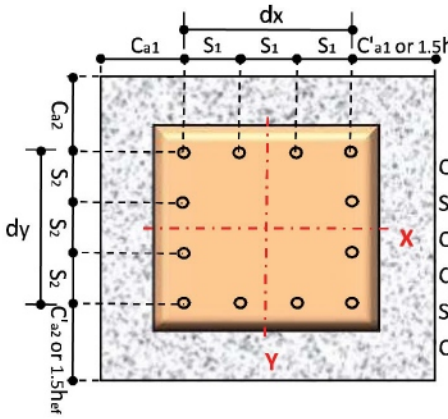
Baseplate Calculation for 15m Aluminum Flagpole

DESIGN OF ANCHOR SYSTEM IN CONCRETE — ACI 318M-11 APPENDIX D

1. Input Data:

Type of Anchor: Cast-In Anchors
Grade of Anchor: 8.8
Anchor Diameter, da = 24 mm
Compressive Strength of Concrete, f'c = 32 MPa
Anchor Embedment Depth, h_{ef} = 600 mm

No. of Intermediate Anchors along X-Direction(one side), n_x
n_x = 0
No. of Intermediate Anchors along Y-Direction(one side), n_y
n_y = 0



C_{a1} = 120 mm
S_1 = 210 mm
C'_{a1} = 120 mm
C_{a2} = 120 mm
S_2 = 210 mm
C'_{a2} = 120 mm

Total No. of Anchors: N = 4
Total No. of Anchors along X-Direction(one side) = 2
Total No. of Anchors along Y-Direction(one side) = 2

2. Applied Loads

Ultimate Tension, N_U = 0 kN
Ultimate Moment along X-direction, M_{UX} = 25 kN.m
Ultimate Moment along Y-direction, M_{UY} = 0 kN.m
Ultimate Shear along X-direction, V_X = 0 kN
Ultimate Shear along Y-direction, V_Y = 4 kN

3. Verification of Anchors against Tension

Clause D.5

For Single Anchor:

Check Applied Tension for each Anchor, N_{ua}

Tension on each Anchor due to Nu, T_A = Nu/N
= 0.00 kN

Tension on each Anchor due to M_{UX}, T_X = (M_{UX}/dy)/Nx where: Nx = No. of anchors for M_{UX}
= 59.524 kN = 2

Tension on each Anchor due to M_{UY}, T_Y = (M_{UY}/dx)/Ny where: Ny = No. of anchors for M_{UY}
= 0.00 kN = 2

$N_{ua} = T_A + T_X + T_Y$ = 59.524 kN

For Anchor Group:

Check Applied Tension for group of anchors , N_{uag}

Tension due to Nu, T_G = Nu = 0 kN
Tension due to M_{UX}, T_{GX} = (M_{UX}/dy) = 119.05 kN
Tension due to M_{UY}, T_{GY} = (M_{UY}/dx) = 0 kN

$N_{uag} = T_G + T_{GX} + T_{GY}$ = 119.05 kN

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3.1. Steel Strength of Anchors — Clause D.5.1

Tension Capacity of each Anchor, $\emptyset N_{sa}$:

$\emptyset N_{sa} = \emptyset A_{se,N} f_{uta}$

where:

$\emptyset$ = 0.7 Clause D.4.3

$A_{se,N}$ = Effective Cross-Sectional Area of Anchor = 245.04 mm^2

f_{uta} = Nominal Tensile Strength of Anchors = 800 MPa

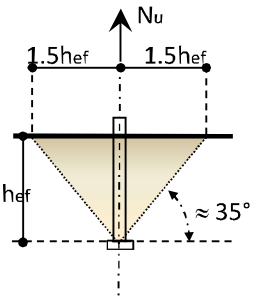
N_{sa} = 196.0 kN

$\emptyset N_{sa}$ = 137.22 kN

N_{ua} = 59.52 kN < $\emptyset N_{sa}$ = 137.22 kN ; **OK** ; Ratio = 0.43

3.2. Concrete Breakout Strength — Clause D.5.2

For Single Anchors:



Concrete Breakout Capacity , $\emptyset N_{cb}$:

$\emptyset N_{cb} = \emptyset(A_{Nc}/A_{Nco}) \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$

where:

$\emptyset$ = 0.7 Clause D.4.3

h'_{ef} = Effective embedment depth = 80 mm

A_{Nc} = Projected concrete failure area of group of anchors

= 202500 mm^2

A_{nco} = Projected concrete failure area of a single anchor with an edge distance equal to or greater than 1.5 h_{ef}

= $9h_{ef}^2$

= 57600 mm^2

$\Psi_{c,N}$ = 1.25 Clause 5.2.6

$\Psi_{ed,N}$ = 1.00 Clause 5.2.5

$\Psi_{cp,N}$ = 1.00 Clause 5.2.7

N_b = $kc.\lambda a.\sqrt{f'c}.\ hef^{1.5}$ Clause D.5.2.2

= 40.5 kN where:

k_c = coefficient for basic concrete breakout

= 10

λa = 1.00 Clause D.3.6

N_{cb} = 177.88 kN

$\emptyset N_{cb}$ = 124.51 kN

N_{ua} = 59.52 kN < $\emptyset N_{cb}$ = 124.51 kN ; **OK** ; Ratio = 0.48

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Check if Anchor Group effects shall be considered: $s_{min} < 3\,h_e$

For Anchor Group:

Concrete Breakout Capacity , ϕN_{cbg} :

$\phi N_{cbg} = \phi (A_{Nc}/A_{Nco})\,\Psi_{ec,N}\Psi_{ed,N}\,\Psi_{c,N}\Psi_{cp,N}N_b$

$\Psi_{ec,N} = 1 / (1 + 2\,e'_N / 3\,h_{ef})$ Clause D.5.2.4

$= 1.00$

where:

e'_N = distance between resultant tension on a group of anchors loaded in tension and centroid of the group of anchors loaded in tension

e'_N = 0 mm Provide input value if applicable and zero if not applicable

$N_{cbg} = 177.88$ kN

$\phi N_{cbg} = 124.51$ kN

$N_{ua} = 119.05$ kN < $\phi N_{cbg} = 124.51$ kN ; **OK** ; Ratio = 0.96

Consider Tension Reinforcement? No

Excess Tension, T_{net}:

$T_{net} = N_{ua} - \phi N_{cbg}$

= - kN

Diameter of Provided Steel Reinforcement 12

Required No. of Additional Tension Reinforcement Bars, n_{tb}

$n_{tb} = T_{net} / (\phi As_b fy_b)$

where:

As_b = Cross-sectional area of steel reinforcement provided

= 113.1 mm^2

fy_b = Yield Strength of Steel Reinforcement

= 420 Mpa

ϕ = 0.9

Therefore,

n_{tb} = - T - additional tension reinforcement required

3.3. Pullout Strength Clause D.5.3

Pullout Capacity , ϕN_{pn} :

$\phi N_{pn} = \phi \Psi_{c,P} N_P$

where:

ϕ = 0.7 Clause D.4.3

$\Psi_{c,P}$ = 1.00 Clause D.5.3.6

For single headed stud or headed bolt: Clause D.5.3.4

$N_P = 8\,A_{brg}\,f'c$

= 100.53 kN

where:

d_n = diameter of Anchor Nut = 30 mm

A_{brg} = net bearing area of the head of anchor

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N_{pn} = 100.53 kN = 392.7 mm^2

$ØN_{pn}$ = 70.37 kN

For single hooked bolt: Clause D.5.3.5

N_p = 0.9 f'c $e_h$da where:

= - kN e_h = distance from the inner surface of the shaft of a J- or L-bolt to the outer tip of J- or L-bolt (3da ≤ eh ≤ 4.5da)

= 0 mm^2 Provide input value if applicable and zero if not applicable

N_{pn} = - kN

$ØN_{pn}$ = - kN

For single headed stud or headed bolt:

N_{ua} = 59.52 kN < $ØN_{pn}$ = 70.37 kN ; OK ; Ratio = 0.85

For single hooked bolt:

N_{ua} = - kN - $ØN_{pn}$ = - kN ; - ; Ratio = -

3.4.Concrete side-face blowout strength of a headed anchor Clause D.5.4

For Single Anchors:

Side-face Blowout Capacity , $ØN_{sb}$:

$ØN_{sb} = Ø(13C_{a1}\sqrt{A_{brg}})\lambda a f'c$

where:

Ø = 0.7 Clause D.4.3

C_{a1} = distance from the center of an anchor shaft to the edge of concrete in one direction /minimum edge distance

= 120 mm

C_{a2} = distance from the center of an anchor shaft to the edge of concrete in the direction perpendicular to C_{a1}

= 120 mm

A_{brg} = net bearing area of the head of anchor

= 392.7 mm^2

λa = 1.00

Consider if $1.0 \le C_{a2}/C_{a1} \le 3.0$: Yes C_{a2}/C_{a1} = 1.00

N_{sb} = 174.88 kN

$ØN_{sb}$ = 61.21 kN

N_{ua} = 59.52 kN < $ØN_{sb}$ = 61.21 kN ; OK ; Ratio = 0.97

Check if Anchor Group effects shall be considered: $s_{min} < 2\,c_{Na}$

For Anchor Group:

Side-face Blowout Capacity , $ØN_{sbg}$:

$ØN_{sbg} = Ø(1+ (s/6C_{a1}))N_{sb}$

N_{sb} = 174.88 kN

$\emptyset N_{sbg}$ = 122.41 kN

N_{uag} = 119.05 kN < $\emptyset N_{sbg}$ = 122.41 kN ; **OK** ; Ratio = 0.97

3.5. Bond Strength of Adhesive Anchor

Clause D.5.5

For Single Anchors:

Bond Strength Capacity , $\emptyset N_a$:

$$\emptyset N_a = \emptyset (A_{Na}/A_{Nao})\, \Psi_{ed,Na}\, \Psi_{cp,Na} N_{ba}$$

where:

$\emptyset$ = 0.7

A_{Na} = projected influence area of group of adhesive anchors

= 202500 mm^2

A_{Nao} = Projected influence area of a single anchor if not limited by edge distance or spacing

= $(2c_{Na})^2$ (If c_{Na} > edge distance)

= 57600 mm^2

c_{Na} = $10\, d_a \sqrt{(\tau_{uncr}/7.6)}$

= 154 mm

τ_{uncr} = 4.5 Table D.5.5.2 Service Environment: Outdoor

$\Psi_{ed,Na}$ = 0.93 Clause D.5.5.4

$\Psi_{cp,Na}$ = 1.00 Clause D.5.5.5

N_{ba} = $\lambda a.\tau_{cr}.\pi.d_a.D$ where:

= 35.19 kN

λa = 1.00 Clause D.3.6

τ_{cr} = 1.4 Table D.5.5.2

N_a = 115.53 kN

$\emptyset N_a$ = 86.64 kN

N_{ua} = 59.524 kN < $\emptyset N_{ag}$ = 86.64 kN ; **OK** ; Ratio = 0.69

Check if Anchor Group effects shall be considered: $s_{min} < 2\, c_{Na}$

Check:

For Anchor Group:

Bond Strength Capacity , $\emptyset N_{ag}$:

$$\emptyset N_{ag} = \emptyset (A_{Na}/A_{Nao})\, \Psi_{ec,Na} \Psi_{ed,Na}\, \Psi_{cp,Na} N_{ba}$$

$\Psi_{ec,Na}$ = $1 / (1 + e'_N / c_{Na})$ Clause D.5.5.3

= 1.00 where:

e'_N = distance between resultant tension on a group of anchors loaded in tension and centroid of the group of anchors loaded in tension

N_{ag} = 115.53 kN e'_N = 0 mm Provide input value if applicable and zero if not applicable

$\emptyset N_{ag}$ = 80.87 kN

N_{uag} = 119.05 kN > $\emptyset N_{ag}$ = 80.87 kN ; **NOT OK** ; Ratio = 1.47

4. Verification of Anchors against Shear

For Single Anchor:

Check Applied Shear for each Anchor, V_{ua}

$V_{ua} = \sqrt{(Vx^2+Vy^2)}/N$

= 1.00 kN

For Anchor Group:

Check Applied Shear for group of anchors , V_{uag}

$V_{uag} = \sqrt{(Vx^2+Vy^2)}$

= 4.00 kN

4.1. Steel Strength of Anchor Clause D.6.1

Shear Capacity of each Anchor, $\emptyset V_{sa}$:

$\emptyset V_{sa} = 0.6 A_{se,V} f_{uta}$

where:

$\emptyset$ = 0.7 Clause D.4.3

$A_{se,V}$ = Effective Cross-Sectional Area of Anchor = 245.04 mm^2

f_{uta} = Nominal Tensile Strength of Anchors = 800 MPa

V_{sa} = 117.62 kN

$\emptyset V_{sa}$ = 82.33 kN

V_{ua} = 1.00 kN < $\emptyset V_{sa}$ = 82.33 kN ; **OK** ; Ratio = 0.01

4.2. Concrete Shear Breakout Strength Clause D.6.2

For Single Anchors:

Concrete Breakout Capacity , $\emptyset V_{cbg}$:

$\emptyset V_{cb} = \emptyset (A_{Vc}/A_{Vco}) \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_b$

where:

$\emptyset$ = 0.7

c'_{a1} = Effective embedment depth = 120 mm

A_{Vc} = Projected concrete failure area of groups of anchor

= 54000 mm^2

A_{Vco} = Projected concrete failure area for a single anchor

= $4.5(c_{a1})^2$

= 64800 mm^2

ha = thickness of member in which an anchor is located, measured parallel to anchor axis.

= 350 mm

$\Psi_{c,V}$ = modification factor based on presence or absence of cracks in concrete

= 1.00

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$\Psi_{ed,V}$ = 0.70 Clause D.6.2.6

$\Psi_{h,V}$ = 1.00 Clause D.6.2.8

$V_b = (0.6 (\ell_e/d_a)^{0.2} \sqrt{d_a}) \lambda a \sqrt{f'c} (C_{a1})^{1.5}$ where:

$= 30.24$ kN ℓ_e = 160 mm

$V_b = 3.7 \lambda \sqrt{f'c} (Ca1)^{1.5}$ λa = 1.00 Clause D.3.6

$= 27.514$ kN

$\emptyset V_{cb}$ = 16.05 kN

$\emptyset V_{cb}$ = 11.23 kN

V_{ua} = 1.00 kN < $\emptyset V_{cb}$ = 11.23 kN ; **OK** ; Ratio = 0.09

For Anchor Group:

Concrete Breakout Capacity , $\emptyset V_{cbg}$:

$\emptyset V_{cbg} = \emptyset (A_{Vc}/A_{Vco}) \Psi_{ec,V} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_b$

$\Psi_{ec,V} = 1 / (1 + 2 e'_V / 3 c_{a1})$ Clause D.6.2.5

$= 1.00$ where:

e'_V = distance between resultant shear on a group of anchors loaded in shear in the same direction, and the centroid of the group of anchors in same direction

e'_V = 0 mm Provide input value if applicable and zero if not applicable

$\emptyset V_{cb}$ = 16.05 kN

$\emptyset V_{cb}$ = 11.23 kN

V_{uag} = 4.00 kN < $\emptyset V_{cbg}$ = 11.23 kN ; **OK** ; Ratio = 0.36

4.3. Pryout Strength Clause D.6.3

For Single Anchors:

Pryout Capacity , $\emptyset V_{cp}$:

$\emptyset V_{cp} = \emptyset k_{cp} N_{cp}$

where:

N_{cp} = 177.9 kN

k_{cp} = 2.00

$\emptyset$ = 0.7

V_{co} = 355.8 kN

$\emptyset V_{cp}$ = 249.0 kN

V_{ua} = 1.00 kN < $\emptyset V_{cp}$ = 249.03 kN ; **OK** ; Ratio = 0.00

For Anchor Group:

Pryout Capacity , $\emptyset V_{cpg}$:

DESIGN OF ANCHOR SYSTEM IN CONCRETE

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

where:

N_{cpg} = 177.9 kN

k_{cp} = 2.00

$\emptyset$ = 0.7

V_{cpg} = 355.8 kN

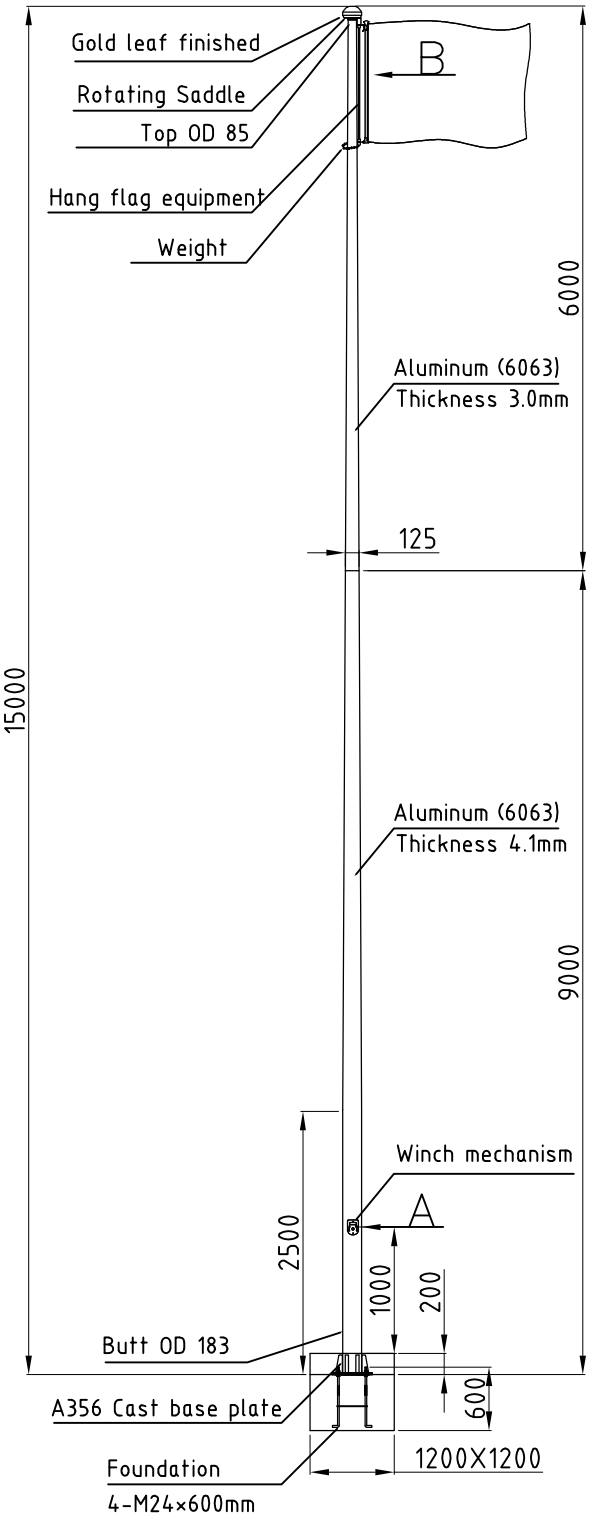
$\emptyset V_{cpg}$ = 249.0 kN

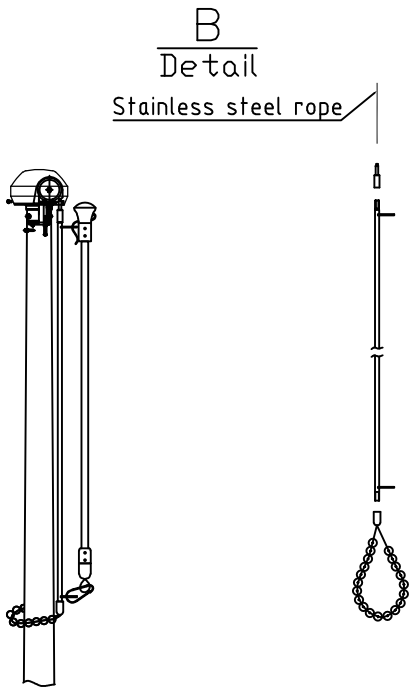
= 4.00 kN < $\emptyset V_{cpg}$ = 249.0 kN ; OK ; Ratio = 0.02

SUMMARY:

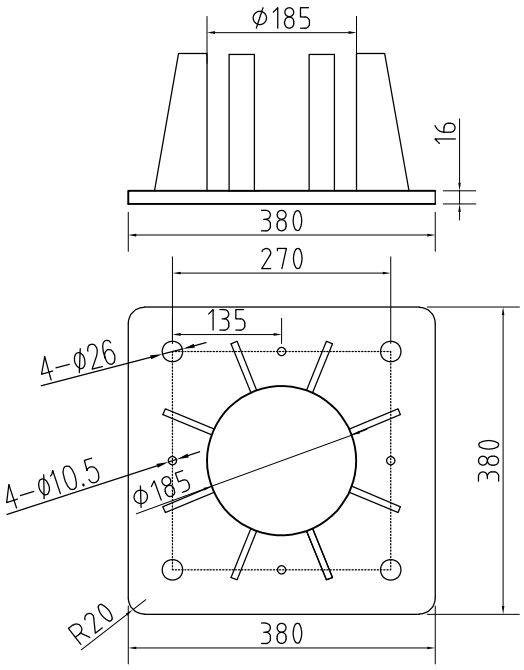
Type of Anchor	:	Cast-In Anchors
Number and Diameter of Anchor	:	4 - M 24
Grade of Anchor	:	Grade 8.8
Anchor Embedment Depth	:	600 mm
Area of Concrete Pedestal or Affected Concrete	:	450 x 450 mm
Compressive Strength of Concrete	:	32 MPa
Yield Strength of Steel	:	420 MPa
Tension Reinforcement in Concrete	:	- T -

Summary	Ratio		Remarks
	Single	Group	
Tensile Loading			
Steel Strength	0.43	N/A	✓
Concrete Breakout	0.48	0.96	✓
Pullout	0.85	N/A	✓
Side-face Blowout	0.97	0.97	✓
Bond Strength	N/A	N/A	✓
Shear Loading			
Steel Strength	0.01	N/A	✓
Concrete Breakout	0.09	0.36	✓
Pryout	0.00	0.02	✓





Base Plate



Remark:
1.All dimensions are in millimeters unless otherwise stated.
2.Material is aluminium alloy 6063-T6.
3.Surface treatment is powder coating.

Itemref	Quantity	Title/Name, designation, material, dimension etc			Article No./Reference	
Designed by		Checked by	Approved by - date	Filename	Date 6 June, 2024	Scale
PROSPEC SPECIALTIES		15m High Aluminum Flagpole				
		FPA15i Modified (Internal Halyard)			Edition	Sheet