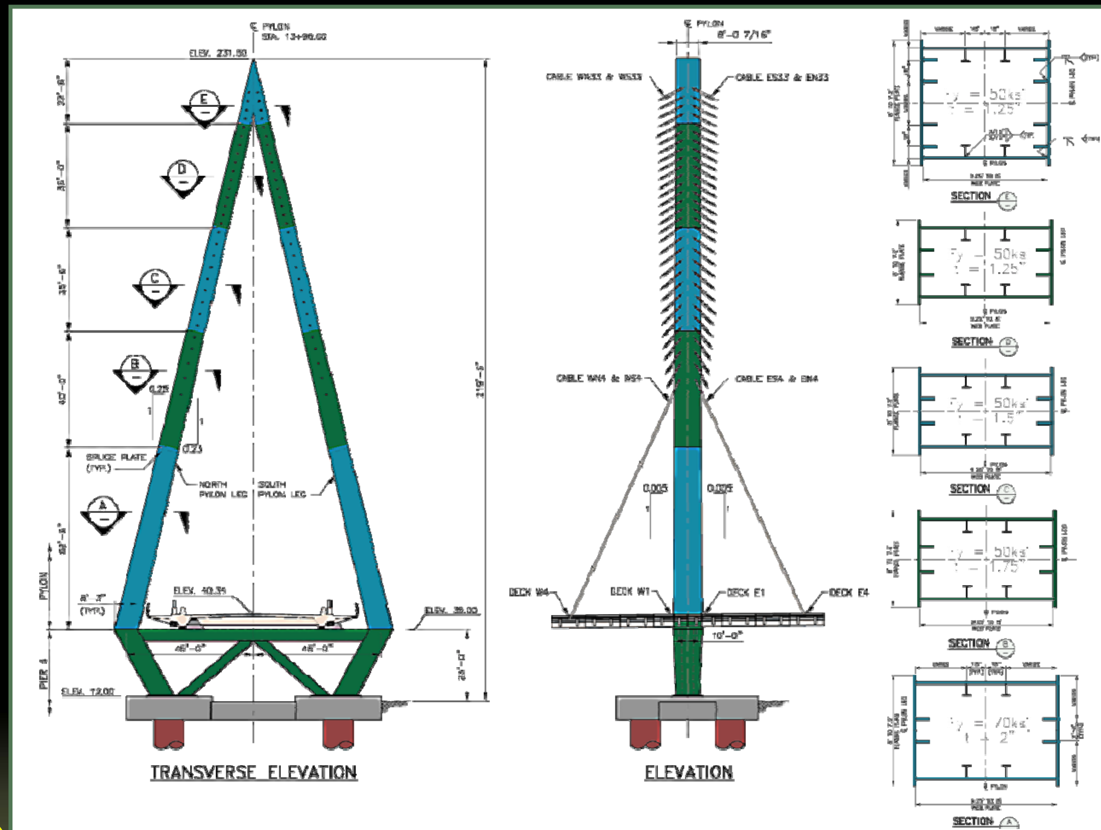
ANCHOR BLOCK DETAILS

DAVID EVANS AND ASSOCIATES INC.

Cost Drivers

Weight
- Height
- Section
- Plate Thickness

Fabrication
- Simplicity
- Repetition
- Thinner Plates



- Simplicity
- Repetition
- Segmentation

Constructability

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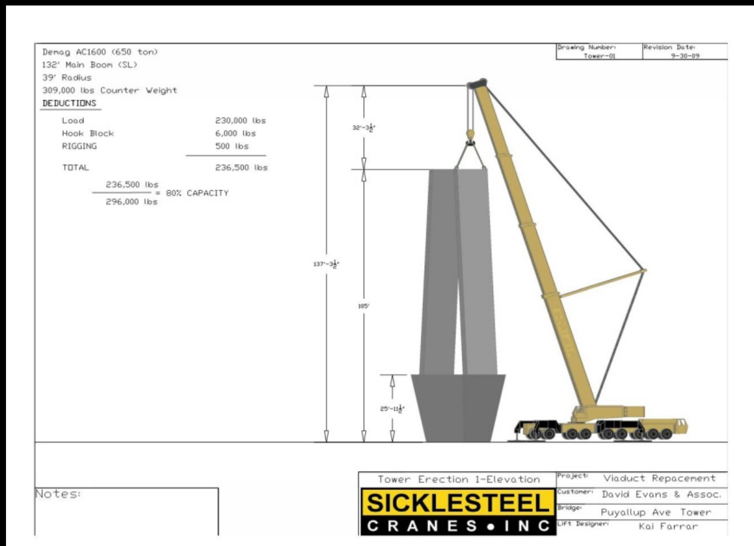
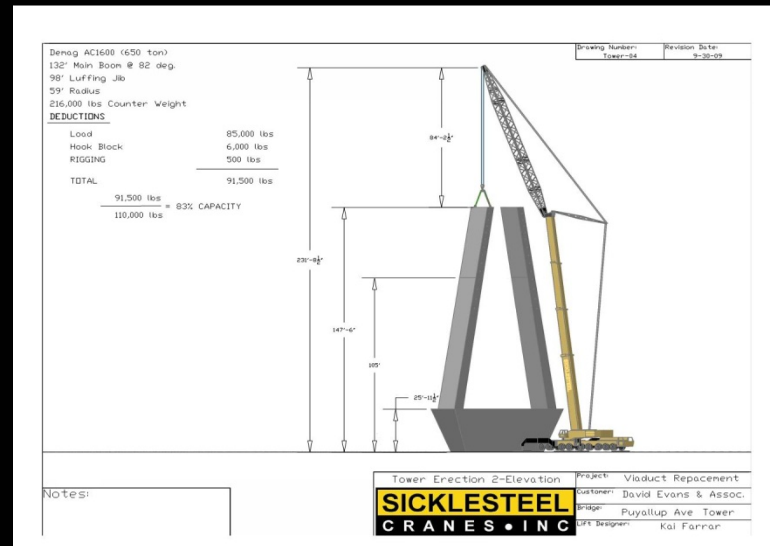
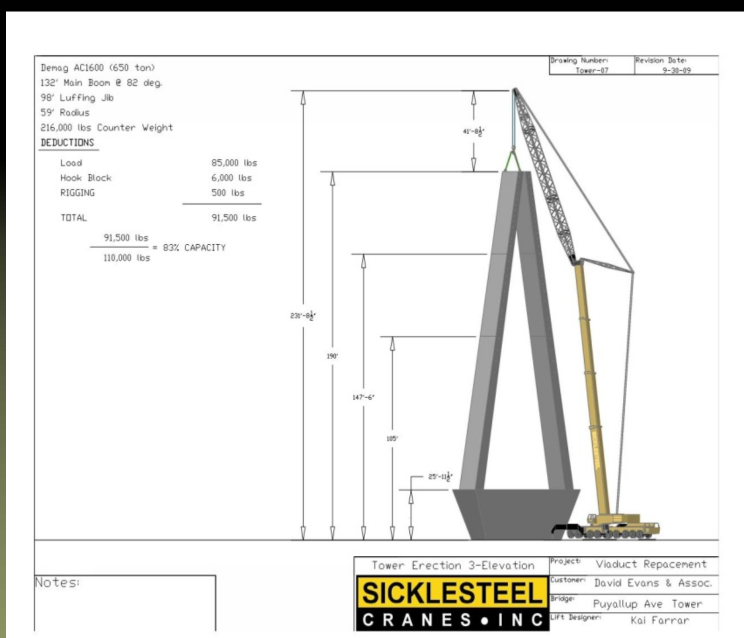
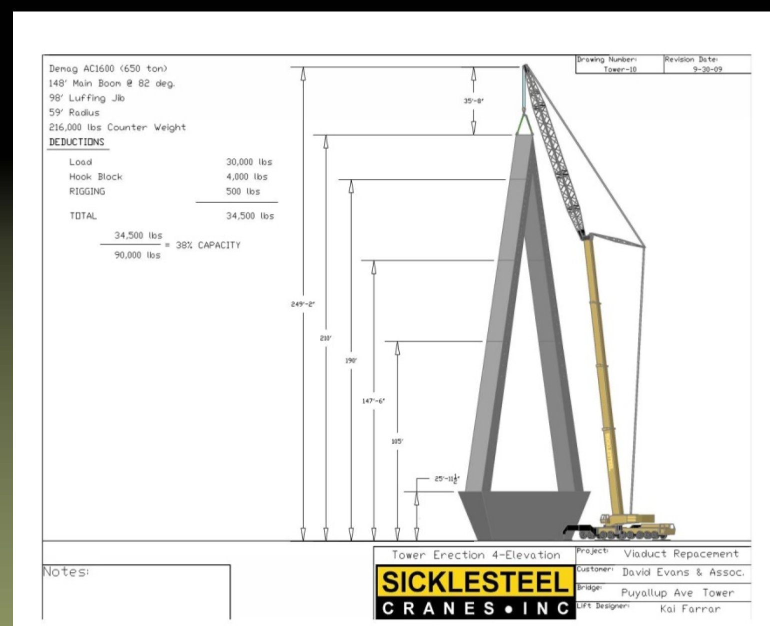
Pylon Erection









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Thank You

NSBA - National Steel Bridge Association

Brad Murphy - Thompson Metal Fabrication, Inc.

Kai Farrar - Sicklesteel Cranes, Inc.

Craig Keller - Taylor Devices, Inc. - Damper devices

Steve Seguirant – Concrete Technologies, Tacoma

Jodi Wills - David Evans Associates- Assistance with presentation

References

Guide to Stability Design Criteria for Metal Structures, 5th Edition Theodore Galambos

AASHTO LRFD Bridge Design Specifications, 5th Edition

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