STRUCTURAL CALCULATIONS

FOR

Connect-EZ PA-EX

Date:
December 11, 2013

GREGORY L. LINNEMAN - PE
MO LICENSE - 2005001013

PREPARED BY:

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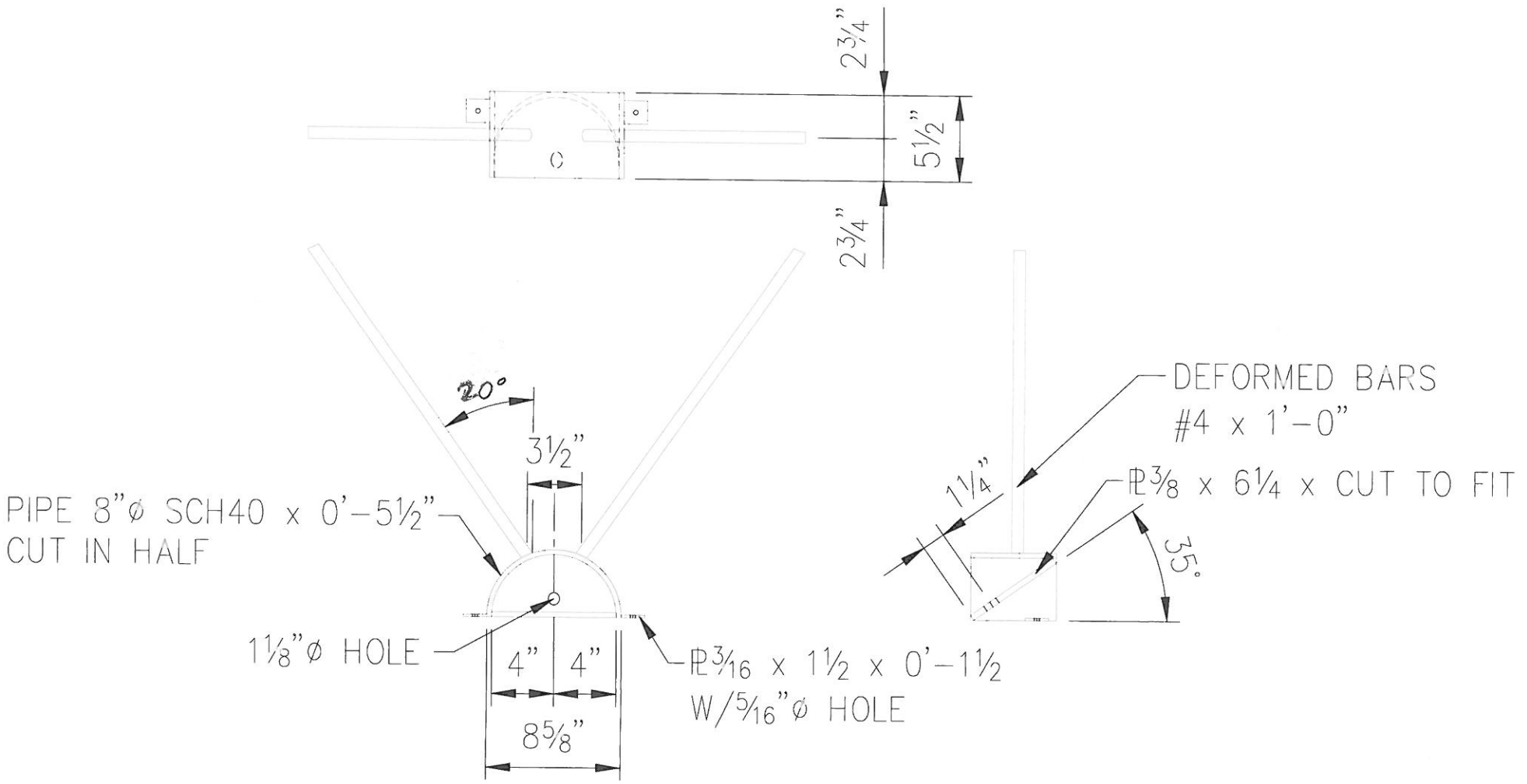
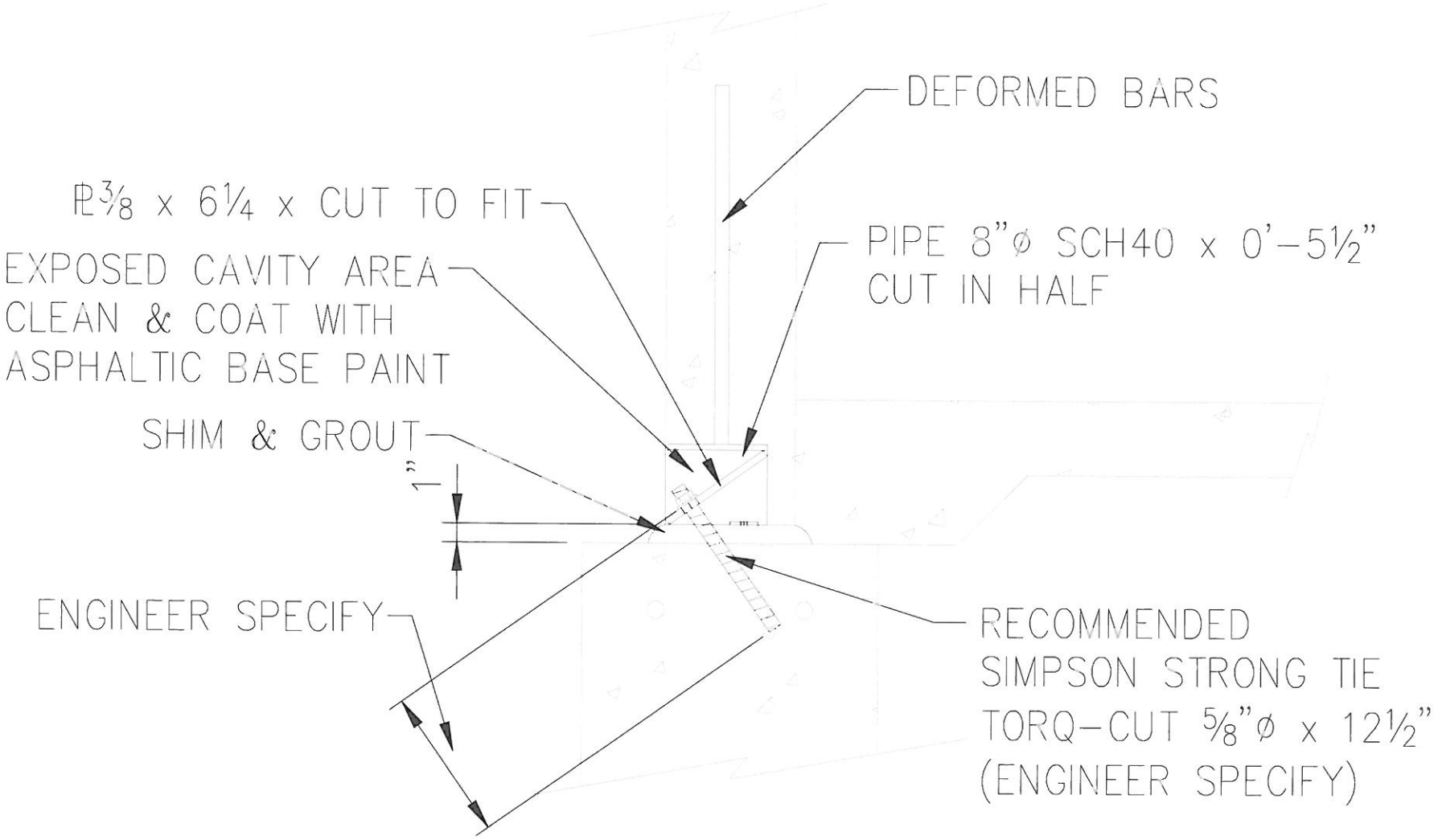


CONNECT-EZ "PA-EX"

PATENT PENDING



CONNECT-EZ "PA-EX"

PATENT PENDING

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PROJECT NUMBER _____ SHEET ___ OF ___
PROJECT CONNECT-EZ PA-EX
BY EWL DATE 12/11/13
SUBJECT _____

CONNECT-EZ PA-EX TENSILE STRENGTH

PURPOSE OF THE PA-EX

TO MEET THE ACI 318 STRUCTURAL INTEGRITY PROVISION 16.5.1.3 (b).

"PRECAST WALL PANELS SHALL HAVE A MINIMUM OF TWO TIES PER PANEL, WITH A NOMINAL TENSILE STRENGTH NOT LESS THAN 10,000 lb PER TIE"

DESIGN CRITERIA

NOMINAL CAPACITY OF ASSEMBLY $\geq$ 10,000#

"NOMINAL" — NO FACTORS OF SAFETY (ASD) OR RESISTANCE REDUCTION (ϕ) FACTORS (LRFD)

LIMIT STATES*

1. TENSION OF DEFORMED BAR ANCHORS (DBA)
2. BENDING OF PIPE BASE
3. BENDING OF ANCHOR PLATE
4. TENSION OF ANCHOR BOLT INTO FOOTING

CHECKED & SPECIFIED BY ENGINEER → ④

* WELDS CONSIDERED OK BY INSPECTION.

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CONNECT-EZ PA-EX (CONT'D)

(1) DEFORMED BAR ANCHORS (DBA)

DEVELOPMENT LENGTH FOR YIELD (ACI 318, 12.2.3)

$$l_d = \left(\frac{3}{40} \frac{f_y}{\lambda \sqrt{f'_c}} \frac{\psi_t \psi_e \psi_s}{\left(\frac{c_b + K_{tr}}{d_b} \right)} \right) d_b$$

$f_y = 70{,}000$ psi	DBA CONFORMS TO AWS D1.1–02, TABLE 7.1, TYPE "C" STUDS
$\lambda = 1.0$	NORMAL WEIGHT CONCRETE
$f'_c = 3500$ psi (MIN.)	TILT PANEL 28-DAY COMPRESSIVE STRENGTH
$\psi_t = 1.0$	NOT A "TOP" BAR (12.2.4)
$\psi_e = 1.0$	UNCOATED (12.2.4)
$\psi_s = 0.8$	½" $\phi \leq$ No. 6 ϕ (12.2.4)
$c_b = 2.75"$	COVER MEASURED TO ℄ OF BAR
$K_{tr} = 0$	NO CONFINING REINF. ACROSS POTENTIAL SPLITTING PLANES

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CONNECT-EZ PA-EX (CONT'D)

(1) DEFORMED BAR ANCHORS (CONT'D)

DEVELOPMENT LENGTH (CONT'D)

$$\frac{c_b + K_{tr}}{d_b} = \frac{2.75" + 0"}{0.5"} = 5.5 \not\leq 2.5 \quad (12.2.3)$$

↑ CONTROLS

$$\therefore l_d = \left(\frac{3}{40}\,\frac{70{,}000}{1.0\sqrt{3500}}\,\frac{(1.0)(1.0)(0.8)}{2.5}\right) d_b$$

$$= 14" \longrightarrow \boxed{\text{USE } 16"}$$

LENGTH OF DBA's TO REACH YIELD ($\frac{1}{2}$"ϕ, UNCOATED, DBA EMBEDDED IN 3500 psi NORMAL WT CONCRETE)

DBA CAPACITY (CONT'D)

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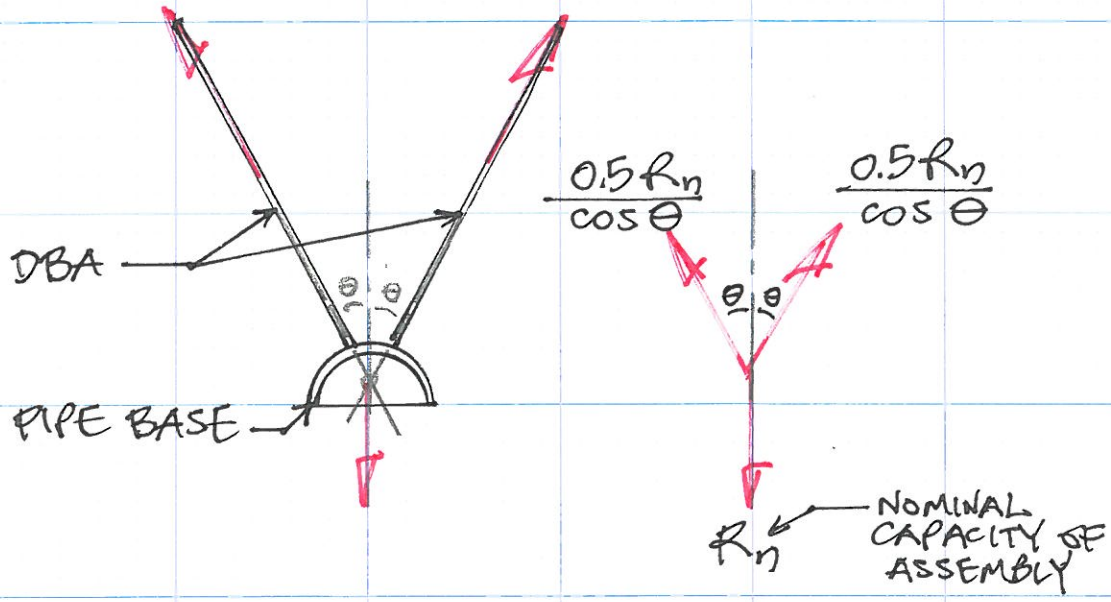
CONNECT-EZ PA-EX (CONT'D)

(1) DEFORMED BAR ANCHORS (CONT'D)

NOMINAL CAPACITY OF ASSEMBLY BASED ON TENSILE CAPACITY OF DBA's (AISC 360, D2)



FREEBODY DIAGRAM

BASED ON YIELDING OF DBA ← CONTROLS OVER RUPTURE, BY INSPECTION

$$P_n = \frac{0.5R_n}{\cos\theta}$$

$$F_y A_g = \frac{0.5R_n}{\cos\theta}$$

$$R_n = 2F_y A_g \cos\theta$$

← NOMINAL CAPACITY OF ASSEMBLY, BASED ON THE NOMINAL TENSILE STRENGTH OF THE DBA's

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CONNECT-EZ PA-EX (CONT'D)

(1) DEFORMED BAR ANCHORS (CONT'D)

NOMINAL CAPACITY OF ASSEMBLY (CONT'D)

$\frac{1}{2}$" ϕ DBA (f_y = 70,000 psi), θ = 20°

$$R_n = 2 f_y A_g \cos\theta$$
$$= 2(70{,}000\ \text{psi})(0.20\ \text{in}^2)\cos(20°)$$
$$= \boxed{26{,}300\#} \geq 10{,}000\#\ \text{OK}$$

NOMINAL CAPACITY OF ASSEMBLY, IF ONLY BASED ON THE NOMINAL CAPACITY OF $\frac{1}{2}$" ϕ DBA @ θ = 20° FROM VERTICAL

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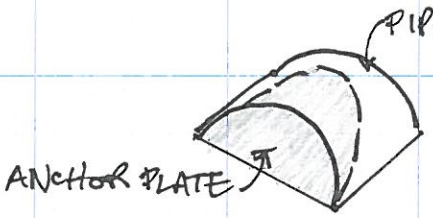
CONNECT-EZ PA-EX (CONT'D)

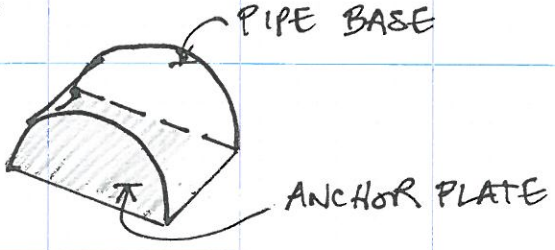
② PIPE BASE

TENSION FROM DBA's CAUSES BENDING IN PIPE BASE.

CONSERVATIVELY ASSUME THE ANCHOR BOLT PLATE IS FLAT ($\theta = 0°$) INSTEAD OF INCLINED ($\theta = 35°$).



INCLINED



FLAT

(CONT'D)

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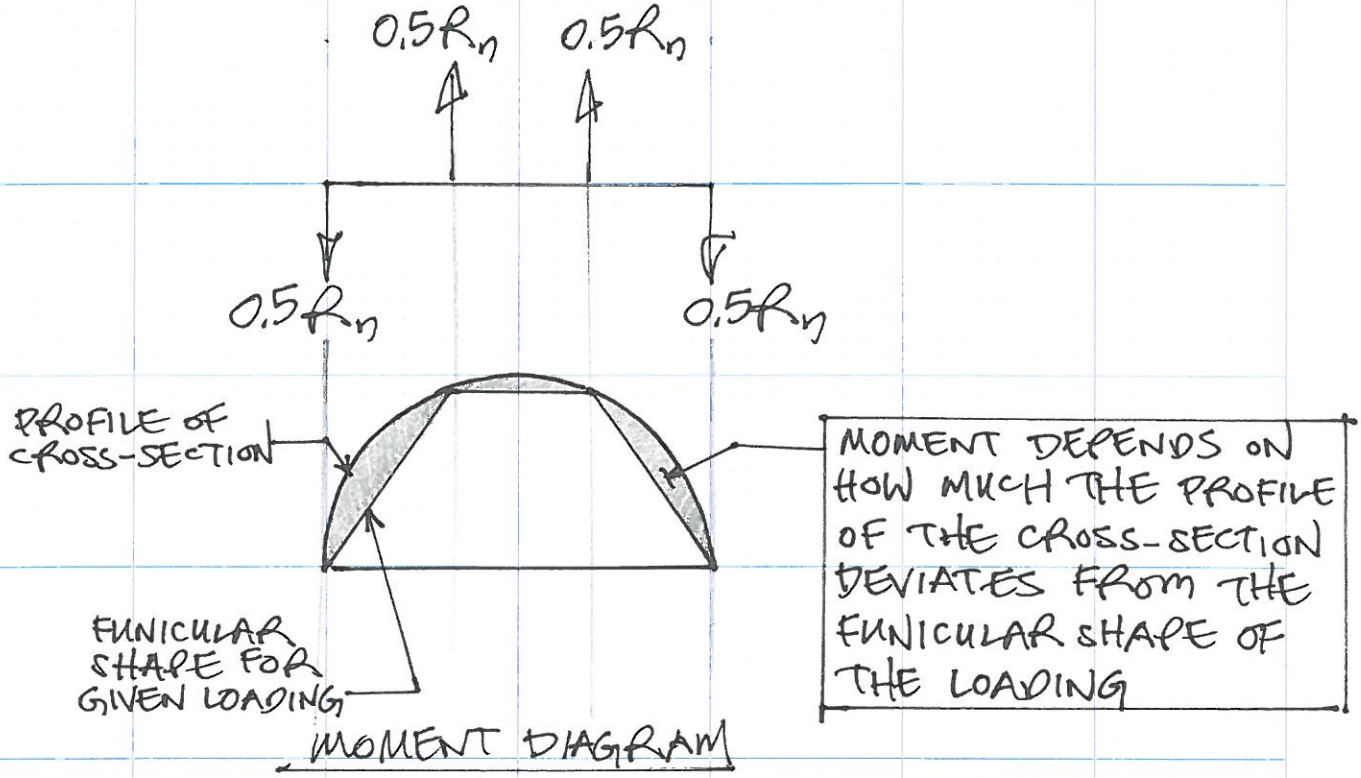
CONNECT-EZ PA-EX (CONT'D)

(2) PIPE BASE (CONT'D)



$$\text{MOMENT} = \left(\begin{array}{l}\text{TENSION OR}\\ \text{COMPRESSION}\\ \text{IN SEGMENT OF}\\ \text{FUNICULAR SHAPE}\end{array}\right)\left(\begin{array}{l}\text{DISTANCE B/T}\\ \text{FUNICULAR SHAPE}\\ \text{\& ACTUAL}\\ \text{CROSS-SECTION}\end{array}\right)$$

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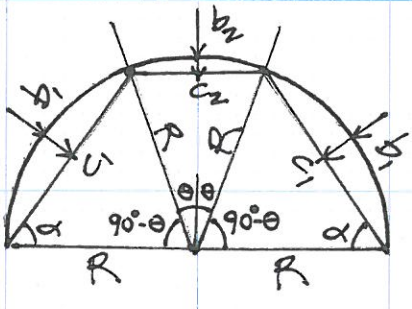
CONNECT-ED PA-EX (CONT'D)

② PIPE BASE (CONT'D)

PROPERTIES OF MOMENT DIAGRAM _____



$$R = \frac{\frac{O.D.}{2} + \frac{I.D.}{2}}{2} = \frac{O.D. + I.D.}{4}$$

$$c_1 = 2R \sin\left(\frac{90° - \theta}{2}\right)$$

$$c_2 = 2R \sin\theta$$

$$b_1 = \frac{c_1}{2} \tan\left(\frac{90° - \theta}{4}\right)$$

$$b_2 = \frac{c_2}{2} \tan\left(\frac{\theta}{2}\right)$$

PER AISC 13TH ED. TABLE 17-26 "PROPERTIES OF THE CIRCLE"

(CONT'D)

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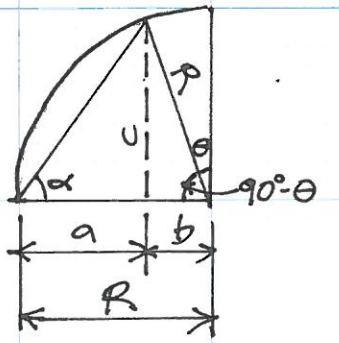
CONNECT-EZ PA-EX (CONT'D)

(2) PIPE BASE (CONT'D)

FOR α _____



$$\tan\alpha = \frac{c}{a}$$

$$\alpha = \tan^{-1}\left(\frac{c}{a}\right)$$

$$\sin(90°-\theta) = \frac{c}{R}$$

$$c = R\sin(90°-\theta)$$

$$a+b = R$$

$$a = R-b$$

$$\cos(90°-\theta) = \frac{b}{R}$$

$$b = R\cos(90°-\theta)$$

$$\therefore \alpha = \tan^{-1}\left(\frac{\sin(90°-\theta)}{1-\cos(90°-\theta)}\right)$$

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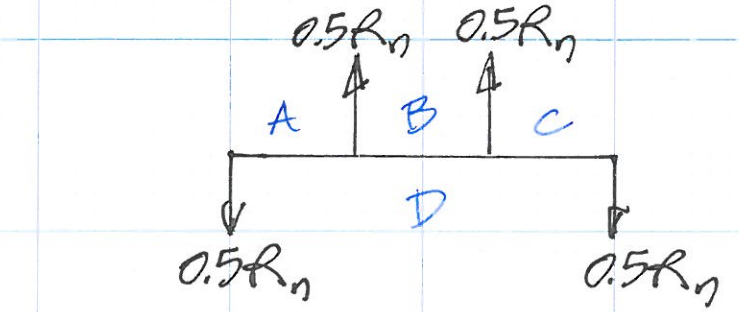
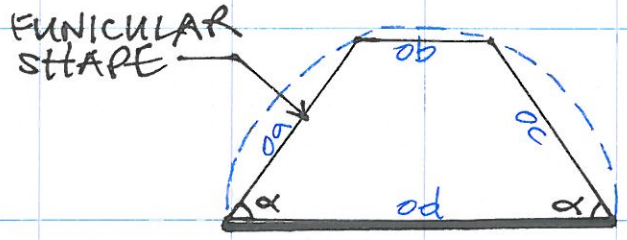
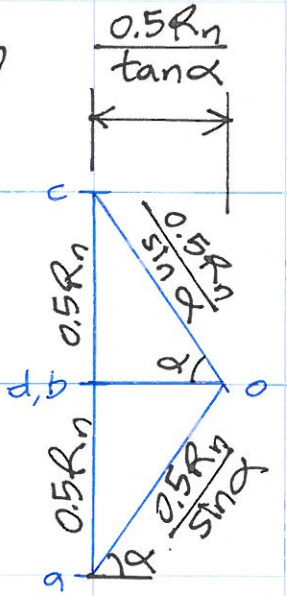
CONNECT-EZ PA-EX (CONT'D)

(2) PIPE BASE (CONT'D)

FORCES IN FUNICULAR SHAPE







$\therefore$ FORCES $oa = oc = \frac{0.5R_n}{\sin\alpha}$ (TENSION)

$ob = \frac{0.5R_n}{\tan\alpha}$ (TENSION)

$od = \frac{0.5R_n}{\tan\alpha}$ (COMPRESSION)

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CONNECT-EZ PA-EX (cont'd)

② PIPE BASE (cont'd)

MAX. MOMENTS

$$M = (\text{FORCE}_{oa})(b_1)$$
$$= \left(\frac{0.5R_n}{\sin\alpha}\right)(b_1)$$

$$M = (\text{FORCE}_{ob})(b_2)$$
$$= \left(\frac{0.5R_n}{\tan\alpha}\right)(b_2)$$

NOMINAL CAPACITY OF ASSEMBLY BASED ON BENDING OF PIPE BASE

$$M_n = F_y Z$$

$$\therefore R_{n_1} = \frac{2F_y Z \sin\alpha}{b_1}$$

$$R_{n_2} = \frac{2F_y Z \tan\alpha}{b_2}$$

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CONNECT-EZ PA-EX (CONT'D)

② PIPE BASE (CONT'D)

TRY 8" STD PIPE (SCH. 40) W/ DBA @ $\theta = 20°$

O.D. = 8.63"
I.D. = 7.98"
t = 0.300"

$\theta = 20°$

$2\theta = 40°$

$90 - \theta = 70°$

$$\alpha = \tan^{-1}\left(\frac{\sin(90-\theta)}{1-\cos(90-\theta)}\right)$$

$$= \tan^{-1}\left(\frac{\sin(70°)}{1-\cos(70°)}\right) = 55°$$

$$R = \frac{O.D. + I.D.}{4} = \frac{8.63" + 7.98"}{4} = 4.15"$$

$$c_1 = 2R\sin\left(\frac{90-\theta}{2}\right) = 2(4.15")\sin(35) = 4.76"$$

$$c_2 = 2R\sin\theta = 2(4.15")\sin(20) = 2.84"$$

$$\therefore\ b_1 = \frac{c_1}{2}\tan\left(\frac{90-\theta}{4}\right) = \frac{4.76"}{2}\tan(17.5) = 0.75"$$

$$b_2 = \frac{c_2}{2}\tan\left(\frac{\theta}{2}\right) = \frac{2.84"}{2}\tan(10) = 0.25"$$

(CONT'D)

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CONNECT-EZ PA-EX (CONT'D)

(2) PIPE BASE (CONT'D)

$$Z = \frac{bh^2}{4} = \frac{(5.5")(0.300")^2}{4} = 0.124\ in^3$$

$$\therefore R_{n_1} = \frac{2F_y Z \sin\alpha}{b_1}$$

$$= \frac{2(35{,}000\ psi)(0.124\ in^3)\sin(55°)}{0.75"}$$

$$= 9480\ lb \approx 10{,}000\ lb \quad (5\%\ OVER)$$

CONSIDERED OK, SINCE ANALYSIS IS CONSERVATIVE.

$$R_{n_2} = \frac{2F_y Z \tan\alpha}{b_2}$$

$$= \frac{2(35{,}000\ psi)(0.124\ in^3)\tan(55°)}{0.25"}$$

$$= 49{,}600\ lb \geq 10{,}000\ lb \quad OK$$

$\therefore R_n \approx 10{,}000\ lb$ BASED ON PIPE BASE

↑ NOMINAL CAPACITY OF ASSEMBLY

8" STD PIPE X 5½" LONG & BARS @ 20° FROM VERTICAL

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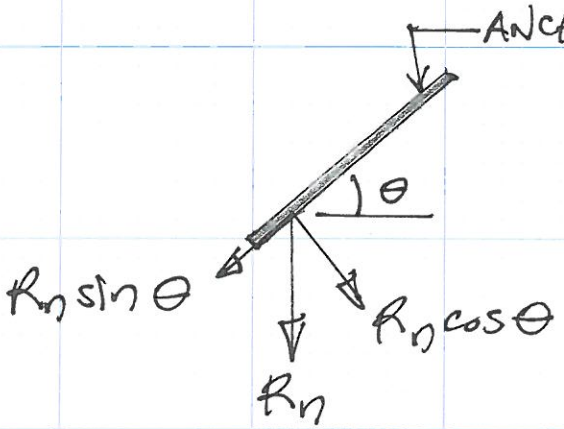
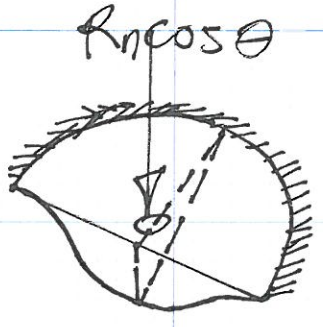
CONNECT-EZ PA-EX (CONT'D)

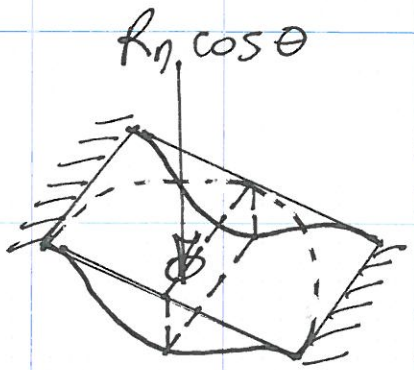
(3) ANCHOR PLATE



SECTION



(CLOSER TO) ACTUAL BEHAVIOR



MODELED BEHAVIOR (CONSERVATIVE)

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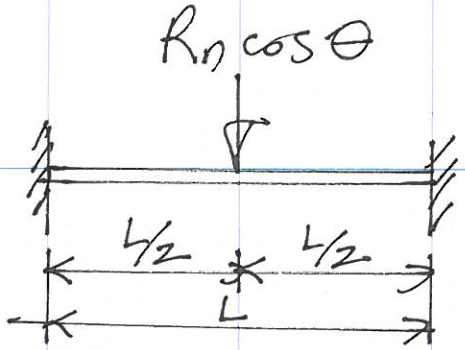
CONNECT-EZ PA-EX (CONT'D)

③ ANCHOR PLATE (CONT'D)



$$M_n = \frac{PL}{8}$$

$$F_y Z = \frac{(R_n \cos\theta) L}{8}$$

$$R_n = \frac{8 F_y Z}{\cos\theta \, L}$$

$$= \frac{8(36{,}000\ \text{psi})\left(\frac{6.7\text{"}\,(0.375\text{"})^2}{4}\right)}{\cos(35°)(8\text{"})}$$

$$= \boxed{10{,}400\ \#} > 10{,}000\ \text{lb} \quad \text{ok}$$

NOMINAL CAPACITY OF ASSEMBLY BASED ON 3/8" ANCHOR PLATE @ $\theta = 35°$