CRWMS/M&O

Calculation Cover Sheet

Complete only applicable items.

1. QA: L
Page: 1 Of: 11

2. Calculation Title ESF GROUND SUPPORT - PROPOSED JACKING BRACKET EVALUATION				(SCPB: N/A)
3. Document Identifier (including Revision Number) DI: BABEE0000-01717-0200-00011, REV. 01				
4. Purpose of Calculation TO EVALUATE PORTIONS OF THE CONSTRUCTOR'S DESIGN OF THE PROPOSED W6x20 STEEL SET JACKING BRACKET AS SHOWN ON SUBMITTALS BABEAB000-01717-6300-02341-VD-86-1 AND -VD-87-1.				
	Print Name	Signature	Date	
5. Originator	Marvin D. Stine	<i>Marvin D. Stine</i>	03/28/96	
6. Checker	Matthew J. Gomez	<i>Matthew J. Gomez</i>	03/28/96	
7. Lead Design Engineer	Malcolm E. Taylor	<i>Marvin D. Stine</i> <i>for</i>	03/28/96	
8. Remarks THIS CALCULATION WAS REVISED TO RE-EVALUATE THE CONSTRUCTOR'S REVISED JACKING BRACKET DESIGN AS SHOWN ON THE REFERENCED SUBMITTALS AND TO EVALUATE THE TAB PLATE ON THE BASE PLATE. CONCLUSIONS AND RECOMMENDATIONS FROM THIS CALCULATION HAVE BEEN TRANSMITTED TO THE CONSTRUCTOR IN THE FORM OF OCCUPATIONAL SAFETY CONCERNS AND RED LINE "INFO ONLY" MARKUPS TO THE SUBMITTAL SHOP DRAWINGS. NOTE: THIS CALCULATION WAS PREPARED UNDER THE CURRENT STEEL SET CI: BABEE0000, EVEN THOUGH IT WAS INITIATED AS A RESULT OF A REVIEW OF THE SUBMITTALS TO A SPECIFICATION WHICH USED THE PREVIOUS CI: BABEAB000.				
Revision History				
9. Revision No.	10. Date Approved	11. Description of Revision		
00	02/16/96	Initial Issue		
01	03/28/96	Added references to sources of data. Added new sources of data: W6x20 shop drawings and Blodgett Added calculation for 4 bolts at 3" o.c. Added calculations for stability during jacking & foot/tab plates Issued Approved		

1. Item: This calculation applies to the Constructor's design of the proposed jacking bracket for the W6x20 steel set.
2. Feature: The specific features of the jacking bracket evaluated in this analysis are the shear on the bracket bolts, and the effects of the applied moment on the W6x20 steel set beam segment.
3. Sources of Data: Input information used in this analysis was obtained from the following sources:
 - a. Submittal BABEAB000-01717-0-6300-02341-VD-86-0, 2/2 (Commercial Pantex Sika Shop Drawing No. D-985-5A-6, Rev. 3).
 - b. Submittal BABEAB000-01717-0-6300-02341-VD-87-0, 2/2 (Commercial Pantex Sika Shop Drawing No. D-985-5A-7, Rev. 1).
 - c. Submittal BABEAB000-01717-0-6300-02341-VD-86-1, 2/2 (Commercial Pantex Sika Shop Drawing No. D-985-5A-6, Rev. 4).
 - d. Submittal BABEAB000-01717-0-6300-02341-VD-87-1, 2/2 (Commercial Pantex Sika Shop Drawing No. D-985-5A-7, Rev. 2).
 - e. BABEE0000-01717-0200-00003, Rev 01, ESF Ground Support - Structural Steel Analysis.
4. Sources of Formula and References:
 - a. AISC M016, Manual of Steel Construction (ASD), 9th Edition.
 - b. Blodgett, Omar W., "Design of Welded Structures", June 1966.
5. Use of Computer Software:
Not Used.
6. Calculation: See pages 3 through 10.

G. CHECK PROPOSED W6X20 JACKING BRACKET DESIGN:

REF: CPS SHOP DRWS D-985-5A-6, REV. 3 & D-985-5A-7, REV. 1
(SUBMITTALS BABEE0000-01717-0200-00011, REV. 01 & V0-86-0 & V0-87-0)
REFS: 3a & 3b

SKETCH:

$$P = 17 \text{ TONS} = 34^k$$

(FROM BABEE0000-01717-0200-00011, REV. 01, PAGE III-54
REF. 3.c)

G. CHECK BRACKET BOLTS:

$$\text{ASSUME } X \text{ DIMENSION} = 0.85(12") = 10.2"$$

$$\sum M_B = 0 = -34^k(4") + T_{\text{BOLTS}}(10.2")$$

$$\therefore T_{\text{BOLTS}} = \frac{34(4)}{10.2} = 13.3^k / 2 \text{ BOLTS} = 6.7^k / \text{BOLT}$$

$$V_{\text{BOLT}} = \frac{34^k}{2} = 17^k / \text{BOLT}$$

ON 1" ϕ A307 BOLTS: $T_{\text{ALL}} = 15.7^k > 6.7^k \therefore \text{OK}$ (AISC TABLE I-A)
 $V_{\text{ALL}} = 7.9^k < 17^k \therefore \text{NG}$ (AISC TABLE I-D)
(REF. 4.c)

TRY 1" ϕ A325 BOLTS: $T_{\text{ALL}} = 34.2^k > 6.7^k$
 $V_{\text{ALL}} = 16.5^k < 17^k \therefore \text{NG}$ (TYPE N, STR.)

TRY 1 1/2" ϕ A325 BOLTS: $T_{\text{ALL}} = 43.7^k > 6.7^k$
 $V_{\text{ALL}} = 20.9^k > 17^k \therefore \text{OK FOR COMBINED } V \& T:$

$$F_t = (44^2 - 4.39 f_v^2)^{1/2} = (44^2 - 4.39 (17.1)^2)^{1/2} = 25.5 \text{ ksi}$$

$$f_v = \frac{17}{0.9940} = 17.1 \text{ ksi}$$

$$f_t = \frac{6.7}{0.9940} = 6.74 \text{ ksi} < 22.5 \text{ ksi} \therefore \text{OK}$$

K.K.K.

(2) 1 1/2" ϕ A325 BOLTS OK

MIN. X DIM: $T_{\text{MAX}} = 22.5 (0.9940) = 22.4^k$; $X_{\text{MIN}} = \frac{34(4)}{22.4(2)} = 3.07"$ $\therefore$ STILL OK

Try (4) $7/8"$ ϕ A325 Bolts on 6" centers:

{ Follow Method on page III-54 of }
{ BABEE0000-01717-0200-00003, REV. 01, Ref. 3.e }

$$I_c = \frac{\pi}{4} \left(\frac{7/8}{2} \right)^4 = .03 \text{ in}^4 \quad A = .6013 \text{ in}^2 \quad \bar{x}_c^2 = 3^2 = 9.0 \text{ in}^2$$

$$I_{\text{Bolts}} = 2 [I_c + A \bar{x}_c^2] = 2 [2(.03) + .6013(9)]$$

$$= 11.0 \text{ in}^4$$

$$T = \frac{M_c}{I} \quad M = 34(4) = 136 \text{ in-k} \quad C = 3"$$

$$T_{\text{Bolt}} = \frac{136(3)}{11.0} = 37.1 \text{ k} \times \frac{1}{2} = 18.5 \text{ k/Bolt} < 26.5 \text{ k ALLOW.}$$

$$V_{\text{Bolt}} = 34 \text{ k} \left(\frac{1}{2} \right) = 8.5 \text{ k/Bolt} < 12.6 \text{ k}$$

COMBINED T & V: $f_v = \frac{8.5}{.6013} = 14.1 \text{ ksi}$

$$F_t = (44^2 + 4.39(14.1)^2)^{1/2} = 32.6 \text{ ksi}$$

$$f_t = \frac{18.5}{.6013} = 30.8 \text{ ksi} < 32.6 \text{ ksi} \therefore \text{OK}$$

(4) $7/8"$ ϕ A325 Bolts @ 6" APART ARE OK

b. CHECK MOMENT ON WL

{ Ref. pages VIII-2, 3, 4 & 14 of }
{ BABEE0000-01717-0200-00003, REV. 01, Ref. 3.e }

$$M = 34 \text{ k} (4' + 3/8') = 242 \text{ in-k} = 20.2 \text{ ft-k} \text{ vs } 14.6$$

By RATIOS: M_{max} from STAAD Analysis, page VIII-2, Ref. 3.e

$$M_{\text{max}} = 15.41 \left(\frac{20.2}{14.67} \right) = 21.2 \text{ ft-k} \quad f_b = \frac{21.2(12)}{13.4} = 19.0$$

$$\text{AEC HI-1} = \frac{f_a}{F_a} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F_{ex}}\right) F_b} = \frac{5.486}{12.49} + \frac{(1.0)(19.0)}{\left(1 - \frac{5.486}{332.7}\right) 24} = 0.314 + .805$$

$$= 1.119 > 1.0 \therefore \text{NG}$$

Try $M = 34 \left(\underbrace{2\frac{1}{4} + 3/8}_{5\frac{3}{8}'' \text{ max}} \right) = 182.8 \text{ in-k} = 15.2 \text{ ft-k} \quad M_{\text{max}} = 16.0$

$$\text{HI-1} = .314 + .677 = 0.99 < 1.0 \therefore Y_{\text{max}} = 5\frac{3}{8}'' \text{ say } 5''$$

HI-2 = By INSPECTION (pg VIII-4) THIS EQN IS NOT CRITICAL

C. CHECK (4) $\frac{7}{8}$ " ϕ ASTM A307 BOLTS @ 3" APART E.W.
(REF. RESUBMITALS - VD-86-1 & - VD-87-1, REF. 3.C. & 3-d)

$$I_c = \frac{\pi}{4} \left(\frac{.875}{2} \right)^4 (2) = 0.029 (2) = .058 \text{ in}^4 \text{ / 2 bolts}$$

$$A = 0.6013 \text{ in}^2$$

$$I_c^2 = 1.5^2 = 2.25 \text{ in}^2$$

$$I_{\text{bolts}} = 2 [I_c + A I_c^2] = 2 [0.058 + .6013 (2.25)] = 2.82 \text{ in}^4$$

$$T = \frac{M_c}{I} \quad M = 34^k (2') = 68 \text{ in-k} \quad C = 1.5"$$

$$T_{\text{bolts}} = \frac{(68)(1.5)}{2.82} = 36.2 \text{ in-k} \times \frac{1}{2} = 18.1^k / \text{bolt} > T_{\text{allow}} = 12.0^k \text{ (AISC PART 4, TABLE 1-A)}$$

$$V_{\text{bolt}} = 34^k \left(\frac{1}{4} \right) = 8.5^k / \text{bolt} > V_{\text{allow}} = 6.0^k \text{ (AISC PART 4, TABLE 1-D) (STD. HOLE, SINGLE SHEAR)}$$

∴ A307 BOLT N.G.

COMBINED T & V :

$$f_v = \frac{8.5}{.6013} = 14.1 \text{ ksi}$$

$$\text{A307 BOLTS: } F_t = (22 - 1.8 f_v) = (22 - 1.8 (14.1)) = 0.62 \text{ ksi} \quad \text{AISC TABLE J3.3}$$

$$f_t = \frac{18.1}{.6013} = 30.1 \text{ ksi} >> 0.62 \text{ ksi} \quad \therefore \text{NG}$$

(4) $\frac{7}{8}$ " ϕ ASTM A307 BOLTS @ 3" APART ARE N.G.

$$\text{TRY A325 BOLTS: } F_t = (44 - 4.39 f_v)^{1/2} = (44 - 4.39 (14.1))^2 = 32.6 \text{ ksi}$$

$$F_v = 16.8 \text{ ksi} > f_v = 14.1 \text{ ksi} \quad \therefore \text{OK}$$

$$f_t = 30.1 \text{ ksi} < 32.6 \text{ ksi} \quad \therefore (2) \text{ A325 BOLTS OK}$$

SEE PAGE 4 FOR CALCULATION OF ADEQUATE BOLT TYPE,
SIZE & SPACING (4) $\frac{7}{8}$ " ϕ A325 BOLTS @ 6" APART

D = DISTANCE FROM CTR TUNNEL CIRCLE TO LINE OF JACKING FORCE WHERE IT INTERSECTS BOTTOM OF BASE PLATE = $\overline{OB}$
 (FROM SERRA BRUNO) $\cos \theta = \frac{DY}{D} = \frac{140.75}{D} = .9859 \therefore D = 142.769 = \overline{OB}$
 LINE OF JACKING FORCE IS INSIDE MIDDLE THIRD OF BASE PLATE
 $\therefore$ NO UPLIFT ON LEFT EDGE OF PL (SEE NEXT PAGE)

$\Delta_{CBX} : \theta = 9.645^\circ ; \overline{OE} = 142.769 - 4.023 = 138.746 ; \overline{CE} = 145.875 - 142.769 = 3.106$
 $\overline{BX} = \frac{\overline{CB}}{\sin \theta} = \frac{3.106}{\sin 9.645^\circ} = 18.539"$

$\overline{YB} = \frac{23.67}{\cos 9.645^\circ} = 24.009"$

$\overline{YX} = 24.009 + 18.539 = 42.548"$

$\overline{CX} = \overline{BX} \cos 9.645^\circ = 18.277$

$H_{PH} = \overline{YE} = \overline{EO} = 23.67$ } CHECK: $\frac{\overline{YX}}{\overline{BX}} = \frac{(\overline{H_{PH}} + \overline{CX})}{\overline{CX}} ; H_{PH} = \frac{\overline{CX}(\overline{YX})}{\overline{BX}} - \overline{CX}$
 $H_{PH} = \frac{(18.277)(42.548)}{18.539} - 18.277 = 23.67 \therefore OK$

$H_{PV} = \overline{YX} \sin \theta = 42.548 \sin 9.645^\circ = 7.129 = \overline{YL} = \overline{CE}$

CHECK: $H_{PV} = \overline{CE} = \overline{OC} - \overline{OE} = 145.875 - 138.746 = 7.129$

RESOLVE JACKING FORCE, P INTO P_V & P_H COMPONENTS:

$P_H = P \sin 9.645^\circ = 0.1675 P = (.1675)(34^k) = 5.70^k$

$P_V = P \cos 9.645^\circ = 0.9859 P = (.9859)(34^k) = 33.52^k$

AND SUPERIMPOSE P_V & P_H TO POINT "C" ON BASE PL

$M_{PV} = P_V (H_{PV}) = (7.129)(.9859)P = 7.028 P = 239.0 \text{ in-k}$

$M_{PH} = P_H (H_{PH}) = (23.67)(.1675)P = 3.965 P = 134.8 \text{ in-k}$

O.T.M. = $7.028 P - 3.965 P = 3.063 P = 104.2 \text{ in-k AWAY FROM TUNNEL WALL}$

$\therefore$ ADD TAB ON INSIDE FOR STABILITY.

C. ANALYZE BASE PLATE & TAB PLATE

(FOLLOW METHODOLOGY IN BABEE0000-01717-0200-00003, REV. 01

ATTACHMENT III, PAGES III-114 THRU III-115, REF. 3-e)

$$A_1 = 10'' \times (8 - \frac{3}{8} - \frac{1}{2}) = 67.5 \text{ in}^2 = \text{FOOT PLATE AREA IN CONTACT WITH CONCRETE}$$

$$A_2 = 1 \frac{3}{4}'' \times 10'' = 17.5 \text{ in}^2 = \text{VERTICAL TAB PLATE}$$

I = MOMENT OF INERTIA ABOUT PT. 'O' OF PROJECTED PLATE

$$= \frac{1}{12} (10) (10.5)^3 + (10) (10.5) (2.125)^2$$

$$= 1439 \text{ in}^4$$

$$C_1 = 3.125 - \frac{1}{2} = 2.625'' \quad C_2 = 10.5 - 3.125 = 7.375''$$

$$P_a = P_v = 33.52''$$

$$M = 104.2 \text{ in-k}$$

$$\frac{P_a}{A_1} = \frac{33.52}{67.5} = 0.497 \text{ ksi}$$

$$\frac{M C_1}{I_1} = \frac{104.2 (2.625)}{1439} = -0.190 \text{ ksi}$$

$$\frac{M C_2}{I_1} = \frac{104.2 (7.375)}{1439} = 0.534 \text{ ksi}$$

$$P_{\text{net}} = 0.534 - \left(\frac{0.534 + 0.190}{10.5} \right) (2.5) = 0.362 \text{ ksi}$$

$$P_{\text{net}} = -0.190 + \left(\frac{0.534 + 0.190}{10.5} \right) (7.5) = -0.156 \text{ ksi}$$

NET PRESSURES

$$P_{\text{net}} = 0.497 - 0.156 = 0.341$$

$$P_{\text{net}} = 0.497 + 0.362 = 0.859$$

$$P_{\text{net}} = 0.497 + 0.362 = 0.859$$

$$P_{\text{net}} = 0.000 + 0.534 = 0.534$$

P_0 : MAX. BRNC PRESSURE ON CONC. = 0.859 ksi < $0.35 f'_c = 0.35 (5 \text{ ksi}) = 1.750 \text{ ksi}$
 ADJUST PRESSURE FOR CHAMFER $P = \left(\frac{.534 + .859}{2} \right) (2.5) = 1.74 \text{ ksi}$
 CHECK VERTICAL FEET: $P_0' = [(1.74)(2) + (2.5 - 3/4)] - .534 = 1.455 \text{ ksi} < 1.750 \text{ ksi}$ OK

M_c TOP OF FE (1" STRIP):

$$M_T = (0.534)(1) \left(\frac{1.75}{2} + .75 \right) + \frac{1}{2} (1.75)(.921) \left(\frac{1.75}{3} + .75 \right) = 2.593 \text{ in-kip}$$

$$S_x = \frac{t^3}{6} = \frac{M_T}{F_y} = \frac{2.593}{27 \text{ ksi}} = 0.0960$$

$$t^3 = 6(0.0960) = 0.576 \quad \phi \quad t = 0.759 \text{ in}$$

DUE TO CONSERVATION OF ANALYSIS, USE $t = 3/4" = 0.750"$
 & FOR CONSISTENCY, INCREASE FOOT FE $\approx 3/4" \times 10"$

ASSUME VERT. FE WELDED BOTH SIDES (FOR 1" STRIP, TREAT AS A LINE)
 (REF. "DESIGN OF WELDED STRUCTURES"; SECTION 7.4; Ref. 4.6.)

$$A_w = 2(1") = 2.0"$$

$$S_w = \frac{d^2}{3} = \frac{1^2}{3} = 0.333 \quad \dots \quad \text{TABLE 5, SECT. 7.4}$$

$$f_v = \frac{P}{L} = \frac{5.70}{10} = 0.57 \text{ ksi} \rightarrow 2.0 = 0.285 \text{ ksi/in}$$

$$f_b = \frac{M_T}{S} = \frac{2.593}{0.333} = 7.787$$

$$f_r = \text{resultant} = (f_v^2 + f_b^2)^{1/2} = (0.285^2 + 7.787^2)^{1/2} = 7.792 \text{ ksi/in}$$

$$\text{Leg Size, } w = \frac{\text{Resultant Force}}{\text{Allowable Force}} = \frac{7.792}{21(1.07)} = 0.515 \approx 1/2"$$

TRY SINGLE PARTIAL PEN WELD:

$$A_w = 1" \quad S_w = \frac{d^2}{6} = \frac{1^2}{6} = 0.167 \quad f_v = 0.570 \text{ ksi/in}$$

$$f_b = \frac{2.593}{0.167} = 15.53 \quad f_r = (0.570^2 + 15.53^2)^{1/2} = 15.54 \text{ ksi/in}$$

$$w = \frac{15.54}{21.00} = 0.740 \quad \therefore \text{USE FULL PENETRATION WELD ON } 3/4" \text{ FE}$$

NOTE: w/ FULL PEN. WELD, ALLOWABLES ARE SAME AS THE FEAT

OPTIONAL WELDS:

UNDERLINED VALUES INCREASED
OVER THOSE SHOWN ON SHOP DRUGS.

(USE)

NOTE: B.Y. INSPECTION, INCREASING TAB P LENGTH TO 3" OR MORE WILL LOWER PRESSURE ON PATE, BUT WILL INCREASE MOMENT EVEN MORE DUE TO INCREASED MOMENT ARM.

CHECK FOR STABILITY w/o TAB R (SKETCH PAGE 3 w/o TAB):

$$C_3 = 2.025'' \quad C_4 = 2\frac{1}{4} + 5\frac{1}{4} - 2\frac{1}{2} - 3\frac{1}{4} = 4.125''$$

$$I_x = \frac{1}{12}(10)(\underbrace{8 \cdot \frac{1}{2} \cdot 4}_{6.75''})^3 + 67.5(\underbrace{\frac{6.75}{2} + 0.50 + 3.125}_{0.75''})^2$$

= EWC to E BRK AREA (A₁)
w/ TAG TP

$$= 256.3 + 38.0 = 294.3 \text{ in}^6$$

$$\frac{P}{A_1} = \frac{33.57}{67.5} = 0.497 \text{ ksi}; \quad \frac{M_{C_1}}{I_1} = \frac{104.2 (24.175)}{294.3} = 0.929 \text{ ksi}; \quad \frac{M_{C_2}}{I_2} = \frac{104.2 (4.175)}{294.3} = 1.460 \text{ ksi}$$

$$\frac{P}{A_1} - \frac{M_{C_1}}{I_{x_1}} = -0.432 \text{ (upward)} \quad + \quad \frac{P}{A_2} + \frac{M_{C_2}}{I_{x_2}} = 1.957 \text{ ksi} > 1.750 \therefore \text{N.G.}$$

SINCE UPLIFT SHOULD = 0, MAX. COMP. PRESSURE WILL EXCEED ALLOWABLE BEARING ON CONCRETE $\therefore$ TAD IS NEEDED TO COUNTERACT O.T.M.

7. Conclusions:

- a. (2) 1" Dia. ASTM A307 as shown on shop drawings are inadequate to resist shear loads due to a 17 ton jacking force.
- b. (2) 1-1/8" Dia. ASTM A325 bolts or (4) 7/8" Dia. ASTM A325 bolts (with bolt pairs at 6" on-center) are adequate to resist shear loads due to a 17 ton jacking force.
- c. The W6x20 steel set beam member can resist bending stresses due to a 17 ton jacking force applied to the jacking bracket at no more than 5" from the centerline of the W6 to the centerline of the reaction force (or 2" from the inside face of the W6 flange to the point of jack load application).
- d. Foot plate and tab plate on W6 are inadequate to resist bending moments due to applied 17 ton jacking load.

8. Recommendations

- a. Increase foot plate length to 10", width to 9-1/2", and thickness to 3/4".
- b. Increase tab plate length to 10", thickness to 3/4", and fillet weld size to 1/2" both sides.
- c. Recommend that Constructor revise W6x20 steel set jacking bracket drawings to incorporate the above recommendations and resubmit for information.