FORM DQP 2.01-1
LEVEL 1 CHECK PRINT SIGN-OFF SHEET

Client Name: **Ohio Department of Transportation**

Job Title: **Cleveland Innerbelt Design-Build Contract**

Job Number: **CUY-90-14.90**

Document Title: Pier Aesthetic lighting Anchor Rod Design

Check Level (Mark One):

- [X] 1A 100% Document Check
- [ ] 1B 100% Input Check

Enter description below:

		Print Name	Signature	Date
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For	Cleveland Innerbelt	Job no.	49633	Sheet no.	
Made by	KDG	Checked by	LJP	Backchecked by	KDG
Date	7-6-12	Date	7/6/12	Date	7-15-12

HNTB

Design Anchor Rods Embedment into concrete Pier Caps using ACI 318 App.D

Force in Anchor Rods

Pier Light Pole:

From light Pole design Anchor Bolt loads

T = 9.8 k
V = 0.3 k

These are ASD Group 2 loads multiply by over stress

T = 9.8 (1.33) = 13.0 k
V = 0.3 (1.33) = 0.4 k

Factor loads: (LRFD AASHTO Str3 Factor = 1.4)

T = 1.4 (13) = 18.2 k
V = 1.4 (0.4) = 0.6 k

per bolt

Side face light brackets

From Design Anchor Bolt load

T = 4.1 k
V = 0.14 k

Factored:

T = 1.4 (1.33) 4.1 = 7.6 k
V = 1.4 (1.33) 0.14 = 0.3 k

per bolt

Front Face of Pier Brackets

From Design Anchor Bolt loads

T = 1.5 k
V = 1.3 k

Factored:

T = 1.4 (1.33) 1.5 = 2.8 k
V = 1.4 (1.33) 1.3 = 2.4 k

per bolt

ME101-1204

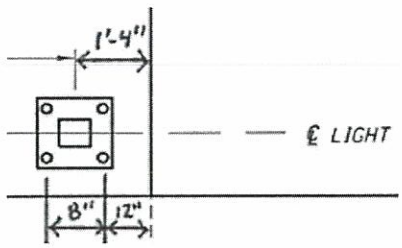
Light Pole Anchor Rods:

Concrete Breakout strength for Anchors in Tension (D.5.2)

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$$

Try: h_{ef} = 10 in
c_a = 12 in
s= 8 in

A_{Nc} = 1026 in^2



A_{Nc} calculated for 2 bolts in tension.

$$A_{Nco} = 9h_{ef}^2$$

A_{Nco} = 900 in^2

$$\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)}$$

e'_N= 0 in

$\psi_{ec,N}$ = 1

if, $c_{a,\min} < 1.5h_{ef}$

$c_{a,min}$ = 12 < $1.5 \cdot h_{ef}$ = 15

$$\psi_{ed,N} = 0.7 + 0.3\left(\frac{c_{a,\min}}{1.5h_{ef}}\right)$$

$\psi_{ed,N}$ = 0.94

$\psi_{c,N}$ = 1.4

The Cap reinforcing is substantial enough to prevent cracking from the anchors, therefore:

$\psi_{cp,N}$ = 1.0

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

k_c = 17
λ_a = 1
f'_c = 4000 psi

N_b = 34.000 k

N_{cbg} = 51.008 k

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{cbg} = 43.357 k

T_u = 18.2 k/bolt * 2 bolts = 36.4

ϕN_{cbg} > T_u **OK**

HNTB The HNTB Companies Engineers Architects Planners	Made KDG	Date 7/6/2012	Job Number
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Bond Strength of Adhesive Anchor in Tension (D.5.5)

$$N_{ag} = \frac{A_{Na}}{A_{Nao}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$$

$$c_{Na} = 10 d_a \sqrt{\frac{\tau_{uncr}}{1100}}$$

d_a = 0.75 in

From Hilti RE-500 SD Literature

τ_{uncr} = 1344 psi = 2067 x 0.65

τ_{cr} = 649 psi = 999 x 0.65

c_{Na} = 8.29 in

A_{Na} = 407 in^2 for 2 anchors in Tension

$$A_{Nao} = (2c_{Na})^2$$

A_{Nao} = 275 in^2

$$N_{ba} = \lambda_a \tau_{uncr} \pi d_a h_{ef}$$

N_{ba} = 31656.65 #

$$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)}$$

$\psi_{ec,Na}$ = 1.0

if, $c_{a,\min} \geq c_{Na}$

$c_{a,min}$ = 12 > c_{Na} = 8.29

$\psi_{ed,Na}$ = 1.0

The Cap is Reinforced therefore

$\psi_{cp,Na}$ = 1.0

N_{cbg} = 46933.48 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{ag} = 39.89 k

T_u = 18.2 k/bolt * 2 bolts = 36.4

ϕN_{ag} > T_u **OK**

Concete breakout strength of anchors in shear (D.6.2)

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$$

s= 8 in
$c_{a1,1}$ = 12 in
$c_{a1,2}$ = 20 in

Conservatively apply entire Shear Force on Front Anchors

$$A_{Vc} = [2(1.5c_{a1,1}) + s] \times (1.5c_{a1,1})$$

A_{Vc} = 792 in^2

$$A_{Vco} = 4.5(c_{a1,1})^2$$

A_{Vco} = 648 in^2

$\psi_{ec,V}$ = 1.0

$\psi_{ed,V}$ = 1.0

$\psi_{c,V}$ = 1.0

$\psi_{h,V}$ = 1.0

$$V_b = [7(\frac{l_e}{d_a})^{0.2}\sqrt{d_a}]\lambda_a\sqrt{f_c'}(c_{a1,1})^{1.5}$$
$$< 9\lambda_a\sqrt{f_c'}(c_{a1,1})^{1.5}$$

$l_e = h_{ef} < 8d_a$ = 6 in

V_b = 23661.61 #

V_{cbg} = 28919.75 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cbg} = 24.58 k

V_u = 0.6 k/bolt * 4 bolts = 2.4 k

ϕV_{cbg} > V_u OK

Concete pryout strength of anchors in shear (D.6.3)

$$V_{cpg} = k_{cp} N_{cpg}$$

k_{cp} = 2.0

N_{cpg} = N_{cbg} < N_{cbg}

N_{cpg} = 46.93 k

V_{cpg} = 93.87

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cpg} = 79.79 k

V_u = 2.4 k

ϕV_{cpg} > V_u OK

Interaction of Tension and Shear (D.7)

$V_{ua} / \phi V_n$ = 2.4 / 24.58 = 0.098

$N_{ua} / \phi N_n$ = 36.4 / 39.89 = 0.912

D.7.1 $V_{ua} / \phi V_n$ < 0.2 ,then full strength in tension shall be permited

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Side Face Light Bracket Anchor Rods:

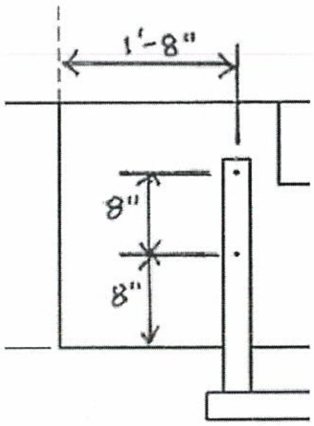
Concrete Breakout strength for Anchors in Tension (D.5.2)

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$$

Try: h_{ef} = 9 in
c_a = 8 in
s= 8 in

A_{Nc} = 581 in^2

One anchor in Tension



$$A_{Nco} = 9 h_{ef}^2$$

A_{Nco} = 729 in^2

if, $c_{a,min} < 1.5 h_{ef}$

$c_{a,min}$ = 8 < 1.5*h_{ef} = 13.5

$$\psi_{ed,N} = 0.7 + 0.3\left(\frac{c_{a,min}}{1.5 h_{ef}}\right)$$

$\psi_{ed,N}$ = 0.88

$\psi_{c,N}$ = 1.4

The Cap is Reinforced therefore

$\psi_{cp,N}$ = 1.0

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

k_c = 17
λ_a = 1
f'_c = 4000 psi

N_b = 29.030 k

N_{cbg} = 28.407 k

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{cbg} = 24.146 k

T_u = 4.1 k

ϕN_{cbg} > T_u **OK**

Bond Strength of Adhesive Anchor in Tension (D.5.5)

$$N_a = \frac{A_{Na}}{A_{Nao}} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$$

$$c_{Na} = 10 d_a \sqrt{\frac{\tau_{uncr}}{1100}}$$

d_a = 0.75 in

From Hilti RE-500 SD Literature

τ_{uncr} = 1344 psi = 2067 x 0.65

τ_{cr} = 649 psi = 999 x 0.65

c_{Na} = 8.29 in

A_{Na} = 270 in^2 for 1 anchor in Tension

$$A_{Nao} = (2c_{Na})^2$$

A_{Nao} = 275 in^2

$$N_{ba} = \lambda_a \tau_{uncr} \pi d_a h_{ef}$$

N_{ba} = 28490.99 #

if, $c_{a,\min} < c_{Na}$

$c_{a,min}$ = 8 < c_{Na} = 8.29

$$\psi_{ed,Na} = 0.7 + 0.3\left(\frac{c_{a,\min}}{c_{Na}}\right)$$

$\psi_{ed,Na}$ = 0.99

The Cap is Reinforced therefore

$\psi_{cp,Na}$= 1.0

N_{cbg} = 27702.01 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{ag} = 23.55 k

T_u = 4.1 k

ϕN_{ag} > T_u **OK**

Concete breakout strength of anchors in shear (D.6.2)

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$$

$c_{a1,1}$ = 8 in
$c_{a1,2}$ = 16 in

Conservatively apply entire Shear Force on Front Anchors

$$A_{Vc} = [2(1.5c_{a1,1})] \times (1.5c_{a1,1})$$

A_{Vc} = 288 in^2

$$A_{Vco} = 4.5(c_{a1,1})^2$$

A_{Vc} = 288 in^2

$\psi_{ec,V}$ = 1.0

$\psi_{ed,V}$ = 1.0

$\psi_{c,V}$ = 1.0

$\psi_{h,V}$ = 1.0

$$V_b = [7(\frac{l_e}{d_a})^{0.2} \sqrt{d_a}] \lambda_a \sqrt{f_c'} (c_{a1,1})^{1.5}$$

$$< 9 \lambda_a \sqrt{f_c'} (c_{a1,1})^{1.5}$$

$l_e = h_{ef} < 8d_a$ = 6 in

V_b = 12879.75 #

V_{cbg} = 12879.75 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cbg} = 10.95 k

V_u = 0.14 k/bolt * 2 bolts = 0.28 k

ϕV_{cbg} > V_u **OK**

Concete pryout strength of anchors in shear (D.6.3)

$$V_{cpg} = k_{cp} N_{cpg}$$

k_{cp} = 2.0

N_{cpg} = N_{cbg} < N_{cbg}

N_{cpg} = 27.70 k

V_{cpg} = 55.40

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cpg} = 47.09 k

V_u = 0.28 k

ϕV_{cpg} > V_u **OK**

Interaction of Tension and Shear (D.7)

$V_{ua} / \phi V_n$ = 0.28 / 10.95 = 0.026

$N_{ua} / \phi N_n$ = 4.1 / 23.55 = 0.174

D.7.1 $V_{ua} / \phi V_n$ < 0.2

D.7.2 $N_{ua} / \phi N_n$ < 0.2

Interaction, OK

Front Face Light Bracket Anchor Rods:

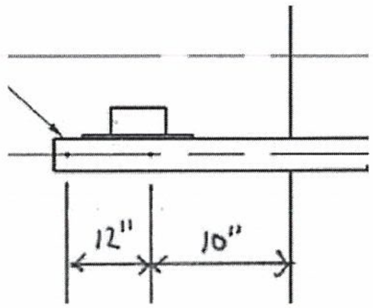
Concrete Breakout strength for Anchors in Tension (D.5.2)

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$$

Try: h_{ef} = 9 in
c_a = 10 in
s= 12 in

A_{Nc} = 635 in^2

One anchor in Tension



$$A_{Nco} = 9 h_{ef}^2$$

A_{Nco} = 729 in^2

if, $c_{a,\min} < 1.5 h_{ef}$

$c_{a,min}$ = 10 < 1.5*h_{ef} = 13.5

$$\psi_{ed,N} = 0.7 + 0.3\left(\frac{c_{a,\min}}{1.5 h_{ef}}\right)$$

$\psi_{ed,N}$ = 0.92

$\psi_{c,N}$ = 1.4

The Cap is Reinforced therefore

$\psi_{cp,N}$ = 1.0

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

k_c = 17
λ_a = 1
f'_c = 4000 psi

N_b = 29.030 k

N_{cbg} = 32.622 k

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{cbg} = 27.729 k

T_u = 1.5 k

ϕN_{cbg} > T_u **OK**

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Bond Strength of Adhesive Anchor in Tension (D.5.5)

$$N_a = \frac{A_{Na}}{A_{Nao}} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$$

$$c_{Na} = 10 d_a \sqrt{\frac{\tau_{uncr}}{1100}}$$

d_a = 0.75 in

From Hilti RE-500 SD Literature

τ_{uncr} = 1344 psi = 2067 x 0.65

τ_{cr} = 649 psi = 999 x 0.65

c_{Na} = 8.29 in

A_{Na} = 275 in^2 for 1 anchor in Tension

$$A_{Nao} = (2c_{Na})^2$$

A_{Nao} = 275 in^2

$$N_{ba} = \lambda_a \tau_{uncr} \pi d_a h_{ef}$$

N_{ba} = 28490.99 #

if, $c_{a,min} \geq c_{Na}$

$c_{a,min}$ = 10 > c_{Na} = 8.29

$\psi_{ed,Na}$ = 1.0

The Cap is Reinforced therefore

$\psi_{cp,Na}$ = 1.0

N_{cbg} = 28490.99 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕN_{ag} = 24.22 k

T_u = 1.5 k

ϕN_{ag} > T_u OK

Concete breakout strength of anchors in shear (D.6.2)

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$$

$c_{a1,1}$ = 10 in
$c_{a1,2}$ = 22 in

Conservatively apply entire Shear Force on Front Anchors

$$A_{Vc} = [2(1.5c_{a1,1})] \times (1.5c_{a1,1})$$

A_{Vc} = 450 in^2

$$A_{Vco} = 4.5(c_{a1,1})^2$$

A_{Vc} = 450 in^2

$\psi_{ec,V}$ = 1.0

$\psi_{ed,V}$ = 1.0

$\psi_{c,V}$ = 1.0

$\psi_{h,V}$ = 1.0

$$V_b = [7(\frac{l_e}{d_a})^{0.2} \sqrt{d_a}] \lambda_a \sqrt{f_c'} (c_{a1,1})^{1.5}$$

$$< 9 \lambda_a \sqrt{f_c'} (c_{a1,1})^{1.5}$$

$l_e = h_{ef} < 8d_a$ = 6 in

V_b = 18000.00 #

V_{cbg} = 18000.00 #

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cbg} = 15.30 k

V_u = 1.3 k/bolt * 2 bolts = 2.6 k

ϕV_{cbg} > V_u OK

Concete pryout strength of anchors in shear (D.6.3)

$$V_{cpg} = k_{cp} N_{cpg}$$

k_{cp} = 2.0

N_{cpg} = N_{cbg} < N_{cbg}

N_{cpg} = 28.49 k

V_{cpg} = 56.98

ϕ = 0.85 (D4.4 Conc. Breakout, Condition A)

ϕV_{cpg} = 48.43 k

V_u = 2.6 k

ϕV_{cpg} > V_u OK

Interaction of Tension and Shear (D.7)

$V_{ua} / \phi V_n$ = 2.6 / 15.30 = 0.170

$N_{ua} / \phi N_n$ = 1.5 / 24.22 = 0.062

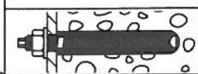
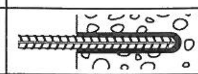
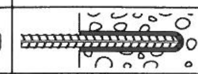
D.7.1 $V_{ua} / \phi V_n$ < 0.2

D.7.2 $N_{ua} / \phi N_n$ < 0.2

Interaction, OK

Applications Grid

Key: ● Very suitable ○ May be suitable per application

Design Criteria	Anchor Products	HIT-HY 150 MAX-SD Adhesive	HIT-RE 500-SD Epoxy	HIT-HY 150 MAX Adhesive w/ threaded rod or rebar	HIT-HY 150 MAX Adhesive w/ HIT-TZ rod	RE 500 Epoxy
						
	Section Number:	3.2.3	3.2.4	3.2.6	3.2.5	3.2.7
	ICC-ES ESR:	ESR-3013	ESR-2322	ESR-2262 (AC308) ESR-1967 (AC58)		
Fastening Base Material[1]	Uncracked concrete	●	●	●	●	●
	Cracked concrete	●	●		○	
	Lightweight concrete	○	○	●	○	○
	Hollow core concrete					
	Grout filled concrete block	○	○	●	○	○
	Hollow concrete block					
	Solid brick	○	○	○		○
	Hollow brick					
Installation	Oversized holes (per ICC)					○
	Cored holes (per ICC)		●		○	○
	Water saturated concrete (per ICC)	●	●	●	○	○
	Water-filled holes (per ICC)		●		○	○
	Submerged (per ICC)		●			○
	Overhead	●	●	●	○	●
	Sustained load	●	●	●	○	●
Application Criteria[2]	In-place (through) fastening	●	●	●	●	●
	Finish		with HIS Insert	with HIS Insert		with HIS Insert
	Removeable to flush surface		with HIS Insert	with HIS Insert		with HIS Insert
	Seismic	●	●	○	○	○
	High cycle fatigue	○	●	○	○	●
	Shock / Impact load	○	○	○	○	○
	High temperature resistance	○	○	○	○	○
Corrosion[3]	Electro/Mechanically zinc plated	●	●	●	●	●
	Sherardized carbon steel					
	Hot-dipped galvanized	7/8-in.	7/8-in.	7/8-in.		7/8-in.
	Stainless steel	304, 316	304, 316	304, 316	316	304, 316
Miscellaneous	Gel time/Cure time[4]	5 min / 30 min	30 min / 12 hours	6 min / 30 min	6 min / 30 min	30 min / 12 hours
	Fastener diameters available (in.)[5]	3/8, 1/2, 5/8, 3/4, 7/8, 1, 1-1/4	3/8, 1/2, 5/8, 3/4, 7/8, 1, 1-1/4	3/8, 1/2, 5/8, 3/4, 7/8, 1, 1-1/4	3/8, 1/2, 5/8, 3/4	3/8, 1/2, 5/8, 3/4, 7/8, 1, 1-1/4
	Anchor working principles[6]	adhesive bond	adhesive bond	adhesive bond	expansion against bonding to base material	adhesive bond

** Refer to product literature for detailed information.

1 Base material may vary widely. Site specific anchor testing may be required.

2 Most testing is perfromed in normal weight concrete. Light weight concrete may be addressed. See product technical information.

3 Refer to Section 2.3 for a more detailed discussion on corrosion and corrision resistance.

4 Gel time and cure time are given at a standard 68°F (20°C).

5 Listed diameters are those with published load data. Larger diameter elements may be used with some adhesive anchor systems, contact Hilti for more information.

6 Refer to Section 3.1.5 for more detailed discussion on anchor working principles.