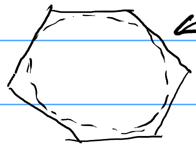
GROUTED BASE PLATES

PROCESS EQUIPMENT DESIGN METHOD

→ EQUIPMENT FIELD

→ LARGE OPENINGS

→ APPROACHING THE INNER DIAMETER OF THE SHELL.



→ METHOD CAN BE CONSERVATIVELY USED FOR POLYGONAL PLATES.

→ WORKING STRESS DESIGN METHOD (WSD)

→ ECCENTRICITY IS SUFFICIENT LARGE TO PRODUCE TENSION ON A PORTION OF THE BASE PLATE.

REINFORCED CONCRETE COLUMN THEORY

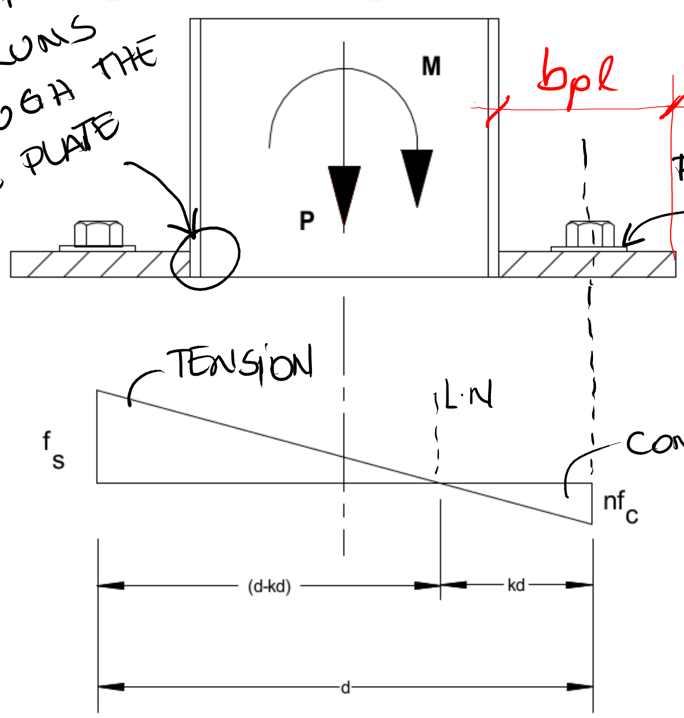


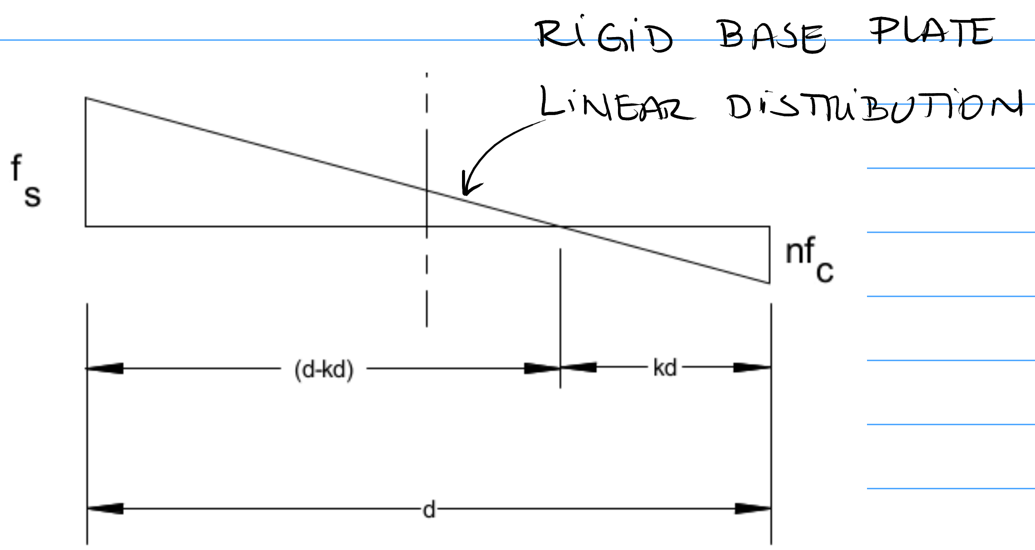
Fig. 2- 1

MODULAR RATION

$$n = \frac{E_s}{E_c}$$ ✓

f_c – COMPRESSIVE STRESS IN THE CONCRETE

$f_s = n \cdot f_c$ – COMPRESSIVE STRESS IN THE STEEL BOLTS



By similar triangles

$$\frac{f_s}{(d-kd)} = \frac{nf_c}{kd}$$

therefore

$$k = \frac{nf_c}{nf_c + f_s} = \frac{1}{1+\left(\frac{f_s}{nf_c}\right)}$$

t_s – EQUIVALENT STEEL RING FOR THE BOLTS AREA. BOLTS UNIFORMLY SPACED AROUND THE BOLT CIRCLE

$dA_s = t_s \cdot r \cdot d\theta$

$dA_c = t_c \cdot r \cdot d\theta$

THE BOLT CIRCLE (d_{PAR})

CENTRAL TENSILE FORCE

CENTRAL COMPRESSION FORCE

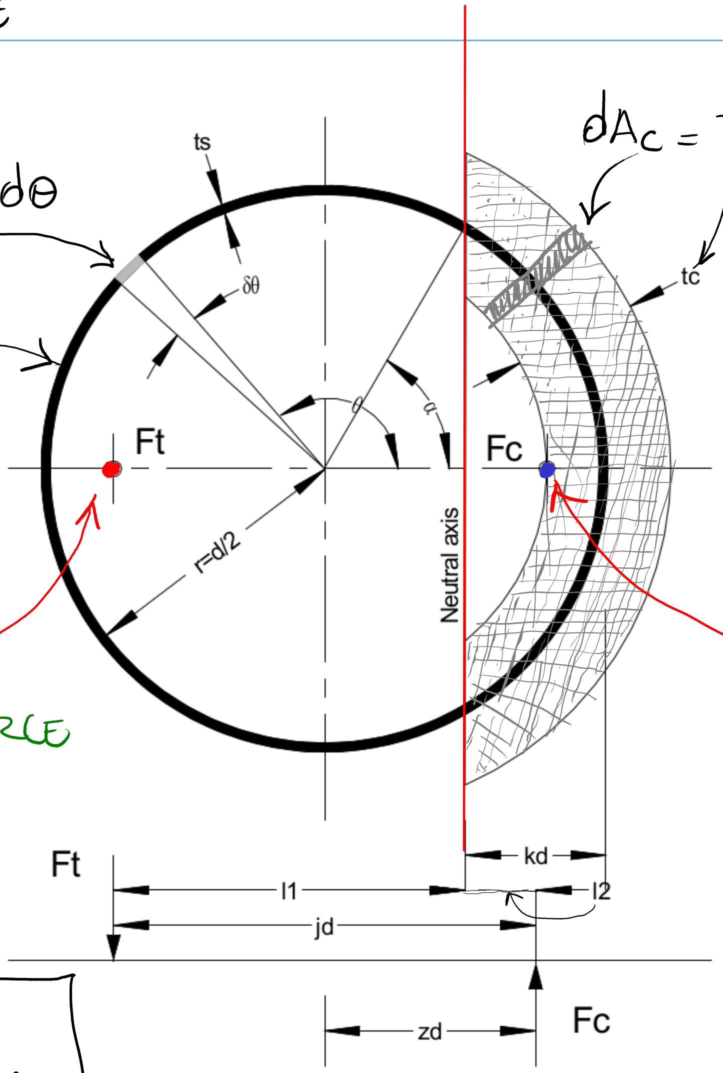


Fig. 2- 2

$$\boxed{t_s = \frac{A_{BOLT}}{\pi \cdot d_{PAR}}}$$

The values of α, C_t and l_1 are constants for a given value of k.

$\cos\alpha = 1 - 2K$

l_1 – DISTANCE FROM NEUTRAL AXIS TO Ft

CENTER OF TENSION PORTION

$$\boxed{\alpha = \underbrace{\cos^{-1}}_{\text{ACOS}}(1-2k)}$$

GNU OCTAVE

l_2 – DISTANCE FROM NEUTRAL AXIS TO F_C

← CENTER OF COMPRESSION PORTION

$$l_1 = \frac{M_t}{F_t} = r\left[\frac{(\pi-\alpha)\cos^2\alpha + \frac{3}{2}(\sin\alpha\cos\alpha) + \frac{1}{2}(\pi-\alpha)}{(\pi-\alpha)\cos\alpha + \sin\alpha}\right]$$ ✓

$$\boxed{r = d/2}$$

TOTAL TENSILE FORCE

$$\boxed{F_t = F_s \cdot t_s \cdot r \cdot C_t}$$ ✓

$$C_t = \left[\frac{2}{(1+\cos\alpha)}\left((\pi-\alpha)\cos\alpha + \sin\alpha\right)\right]$$ ✓

TOTAL COMPRESSION FORCE

$$F_c = (t_c + n \cdot t_s) \cdot r \cdot f_c \cdot C_c$$

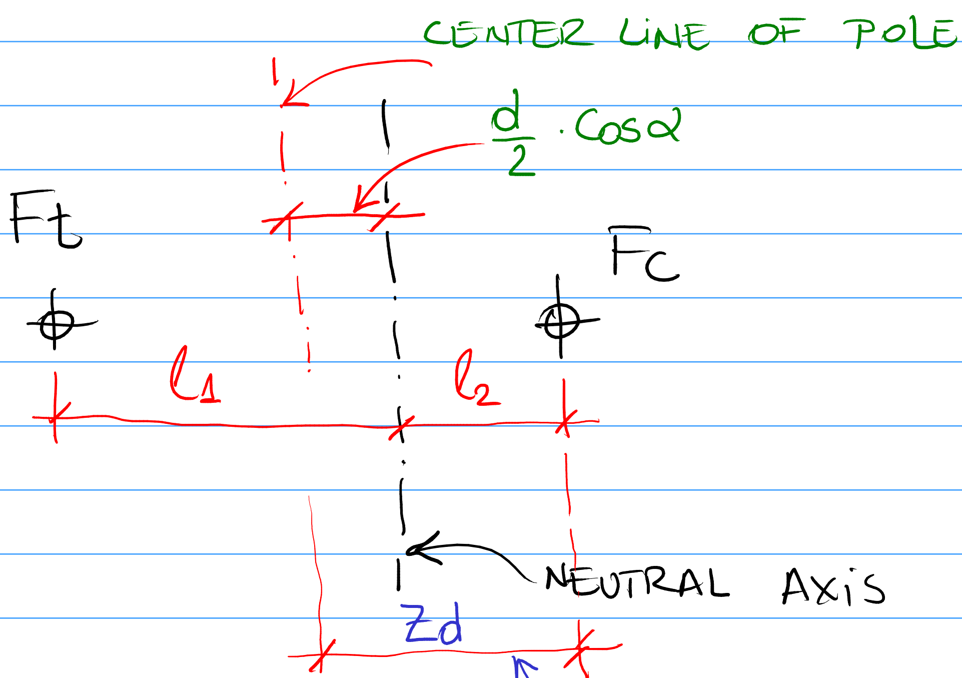
$$\boxed{C_c = 2\left[\frac{\sin\alpha - \alpha\cos\alpha}{1-\cos\alpha}\right]}$$

$$\boxed{t_c = b_{pl} - t_s}$$

$$\boxed{f_c = \frac{F_c}{(t_c + nt_s)rC_c}}$$

CONVERSELY

$$l_2 = \frac{M_c}{F_c} = r\left[\frac{\alpha\cos^2\alpha - \frac{3}{2}(\sin\alpha\cos\alpha) + \frac{1}{2}\alpha}{\sin\alpha - \alpha\cos\alpha}\right]$$



DIMENTIONLESS RATIO j

$$\boxed{j = \frac{l_1 + l_2}{d}}$$

$$\boxed{zd = l_2 + \frac{d}{2}\cos\alpha}$$

EQUILIBRIUM CONDITIONS

$$\Sigma M = 0$$

$$\boxed{M - P \cdot z_d - \underbrace{F_t \cdot j \cdot d}_{F_t \cdot (\ell_1 + \ell_2)} = 0}$$

$$\boxed{f_s = \frac{F_t}{t_s \cdot r \cdot C_t}}$$

TENSION STRESS ON EQUIVALENT RING

CONVERSELY

$$\boxed{F_t = \frac{M - P \cdot z_d}{J \cdot d}}$$

USEFUL

$$\Sigma F_v = 0$$

$$F_t + P - F_c = 0$$

$$F_c = F_t + P$$

$$\boxed{f_c = \frac{k \cdot d \cdot f_s}{n \cdot (d - k \cdot d)}}$$

THE PEAK BEARING STRESS

$$f_{c\,max} = f_c \cdot \left(\frac{2 \cdot k \cdot d + b_{pl}}{2 \cdot k \cdot d} \right)$$

Example 2.1

Analyze a grouted base plate for a 55″ diameter pole that runs through the base plate. The bolt circle is 64″ with (20) 2-1/4″ bolts. The vertical load is 46 kips and the moment is 3565 kip-ft (42780 in-kips). The thickness of the base plate is 2-1/4″. The outer diameter of the base plate is 73″. The concrete has a strength of 3000 psi.

57,15 mm

$$n = \frac{E_s}{E_c} = \frac{29000}{57\sqrt{3000}} = 9.29$$

$$A_s = 20(3.25) = 65\,\text{in}^2$$

$$r = \frac{64}{2} = 32\,\text{in}$$

$$t_s = \frac{65}{64\pi} = .323\,\text{in}$$

$$t_c = \frac{73-55}{2} - .323 = 8.677$$

Diâmetro interno (55″) 139,70 cm

Diâmetro externo (73″) 185,42cm

Diâmetro da linha de parafusos 162,56cm

20 chumbadores ø57,15 mm (5,175cm)

Nd = 204,61819 kN (46 kips)

Md = 4833,491 kN.m (3565 kip-foot)

Es/Ec = 9,29

Tração no chumbador (107 kips) = 475.95971 kN

bpl = 22,86 cm

MANUAL x TRAMEMAST

$\alpha = 1.165$ → alfa = 1.1669 ✓

$C_c = 1.516$ → Cc = 1.5188 ✓

$C_t = 2.4366$ → Ct = 2.4344 ✓

$z = .437$ → z = 0.4369 ✓

$j = .781$ → j = 0.7813 ✓

1 KIPS

$F_t = 829.8$ KIPS → >> Ft/4.4482216 ✓
ans = 829.80

$F_c = 875.8$ → >> Fc/4.4482216 ✓
ans = 875.80

$f_s = 32.92$ KSI → fs = 22.646 KN/cm² ✓

$f_c = 1.546$ KSI → fc = 1.0630 KN/cm² ✓

$k_{calc} = .303$ → kc = 0.3036

IT'S ALL RIGHT !!!

Which is sufficiently accurate to proceed to final calculations

$$P_{bolt} = f_s A_{bolt} = 32.92 \times 3.25 = 107 \text{ kips}$$ ✓

TENSILE FORCE ON ANCHOR BOLT

Ntsd = 476.33 KN ✓

= 107,083 KIPS ✓

$$f_{c\max} = f_c\left(\frac{2kd + b_{pl}}{2kd}\right)$$

WITHOUT BRACKETS

1,3053 ksi

$$f_{c\max} = \frac{1.546\left[2\times.3025\times64+\left(\frac{73-55}{2}\right)\right]}{2\times.3025\times64} = 1.78\,\text{ksi} \le .7\times3\times1.33 = 2.8\,\text{ksi o.k.}$$

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(1.546 * ( 2 * 0.3025 * 64 + ((73-55)/2))) / (2 * 0.3025 * 64)
ans = 1.9053
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ksi

1,3053 ksi = 1,31 kN/cm^2

TRAMEMAST RESULT

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fcmax = 1.3093
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MOMENT ON THE COMPRESSION SIDE OF THE PLATE

$$M_{\max} = \frac{f_c l^2}{2} = \frac{1.546\times9^2}{2} = 62.6\,\frac{\text{in}-\text{kip}}{\text{in}}$$

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Mmax = 277.75
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kN·cm/cm

OK!

TRAMEMAST.

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VERIFICAÇÃO DE LIGAÇÃO DE BASE CIRCULAR GRAUTEADA
Cálculo baseado no Equipment Design Method
Technical Manual 1 – Design Monopole Base Plates
By Daniel Horn, P.E.
Autor: Eng. Paulo C. Ormonde - REV: 24.09.18
-------------------------------------------------------
Esforços solicitantes de cálculo
Momento fletor...........................: 483349.10 kN.cm
Normal de compressão.....................: 204.62 kN
Cortante.................................: 0.00 kN

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Resultados da análise
Razão modular............................: 9.29
Fator K do processo iterativo............: 0.3036
Braço de alavanca (l1+l2)................: 1270.1151 mm
L.N em relação ao centro do mastro.......: 319.43 mm

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Verificação da placa de base

Tensão de escoamento do aço da placa.....: 25.00 kN/cm²
Tensão de ruptura do aço da placa........: 40.00 kN/cm²
Diâmetro da placa de base................: 1854.20 mm
Largura da placa (anel). ................: 228.60 mm

Momento fletor no lado comprimido........: 277.75 kN.cm/cm
Momento fletor no lado tracionado........: 248.11 kN.cm/cm

Espessura mínima de cálculo da placa.....: 69.92 mm
Espessura adotada para placa de base.....: 76.20 mm

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Verificação dos chumbadores

Diâmetro dos chumbadores.................: 51.75 mm
Área bruta de aço do chumbador...........: 21.03 cm²
Número de chumbadores....................: 20
Tensão de ruptura do aço dos chumbadores.: 40.00 kN/cm²

Normal de tração solicitante  de cálculo.: 476.33 kN
Normal resistente de tração de cálculo...: 467.41 kN

Cisalhamento solicitante de cálculo......: 0.00 kN
Cisalhamento resistente de cálculo.......: 280.45 kN

Tração + Cisalhamento dos parafusos
Taxas de trabalho
      - Tração...........................: 1.02
      - Cisalhamento.....................: 0.00
      - Tração + Cisalhamento............: 1.04

Comprimento de ancoragem de cálculo......: 2260.00 mm
Comprimento do chumbador.................: 2460.00 mm
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Peso da placa de base....................: 698.34 kg
Peso dos chumbadores.....................: 812.35 kg
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Peso dos Total...........................: 1510.69 kg
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