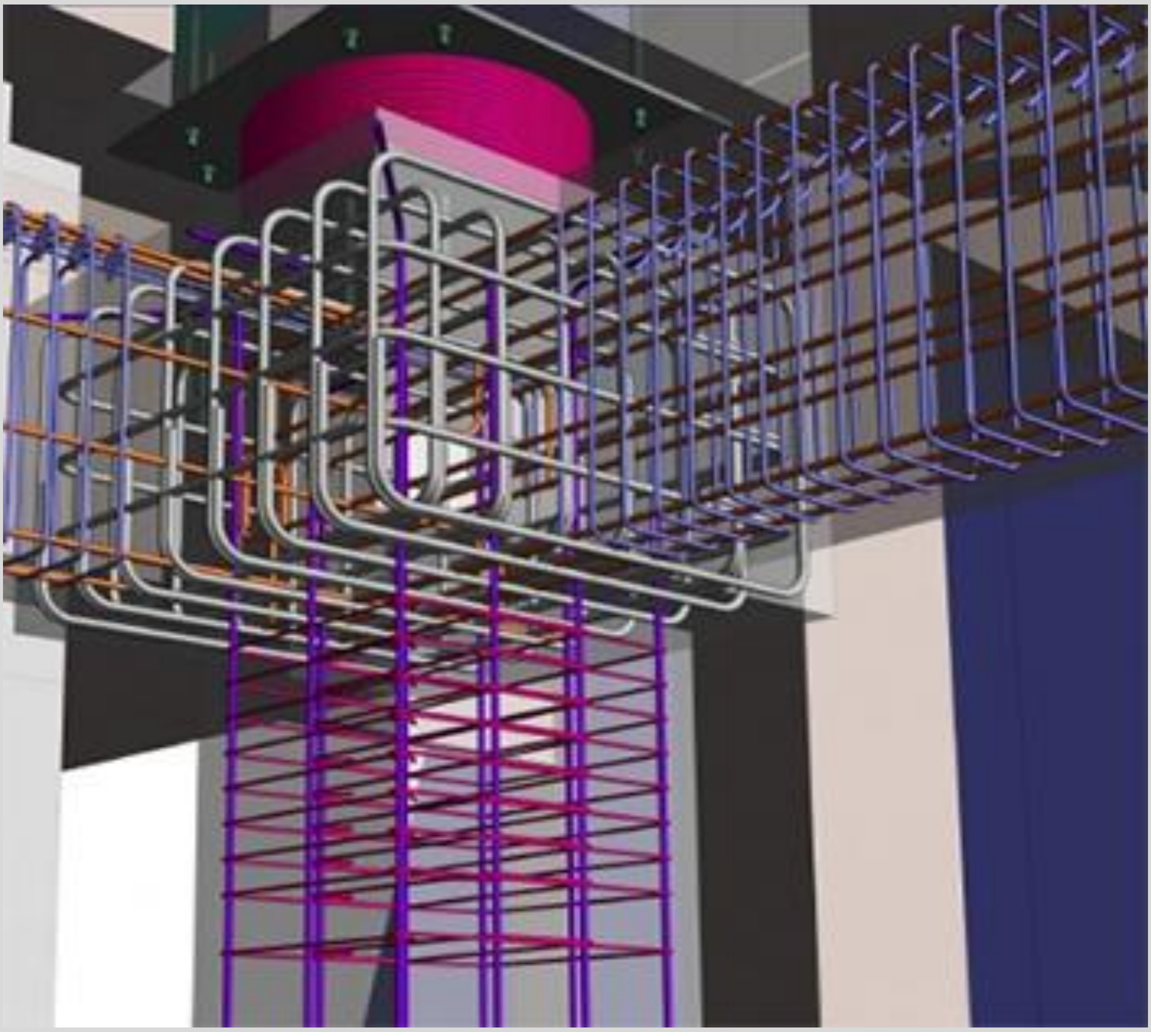
# CONCRETO ARMADO II

# EJERCICIOS RESUELTOS

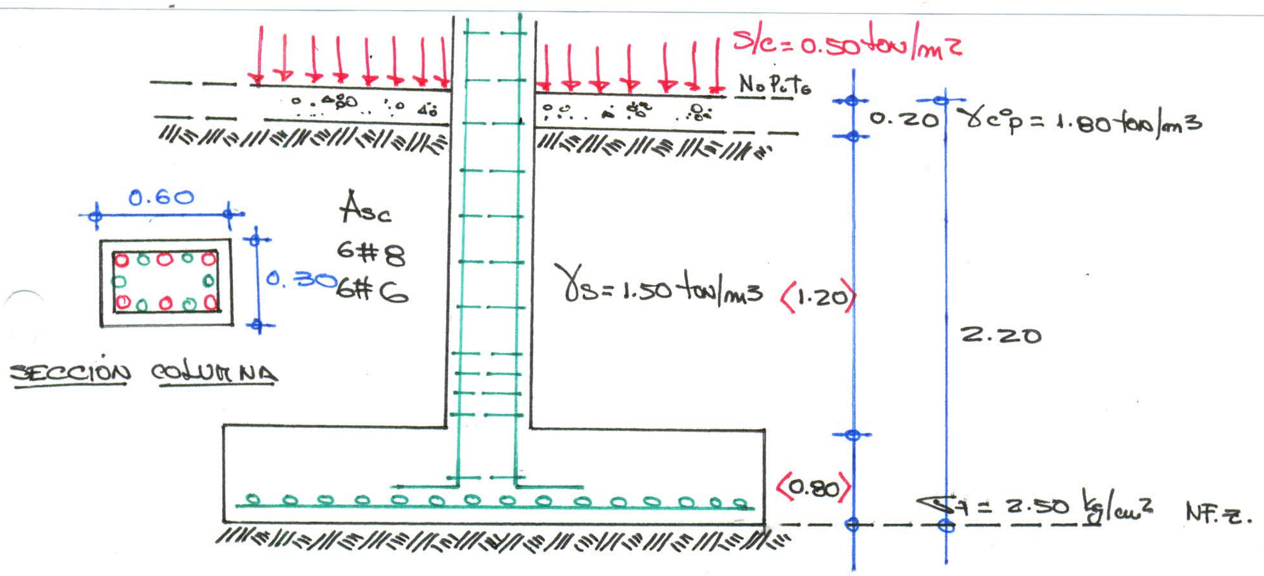


"CIMENTACIONES II".

ABRIL DEL 2020

**PROBLEMA N° 02:**

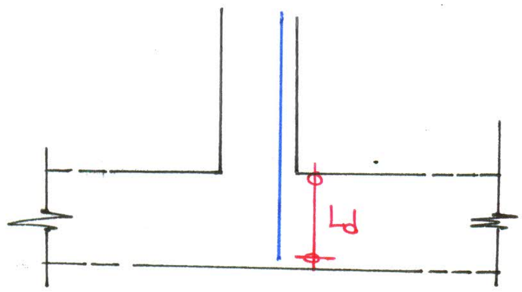
Determinar, verificar y diseñar la zapata aislada mostrada en la figura adjunta que soporta una columna de sección rectangular de 0.30x0.60 m. (bxt) reforzada con 6 varillas # 8 y 6 varillas # 6, la carga que transmite a la columna es de Pd=180 ton, Pl=120 ton., el peso específico del suelo es de 1.50 ton/m3 y la capacidad portante admisible del suelo según el (EMS) es de 2.50 kg/cm2, además está sometido a la acción de una sobrecarga de 500 kg/m2, emplear para el diseño fc=210 kg/cm2 y fy=4200 kg/cm2.




## I DIMENSIONAMIENTO DE LA ZAPATA:

$As_{COL}$ { 6#8 = 1" ; 6#6 = 3/4" } ⇒ ELEGIMOS EL MAYOR #8 = 1" { $A_b = 5.10\ cm^2$ ; $d_b = 2.54\ cm.$ }

"d" DEBE SER CAPAZ PERMITIR EL DESARROLLO DEL REFUERZO EN COMPRESIÓN EN LA COLUMNA




∴ Normas Peruanas Ld compresión

$$\begin{cases} L_d = 0.08\ d_b\ f_y/\sqrt{f'c} \\ L_d = 0.004\ d_b\ f_y \\ L_d \geq 20\ cm \end{cases}$$

$L_d = 0.08 d_b\ f_y/\sqrt{f'c} = 0.08\ (2.54)\ 4200/\sqrt{210} = 58.893\ cm.$

$L_d = 0.004\ d_b\ f_y = 0.004\ (2.54)\ 4200 = 42.67\ cm$ ⇒ $L_d = 60\ cm.$

$L_d \geq 20\ cm = 20\ cm. = 20.00\ cm.$

∴ $d = L_d + 0.10 \Rightarrow d = 70\ cm.$ ⇒ $h = d + r + \phi$ (0.10) ⇒ $h = 80\ cm.$

## CAPACIDAD EFECTIVA DEL TERRENO = CAPACIDAD PORTANTE NETA DEL TERRENO ($q_e$)

$$q_e = \sigma_t - (\gamma_{c^o z}\, h_z) - (\gamma_s\, h_s) - (\gamma_{c^o p}\, h_p) - s/c$$

$q_e = 25 - (2.40 * 0.80) - (1.50 * 1.20) - (1.80 * 0.20) - 0.50$ ........ $\Rightarrow q_e = 20.42$ ton/m2

$q_e = 2.042$ kg/cm²

## AREA DE LA ZAPATA REQUERIDA : $q_e = 20.42$ ton/m², $P_d = 180$ ton, $P_L = 120$ ton.

$$A = \frac{P_T}{q_e} \qquad A = \frac{P_d + P_L}{q_e} = \frac{180+120}{20.42} \Rightarrow A = 14.691\ m^2$$

## DIMENSIONAMIENTO DE LOS LADOS DE LA ZAPATA :

$$A_z = (b+2m)(t+2m)$$

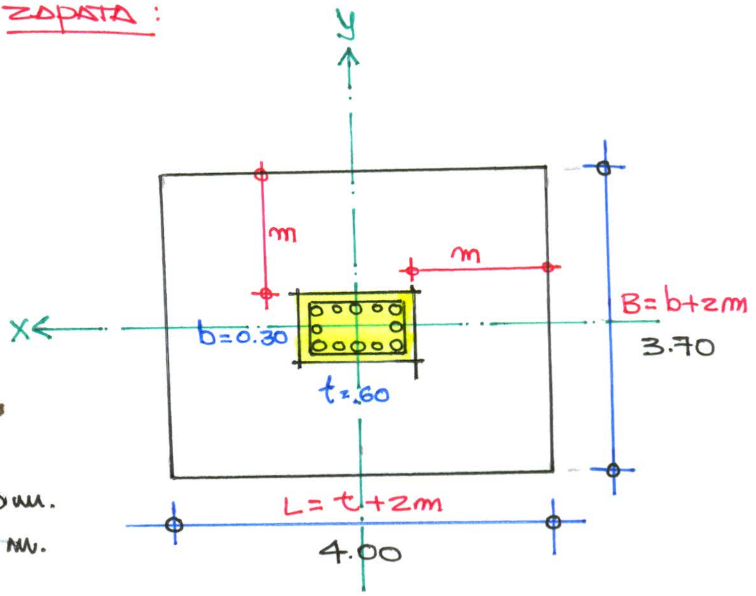
$14.691 = (0.30+2m)(0.60+2m)$

$14.691 = 0.180 + 0.60m + 1.20m + 4m^2$

$4m^2 + 1.80m - 14.511 = 0$

$m_1 = 1.693$ m.

$m_2 = -2.143$ m $\therefore$ $m = 1.70$ m




$B = b+2m = 0.30 + (1.70)2 \Rightarrow B = 3.70$ m.

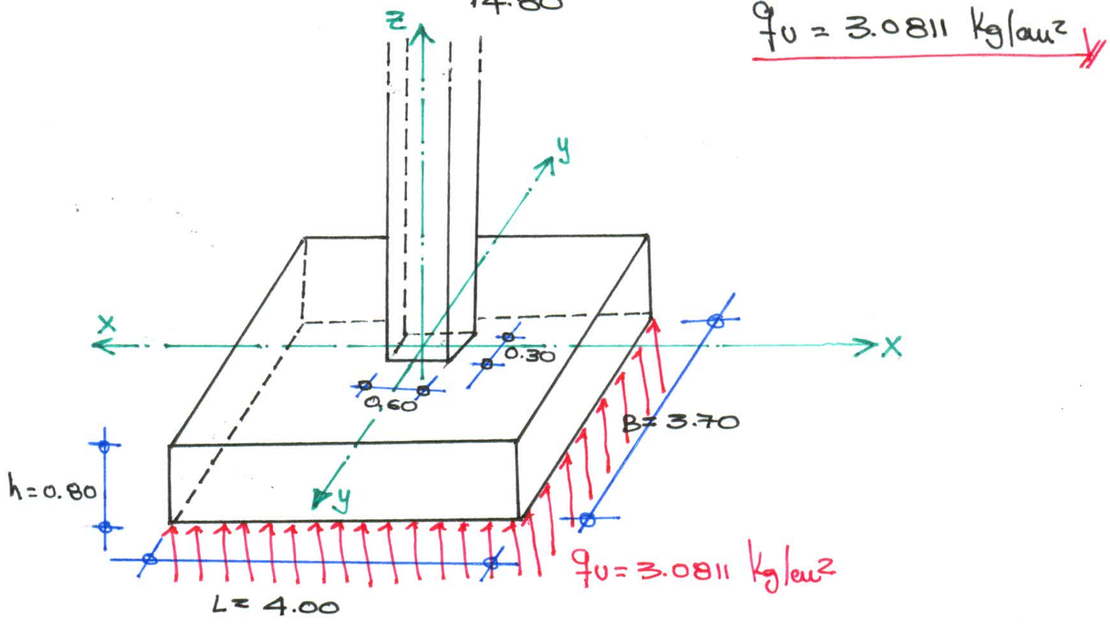
$L = t+2m = 0.60 + (1.70)2 \Rightarrow L = 4.00$ m.

$\Rightarrow A_z = 14.80\ m^2$

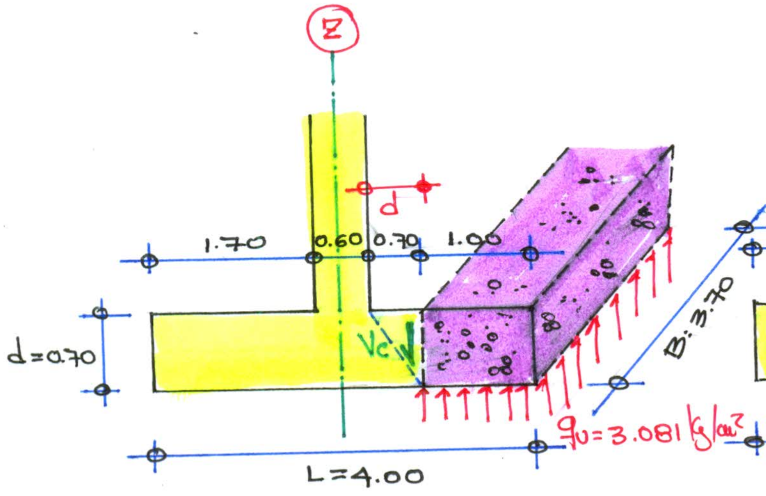
## REACCION AMPLIFICADA DEL SUELO ($q_u$) SEGUN RNE : $P_u = 1.70\,P_L + 1.40\,P_d$

$$q_u = \frac{P_u}{A} = \frac{1.70\,P_L + 1.40\,P_d}{A} = \frac{1.70(120) + 1.40(180)}{14.80} \Rightarrow q_u = 30.811\ \text{ton/m}^2$$

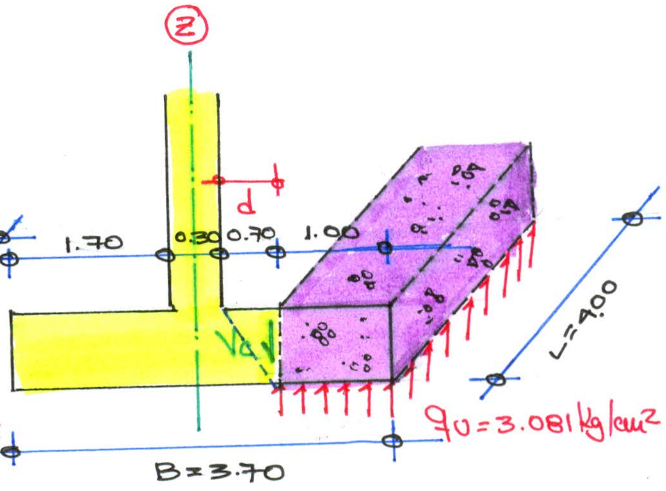
$q_u = 3.0811$ kg/cm²



# Verificacion por corte: flexion




Direccion: X-X




Direccion: Y-Y

## Condicion Normativa

$$V_u \leq \phi V_c$$

Fuerza cortante ultima — Resistencia del concreto @ corte

**Dirección X-X**

$$V_u = q_u * A$$

$V_u = 3.081 * (1.00 * 3.70)$

$V_u = 113\,997.00 \text{ kg} = 113.997 \text{ ton}$

$$\phi V_c = \phi\, 0.53 \sqrt{f'c} * B * d$$

$\phi V_c = 0.85 * 0.53 \sqrt{210} * 370 * 70$

$\phi V_c = 169\,084.659 \text{ kg} = 169.084 \text{ ton}$

$V_u = 113.997 \text{ ton} < \phi V_c = 169.084 \text{ ton}$

Conforme

**Dirección Y-Y**

$$V_u = q_u * A$$

$V_u = 3.081 (100 * 400)$

$V_u = 123\,240.00 \text{ kg} = 123.240 \text{ ton}$

$$\phi V_c = \phi\, 0.53 \sqrt{f'c}\, L * d$$

$\phi V_c = 0.85 * 0.53 \sqrt{210} * 400 * 70$

$\phi V_c = 182\,794.226 \text{ kg} = 182.794 \text{ ton}$

$V_u = 123.240 < \phi V_c = 182.794 \text{ ton}$

Conforme

## Peralte Necesario ($d_{nec}$)

$q_u A = \phi\, 0.53 \sqrt{f'c}\, L\, d$ $\qquad l_c = 100 \text{ cm.}$

$q_u (L_c * \cancel{L}) = \phi 0.53 \sqrt{f'c}\, \cancel{L}\, d$

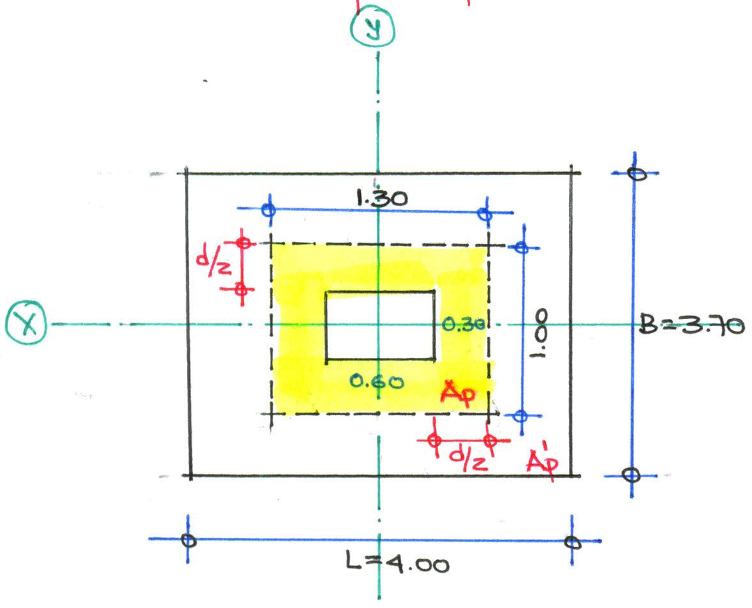
$q_u\, l_c = \phi\, 0.53 \sqrt{f'c}\, d$

$$d_{nec} = \frac{q_u\, l_c}{\phi 0.53 \sqrt{f'c}} \Rightarrow d_{nec} = \frac{3.081 * 100}{0.85 * 0.53 \sqrt{210}} \Rightarrow d_{nec} = 47.194 \text{ cm}$$

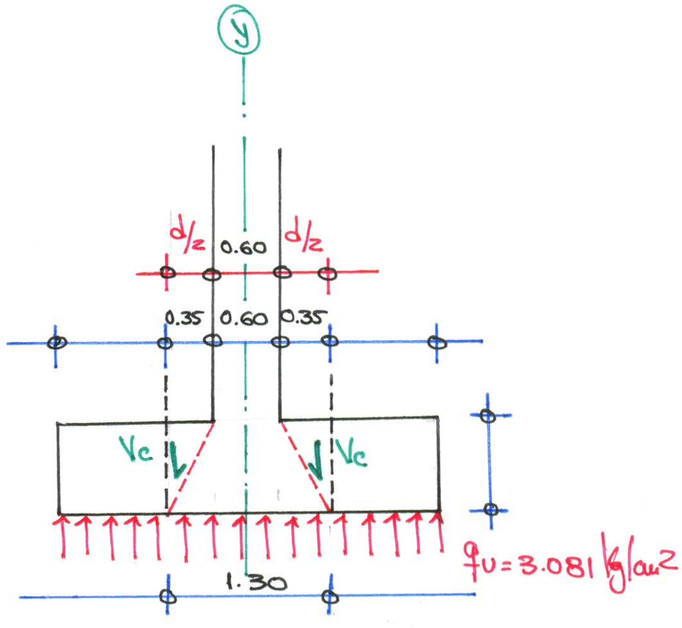
$d_{nec} = 47.194 \text{ cm.} < d_{cal} = 70.00 \text{ cm}$

Conforme

# VERIFICACION POR PUNZONAMIENTO:




PLANTA




SECCION: X – X

## CONDICION NORMATIVA

Fuerza cortante ultima $V_u \leq \phi V_c$ Resistencia del concreto @ corte

$A'p = A_z - A_p$

$A'p = (400 * 370) - (130 * 100)$

$A'p = 135\,000 \text{ cm}^2$

$V_u = q_u * A'p$

$V_u = 3.081 * 135000$

$V_u = 415\,935.00 \text{ kg} = 415.935 \text{ ton}$

$B_o = \dfrac{\text{Lado} > \text{col.}}{\text{Lado} < \text{col.}} = \dfrac{0.60}{0.30} \Rightarrow \beta_o = 2$

PERIMETRO DE PUNZONAMIENTO

$b_o = 2(100 + 130)$

$b_o = 460.00 \text{ cm.}$

$\phi V_c = \phi\left(0.53 + \dfrac{1.10}{\beta_o}\right)\sqrt{f'c}\, b_o d$

$\phi V_c = 0.85\left(0.53 + \dfrac{1.10}{2}\right)\sqrt{210} * 460 * 70$

$\phi V_c = 428\,359.30 \text{ kg} = 428.359 \text{ ton}$

$\therefore V_u = 415.935 \text{ ton} < \phi V_c = 428.359 \text{ ton}$

CONFORME

## PERALTE NECESARIO $d_{nec}$

$v_o b_o d = q_u A'p$

$d_{nec} = \dfrac{q_u A'p}{v_o b_o} = \dfrac{3.081(135000)}{13.549 * 460}$

$d_{nec} = 66.736 \text{ cm}$

$v_o = \phi 1.10\sqrt{210}$

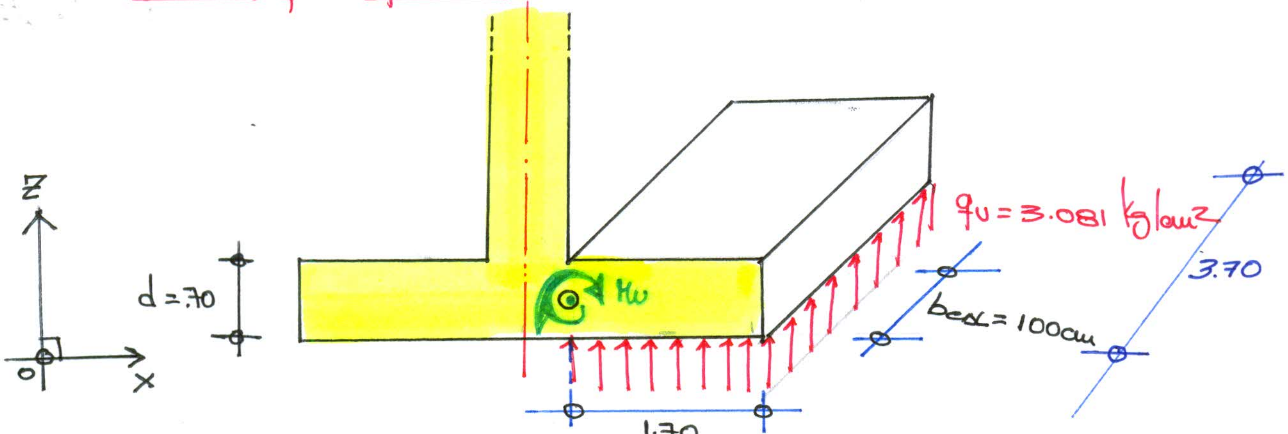
$v_o = 0.85 * 1.10\sqrt{210}$

$v_o = 13.549 \text{ kg.}$

$\therefore d_{nec} = 66.736 \text{ cm} < d_{col} = 70.00 \text{ cm}$

CONFORME

## DISEÑO POR FLEXIÓN:




SECCIÓN: X-X

$$M_u = \frac{q_u L^2}{2} b_{col} \Rightarrow M_u = \frac{30.81 (1.70)^2 (1.00)}{2} \Rightarrow M_u = 44.52 \text{ ton-m}$$

**DATOS DE DISEÑO**

$b = 100 cm$

$d = 70 cm$

$f'c = 210 kg/cm2$

$f'y = 4200 kg/cm2$

$M_u = 44.52$ ton-m.

$$a = \frac{As\, f_y}{0.85 f'c\, b}$$

$$M_u = \phi As f_y \left(d - \frac{a}{2}\right)$$

$$0.59\omega^2 - \omega + \frac{M_u}{\phi b d^2 f'c} = 0$$

$$\omega = \rho_d \frac{f_y}{f'c}, \quad \rho_d = Asd/bd, \quad \rho_d = \omega \frac{f'c}{f_y}, \quad Asd = \rho_d b d$$

$$\rho_{min} = \frac{0.70\sqrt{f'c}}{f_y} \Rightarrow \rho_{min} = 0.00242 \qquad As_{min} = \rho_{min} bd \Rightarrow As_{min} = 16.90661 cm^2$$

$$\rho_b = 0.85\beta_1 \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right) \Rightarrow \rho_b = 0.02125 \qquad Asb = \rho_b b d \Rightarrow Asb = 148.75 cm^2$$

$$\rho_d = \quad \Rightarrow \rho_d = 0.00248 \qquad Asd = \rho_d b d \Rightarrow Asd = 17.33177 cm^2$$

$$\rho_{max} = 0.75\rho_b \Rightarrow \rho_{max} = 0.01594 \qquad As_{max} = \rho_{max} bd \Rightarrow As_{max} = 111.5622 cm^2$$

$\rho_d < \rho_{max} < \rho_b$ ∴ FALLA DUCTIL

**DISTRIBUCIÓN DE ACEROS:** $Astd = 17.332 * 3.70 \Rightarrow Astd = 64.128 cm^2$

$\phi 3/4'' = 2.84 cm^2$

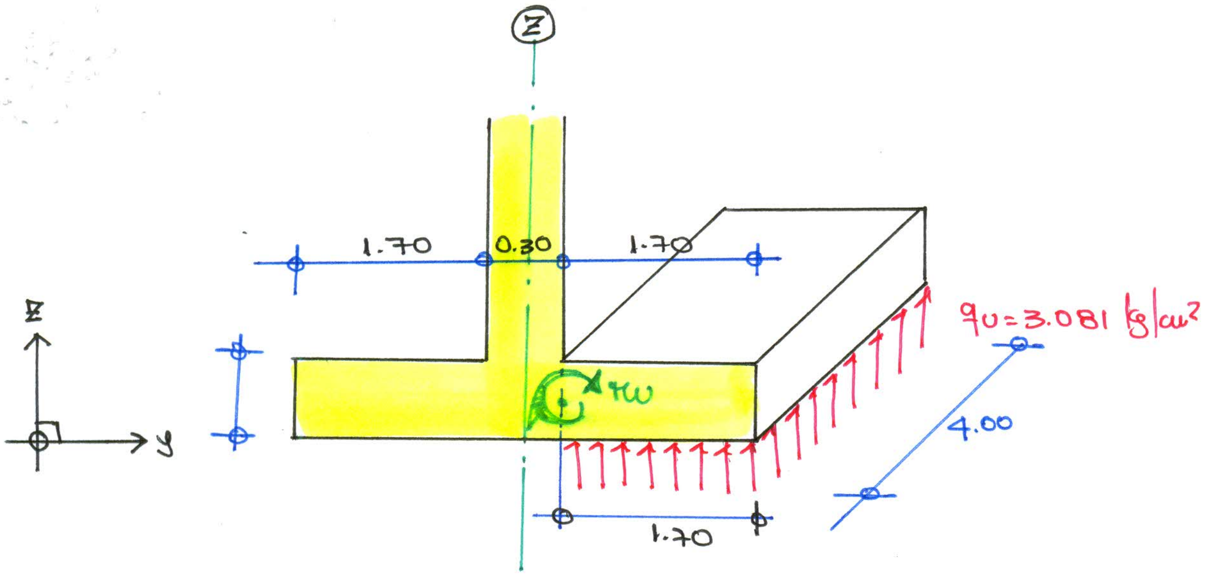
$$n = \frac{Astd}{As\phi} \Rightarrow n = \frac{64.128}{2.84} \Rightarrow n = 22.58 \Rightarrow n = 23 \text{ UNIDADES}$$

$db\ \phi 3/4 = 0.019 m$

**ESPACIAMIENTO:**

$$S = \frac{B - 2(r) - \phi - 0.10}{n-1} = \frac{3.70(2*0.075) - 0.019 - 0.10}{22} \Rightarrow S = 0.156 cm.$$

23 $\phi$3/4 @ 0.156 cm :




SECCIÓN: y-y

$$Mu = \frac{q_u L^2 b_{col}}{2} \Rightarrow Mu = \frac{3.081 * 1.70^2 \times 100}{2} \Rightarrow Mu = 44.52 \text{ ton-m}$$

**Datos de diseño:**

b = 100 cm

d = 70 cm

$f'c = 210$ kg/cm²

$f_y = 4200$ kg/cm²

Mu = 44.52 ton-m

$$a = \frac{As f_y}{0.85 f'c b} \qquad Mu = \phi As f_y \left(d - \frac{a}{2}\right)$$

$$0.59\omega^2 - \omega - \frac{Mu}{\phi b d^2 f'c} = 0$$

$$\omega = \rho_d \frac{f_y}{f'c}, \quad \rho_d = \omega \frac{f'c}{f_y}, \quad As_d = \rho_d b d$$

$$\rho_{min} = \frac{0.70\sqrt{f'c}}{f_y} \Rightarrow \rho_{min} = 0.00242 \longrightarrow As_{min} = \rho_{min} b d \Rightarrow As_{min} = 16.906 \text{ cm}^2$$

$$\rho_b = 0.85\beta \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right) \Rightarrow \rho_b = 0.02125 \longrightarrow As_b = \rho_b b d \Rightarrow As_b = 148.75 \text{ cm}^2$$

$$\rho_d = \quad \rho_d = 0.00248 \longrightarrow As_d = \rho_d b d \Rightarrow As_d = 17.332 \text{ cm}^2$$

$$\rho_{MAX} = 0.75 \rho_b \Rightarrow \rho_{MAX} = 0.01594 \longrightarrow As_{max} = \rho_{max} b d \Rightarrow As_{max} = 111.562 \text{ cm}^2$$

$\rho_d < \rho_{MAX} < \rho_b \therefore$ FALLA DUCTIL

**Distribución de acero:** $As_{td} = 17.332(4) \Rightarrow As_{td} = 69.328$ cm²

$As\phi\, 3/4 = 2.84$ cm² $\quad d_b = 0.019$ m

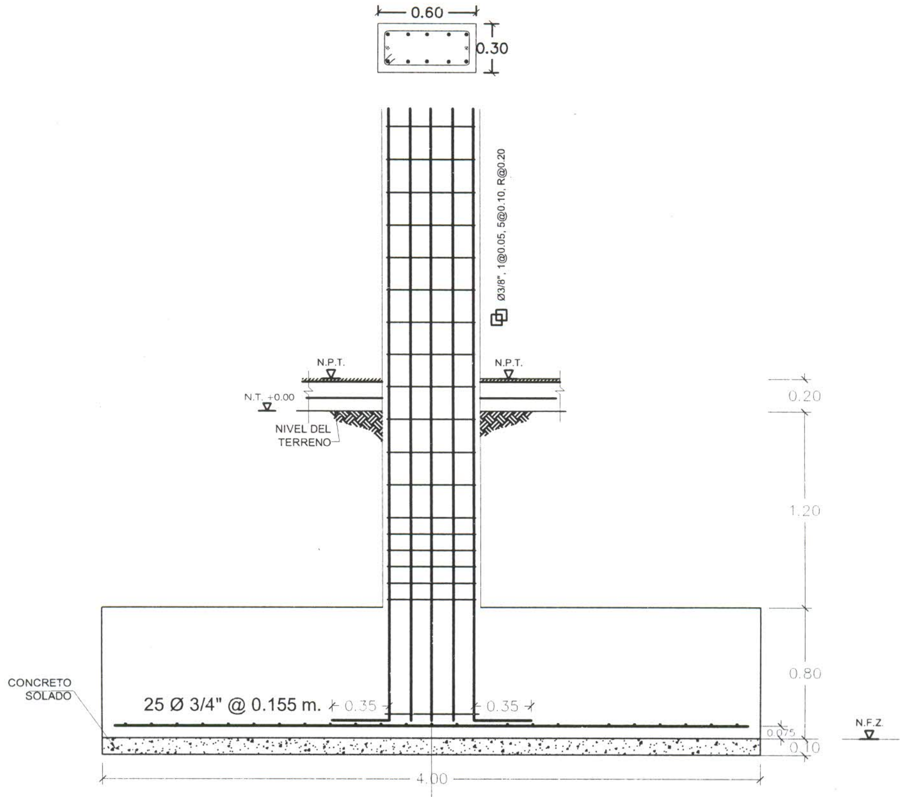
**# Aceros**

$$n = \frac{As_{td}}{As\phi} \Rightarrow n = \frac{69.328}{2.84} \Rightarrow n = 24.411 \Rightarrow n = 25 \text{ unidades.}$$

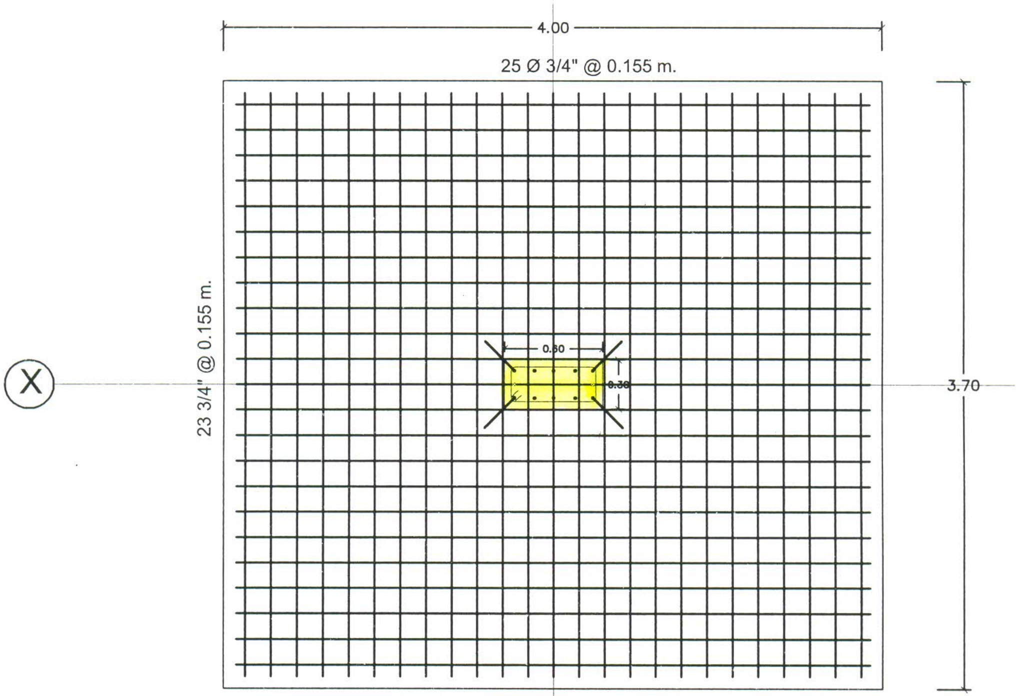
**Espaciamiento:**

$$s = \frac{L - 2r - \phi - 0.10}{n - 1} = \frac{4.00 - 0.15 - 0.019 - 0.10}{24} \Rightarrow S = 0.155 \text{ cm}$$

25 φ3/4 @ 0.155




DETALLE DE ZAPATA TIPICO
ESCALA 1:25




DETALLE DE ZAPATA EN PLANTA
ESCALA 1:25

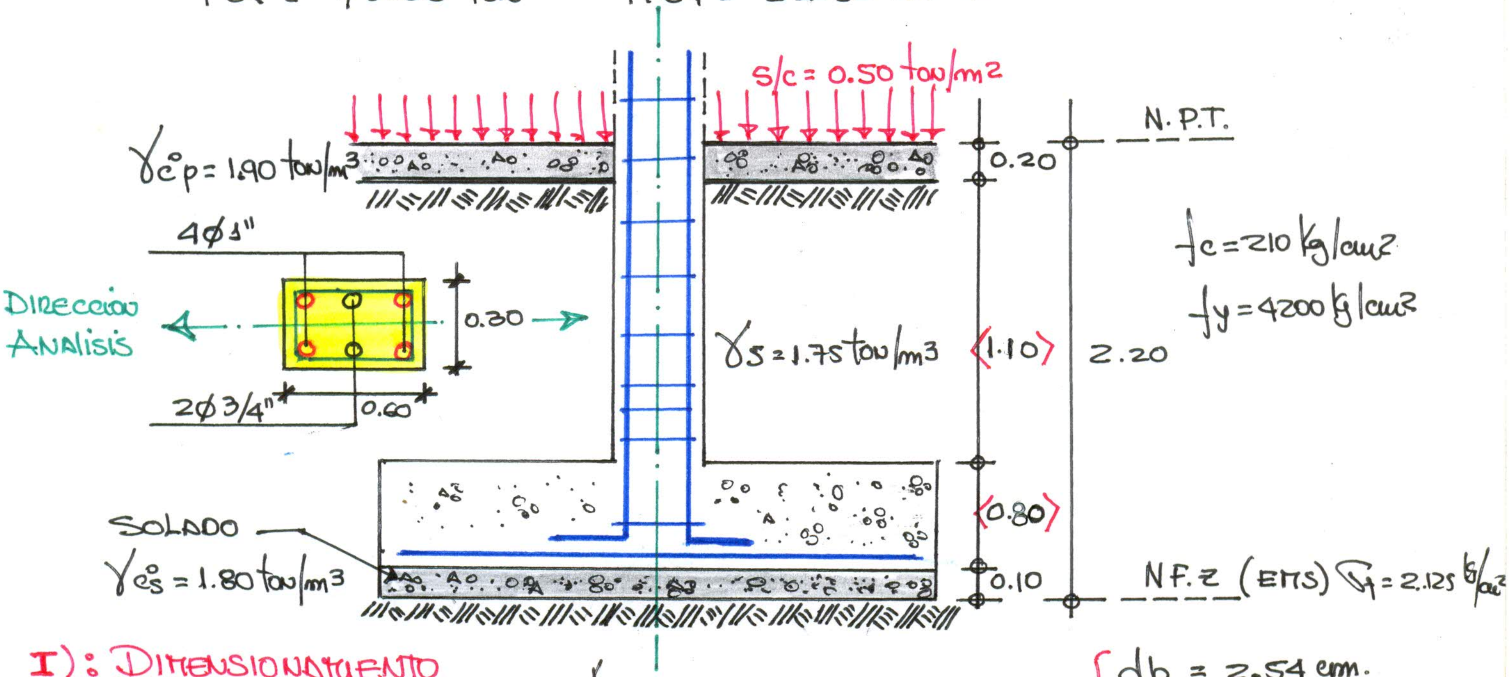
Y

## PROBLEMA #03:

DISEÑAR LA ZAPATA AISLADA CONSIDERANDO LOS DATOS TECNICOS Y ESTRUCTURALES

$P_{CM} = 92.50$ ton $\quad M_{CM} = 36.50$ ton-m $\quad \sigma_t = 2.125$ kg/cm²

$P_{CV} = 73.00$ ton $\quad M_{CV} = 22.50$ ton-m




## I): DIMENSIONAMIENTO

**PERALTE DE LA ZAPATA:** $As_{COL} = 4\phi 1" + 2\phi 3/4 \Rightarrow \phi 1"$ $\quad \begin{cases} d_b = 2.54 \text{ cm.} \\ A_b = 5.10 \text{ cm2.} \end{cases}$

**CONSIDERACIONES NORMATIVAS:**

$$\left.\begin{array}{ll} L_d = 0.08\, d_b\, f_y / \sqrt{f'c} & = 58.893 \text{ cm.} \\ L_d = 0.004\, d_b\, f_y & = 42.672 \text{ cm.} \\ L_d \geq 20 \text{ cm.} & = 20.00 \text{ cm} \end{array}\right\} \begin{array}{l} L_d = 58.893 \\ L_d = 60.00 \text{ cm.} \end{array}$$

$\therefore d = L_d + 10 \text{ cm} \Rightarrow \underline{d = 70.00 \text{ cm.}} \Rightarrow h = d + 10 \text{ cm} \Rightarrow \underline{h = 80.00 \text{ cm}}$

## CAPACIDAD PORTANTE NETA DEL TERRENO ($q_e$)

$$q_e = \sigma_t - (\gamma_{cs} * h_s) - (\gamma_{cz} * h_z) - (\gamma_s * h_s) - (\gamma_{cp} * h_p) - s/c$$

$$q_e = 21.25 - (1.80 * 0.10) - (2.40 * 0.80) - (1.75 * 1.10) - (1.90 * 0.20) - 0.50$$

$$q_e = 16.345 \text{ ton/m}^2 = 1.6345 \text{ kg/cm}^2$$

## AREA DE LA ZAPATA:

$$\boxed{A = \frac{P_T}{q_e}} \Rightarrow A = \frac{P_{CM} + P_{CV}}{q_e} \Rightarrow \frac{92.50 + 73.00}{16.345} \Rightarrow A = 10.125 \text{ m}^2$$

$A = (t+2m)(b+2m)$

$10.125 = (0.60 + 2m)(0.30 + 2m)$

$10.125 = 0.18 + 1.20m + 0.60m + 4m^2$

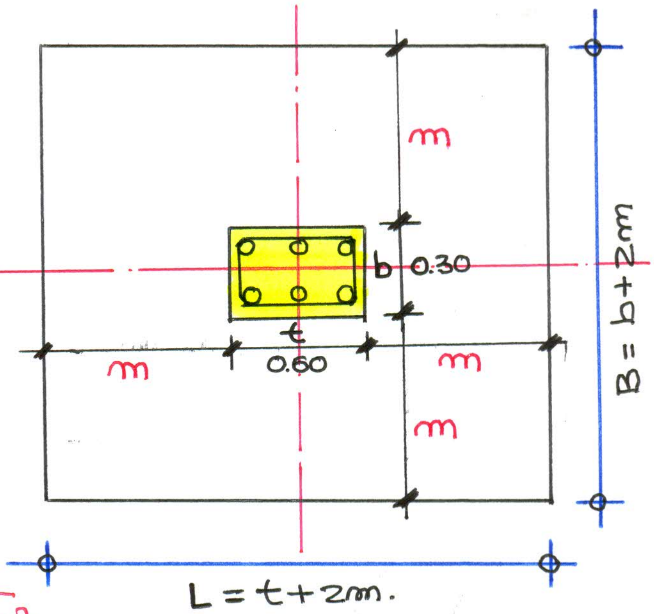
$4m^2 + 1.8m - 9.945 = \emptyset$

$m = 1.368\ m.$

$L = t+2m = 0.60 + 2(1.368) \Rightarrow L = 3.336m$

$B = b+2m = 0.30 + 2(1.368) \Rightarrow B = 3.036m$

∴ $L = 3.30$, $B = 3.00$, $A = 9.90\ m^2$




**Verificación de presion $\sigma_{max} < \sigma_t$**

$P_s = P_{cm} + P_{cv} = 92.50 + 73.00 \Rightarrow P_s = 165.50\ ton$

$M_s = M_{cm} + M_{cv} = 36.50 + 22.50 \Rightarrow M_s = 59.00\ ton\text{-}m$

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_s c}{I}$$

$A = 9.90\ m^2$

$c = L/2 \Rightarrow C = 1.65\ m.$

$I = \frac{B L^3}{12} \Rightarrow I = 8.984\ m^4$

$$\sigma_{max} = \frac{165.50}{9.90} + \frac{59.00(1.65)}{8.984}$$

$\sigma_{max} = 27.553\ ton/m^2 > \sigma_t = 21.25\ ton/m^2$ (No cumple la condicion)

**∴ Redimensionamos B y L**

$B = 3.40\ m$, $L = 3.70\ m$, $A = 12.58\ m^2$, $c = 1.85m$, $I = 14.352\ m^4$

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_s * c}{I}$$

$$\sigma_{max} = \frac{165.50}{12.58} + \frac{59.00\ (1.85)}{14.352} \Rightarrow \sigma_{max} = 20.761\ ton/m^2$$

∴ $\sigma_{max} = 20.761\ ton/m^2 < \sigma_t = 21.25\ ton/m^2$

(CONFORME)

## CARGAS DE DISEÑO ($P_U, M_U$)

## REACCIÓN AMPLIFICADA DEL SUELO:

$P_{CM} = 92.50$ ton  $M_{CM} = 36.50$ ton-m.

$P_{CV} = 73.00$ ton  $M_{CV} = 22.50$ ton-m.

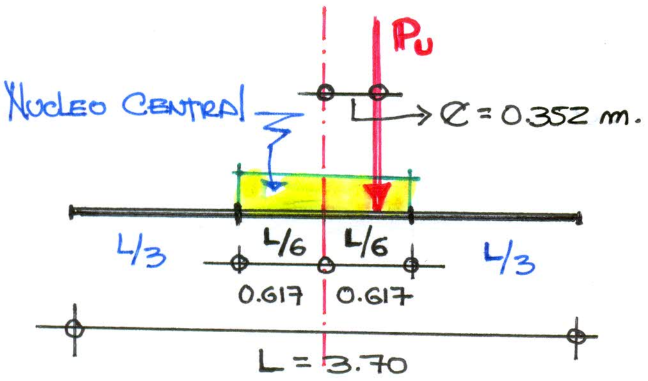
$$P_U = 1.70\,P_{CV} + 1.40\,P_{CM} = 1.70(73.00) + 1.40(92.50) \Rightarrow 253.60 \text{ ton}$$

$$M_U = 1.70\,M_{CV} + 1.40\,M_{CM} = 1.70(22.50) + 1.40(36.50) \Rightarrow 89.35 \text{ ton-m.}$$

$$M = F * d \Rightarrow M_U = P_U * e \Rightarrow e = \frac{M_U}{P_U} = \frac{89.35}{253.60} \Rightarrow e = 0.352 \text{ m.}$$

$$\frac{L}{6} = \frac{3.70}{6} \Rightarrow \frac{L}{6} = 0.617 \text{ m} \qquad \therefore e = 0.352 < \frac{L}{6} = 0.617$$

PRESIÓN DE CONTACTO FORMA TRAPEZOIDAL



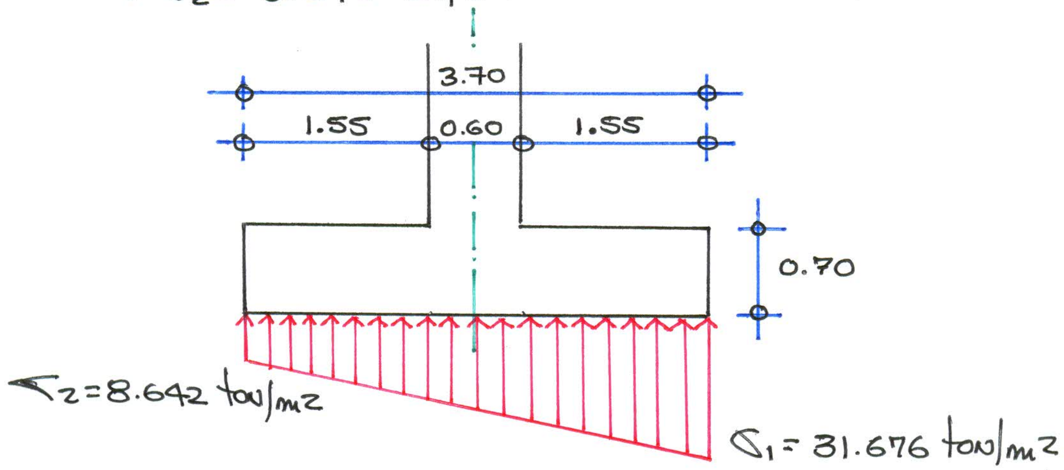

## PRESIONES PARA EL DISEÑO (METODO DE RESISTENCIA ULTIMA)

$$\sigma_{1,2} = \frac{P_U}{A} \pm \frac{M_U * c}{I}$$

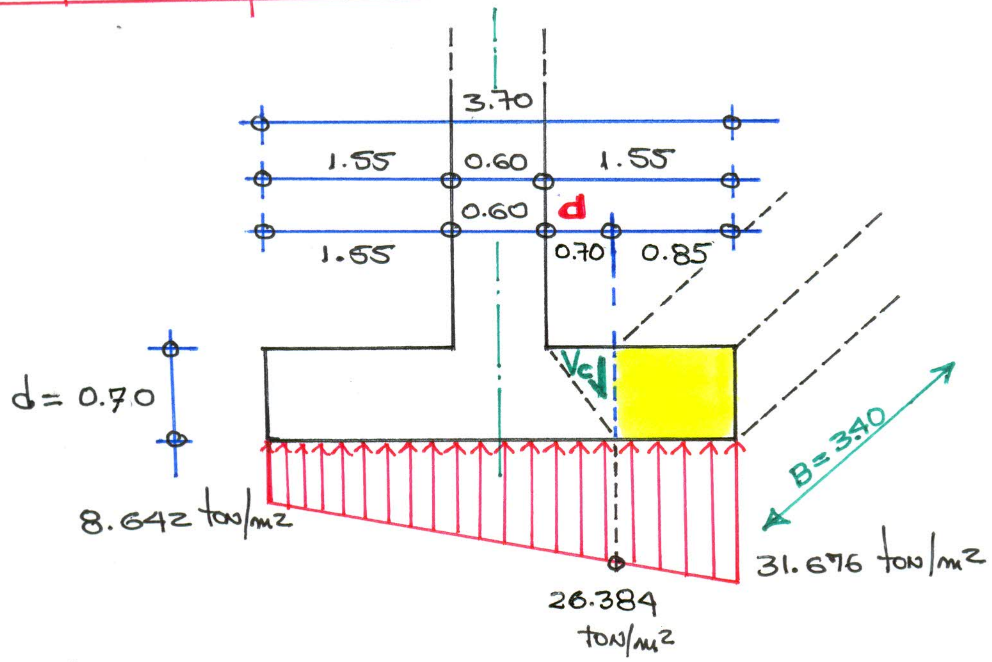
$P_U = 253.60$ ton
$M_U = 89.35$ ton-m.
$L = 3.70$ m
$B = 3.40$ m.
$A = 12.58$ m2
$c = 1.85$ m
$I = 14.352$ m4

$$\sigma_{1,2} = \frac{253.60}{12.58} \pm \frac{89.35(1.85)}{14.352}$$

$$\sigma_{1,2} = \begin{cases} \sigma_1 = 31.676 \text{ ton/m}^2 \\ \sigma_2 = 8.642 \text{ ton/m}^2 \end{cases}$$



# VERIFICACION POR CORTANTE




$$V_u \leq \phi V_c$$

Fuerza cortante ultima ↕ — ↕ Resistencia del concreto @ corte

$$V_u = \left[\frac{(31.676 + 26.384)\,0.85}{2}\right] * 3.40$$

$$V_u = 83.897 \text{ ton} = 83896.700 \text{ Kg}$$

$$\phi V_c = \phi\, 0.53 \sqrt{f'c}\; B.d$$

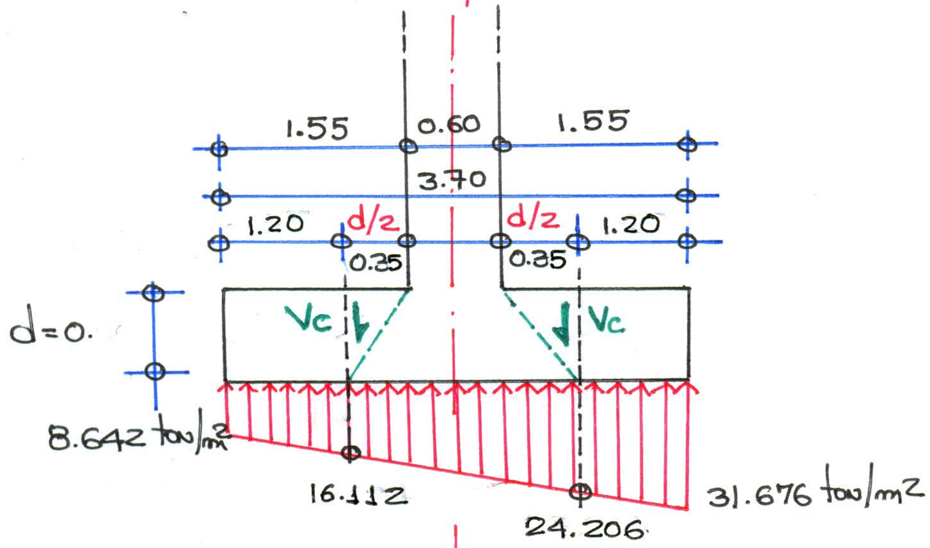
$$\phi V_c = 0.85 * 0.53 \sqrt{210} * 340 * 70$$

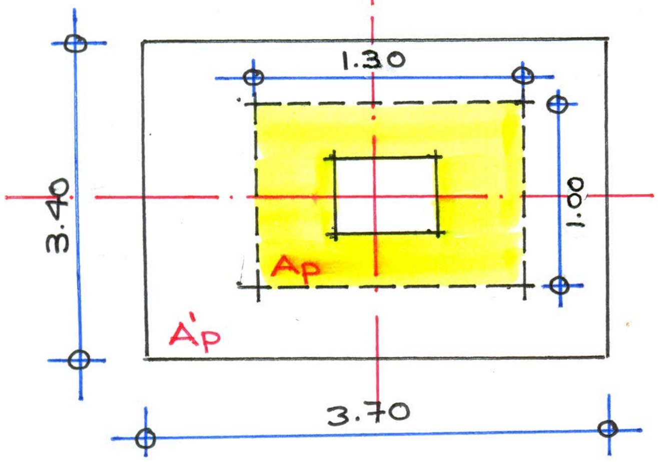
$$\phi V_c = 155.375 \text{ ton} = 155375.092 \text{ Kg}$$

$$\therefore V_u = 83.897 \text{ ton} < \phi V_c = 155.375 \text{ ton}$$

CONFORME

# VERIFICACIÓN POR PUNZONAMIENTO




PERIMETRO DE PUNZONAMIENTO

$b_o = 2(130)+2(100) \Rightarrow b_o = 460\ cm$

RELACION LADOS DE COLUMNA

$\beta_o = \dfrac{\text{LADO MAYOR COL.}}{\text{LADO MENOR COL.}}$

$\beta_o = \dfrac{0.60}{0.30} \Rightarrow \beta_o = 2$

$A'_p = A_z - A_p$

$A'_p = (370 * 340) - (130 * 100)$

$A'_p = 112800.000\ cm^2$

$V_u \leq \phi V_c$

Fuerza Cortante Ultima ↑ ↑ Resistencia del Concreto @ corte Punzonamiento

$V_u = q_u A'_p$

$\phi V_c = \phi \left(0.53 + \dfrac{1.10}{\beta_o}\right)\sqrt{f'c}\ b_o d$

$V_u = \left[\dfrac{(31.676+8.642)}{2} 3.70 (3.40)\right] - \left[\dfrac{(24.206+16.112)}{2} 1.30 (1.00)\right]$

$V_u = 227.394\ ton = 227393.520\ Kg$

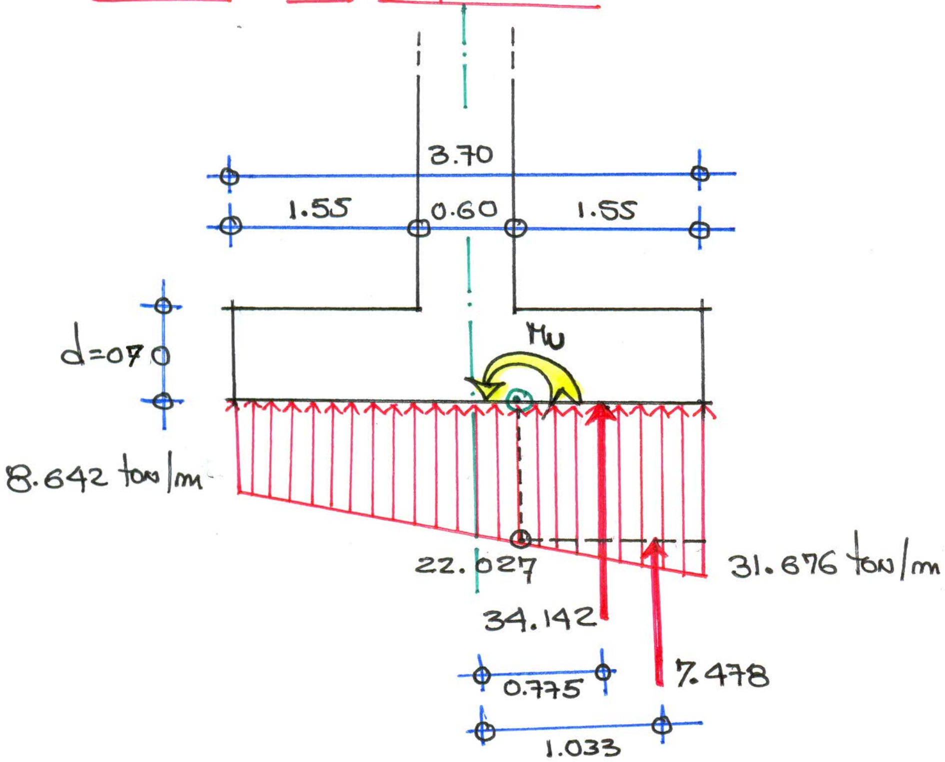
$\phi V_c = 0.85\left(0.53 + \dfrac{1.10}{2}\right)\sqrt{210} * 4\ \ 0 * 70$

$\phi V_c = 428.359\ ton = 428.359.300\ Kg.$

$V_u = 227.394\ ton < \phi V_c = 428.359\ ton$

CONFORME

# DISEÑO DE REFUERZO:




$$M_u = 34.142(0.775) + 7.478(1.033) \Rightarrow M_u = 34.185 \text{ ton-m}$$

# DISEÑO DE REFUERZO LONGITUDINAL

DATOS DE DISEÑO:

$M_u = 34.185$ ton-m, $b = 100$ cm. $d = 70$ cm. $f'c = 210$ kg/cm², $f_y = 4200$ kg/cm²

$$a = \frac{A_s f_y}{0.85 f'c\, b} \qquad M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\rho_{min} = \frac{0.70\sqrt{f'c}}{f_y} \Rightarrow \rho_{min} = 0.00242 \Rightarrow A_{smin} = \rho_{min}\, b d \Rightarrow A_{smin} = 16.906 \text{ cm}^2$$

$$\rho_b = 0.85\beta_1 \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right) \Rightarrow \rho_b = 0.02125 \Rightarrow A_{sb} = \rho_b b d \Rightarrow A_{sb} = 148.75 \text{ cm}^2$$

$$\rho_{max} = 0.75\rho_b \Rightarrow \rho_{max} = 0.01594 \Rightarrow A_{smax} = \rho_{max} b d \Rightarrow A_{smax} = 111.563 \text{ cm}^2$$

$$\rho_b = \omega \frac{f'c}{f_y} \Rightarrow \rho_d = 0.00189 \Rightarrow A_{sd} = \rho_d b d \Rightarrow A_{sd} = 13.214 \text{ cm}^2$$

$A_s\ \phi 3/4 = 2.84$ cm²  $d_b\ \phi 3/4 = 1.905$ cm. $= 0.01905$ m.

$$A_{sd} < A_{smin} \Rightarrow A_{sd} = A_{smin} = 16.906 \text{ cm}^2$$

**NUMERO DE VARILLAS**

$A_{std} = A_{sd}\,(3.40) \Rightarrow A_{std} = 57.480\ cm^2$

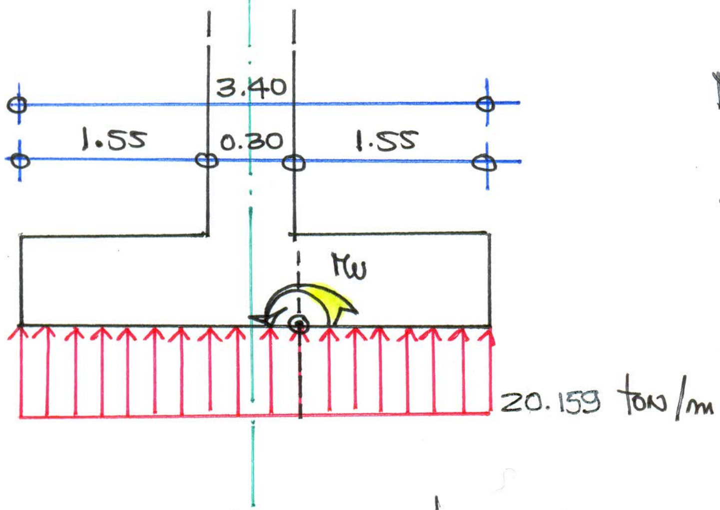
$N = \frac{A_{std}}{A_{s\phi}} \Rightarrow N = \frac{57.480}{2.84} \Rightarrow N = 20.24 \Rightarrow N = 20$ UNIDADES.

**DISTRIBUCION DE ACERO :**

$S = \frac{B - 2r - \phi - 0.10}{N-1} \Rightarrow S = \frac{3.40 - 2(0.075) - 0.01905 - 0.10}{1} \Rightarrow S = 0.165\ m$

∴ Acero longitudinal : $20\phi 3/4$ @ 0.165 m.

**DISEÑO DE ACERO TRANSVERSAL :**




$M_u = \frac{q L^2}{2} = \frac{20.159\,(1.55)^2}{2}$

$M_u = 24.216$ ton-m

**Datos de Diseño :** $M_u = 24.216$ ton-m, $b = 100$ cm. $d = 70$ cm. $f'c = 210\ kg/cm^2$ $f_y = 4200\ kg/cm^2$

$\rho_{min} = \frac{0.70\sqrt{f'c}}{f_y} \Rightarrow \rho_{min} = 0.00242 \Rightarrow A_{smin} = \rho_{min}\, b d \Rightarrow A_{smin} = 16.90\ cm^2$

$\rho_b = 0.85\beta_1 \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right)$ $\rho_b = 0.02125 \Rightarrow A_{sb} = \rho_b\, b d \Rightarrow A_{sb} = 148.75\ cm^2$

$\rho_{max} = 0.75\,\rho_b$ $\rho_{max} = 0.01594 \Rightarrow A_{smax} = \rho_{max}\, b d \Rightarrow A_{smax} = 111.56\ cm^2$

$\rho_d = \omega \frac{f'c}{f_y}$ $\rho_d = 0.00 \Rightarrow A_{sd} = \rho_d\, b d \Rightarrow A_{sd} = 7.719\ cm^2$

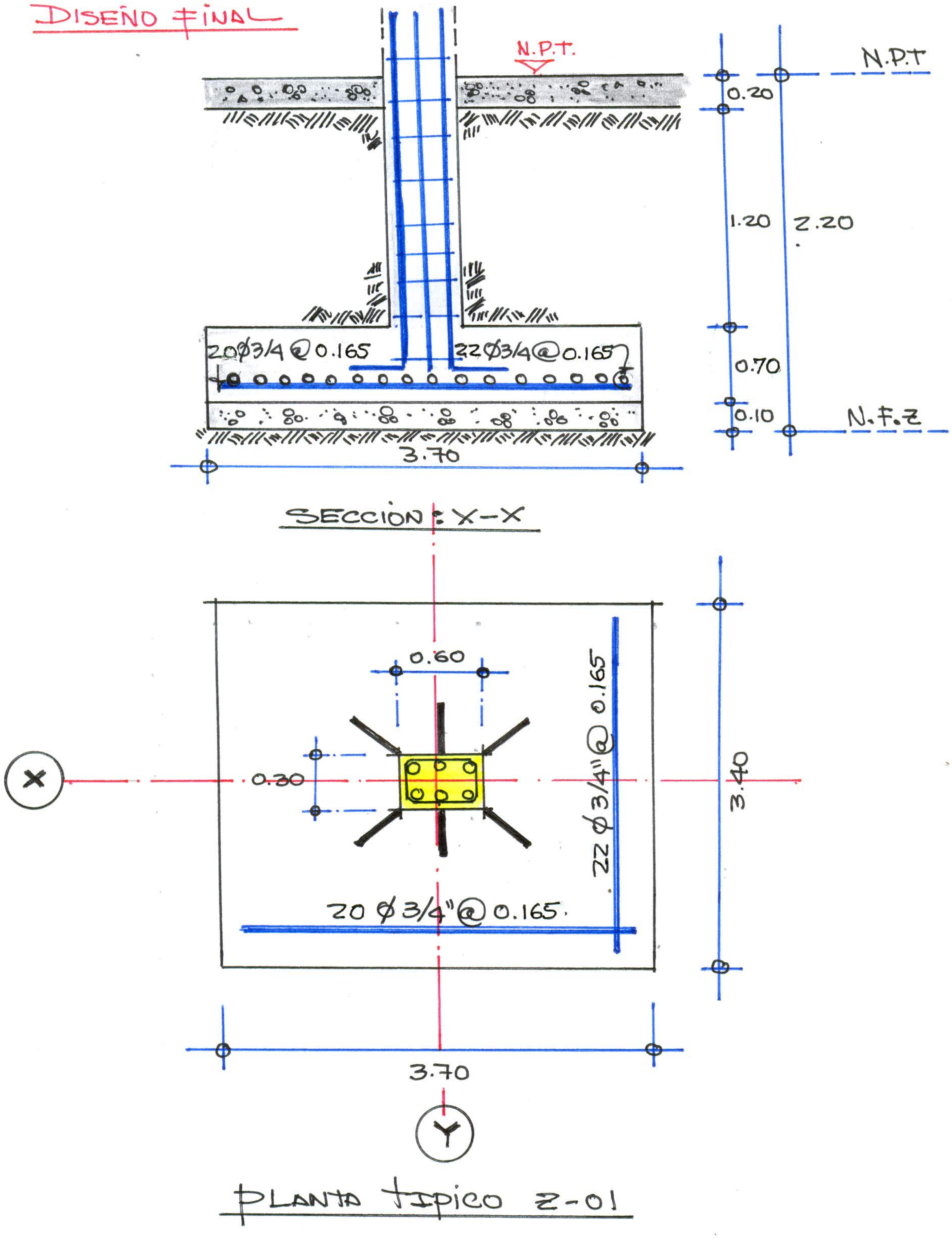
$A_{sd} < A_{smin} \Rightarrow A_{sd} = 16.90\ cm^2 \Rightarrow A_{std} = A_{sd}\,(L) \Rightarrow A_{std} = 62.55\ cm^2$

$N = \frac{A_{std}}{A_{s\phi}} \Rightarrow N = \frac{62.55}{2.84} \Rightarrow N = 22.027$ UNIDADES $\Rightarrow N = 22$ UNIDADES.

$S = \frac{L - 2r - \phi - 0.10}{N-1} \Rightarrow \frac{3.70 - 0.15 - 0.01905 - 0.10}{21} \Rightarrow S = 0.16\ m.$

∴ Acero transversal : $22\phi 3/4''$ @ 0.16 m

DISEÑO FINAL




DETALLE FINAL DE ZAPATA

# PROBLEMA Nº 04

DISEÑAR UNA ZAPATA AISLADA CON LAS SIGUENTES CONSIDERACIONES TECNICAS Y ESTRUCTURALES.

$P_{CM} = 125$ ton  $M_{CMx} = 2.75$ ton-m  $M_{CMy} = 2.45$ ton-m

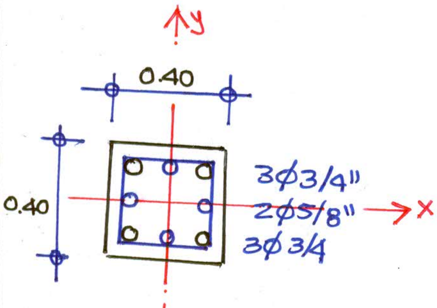
$P_{CV} = 65$ ton  $M_{CVx} = 1.65$ ton-m  $M_{CVy} = 1.25$ ton-m

$P_{CS} = \emptyset$ ton  $M_{CSx} = 4.15$ ton-m  $M_{CSy} = 6.55$ ton-m.

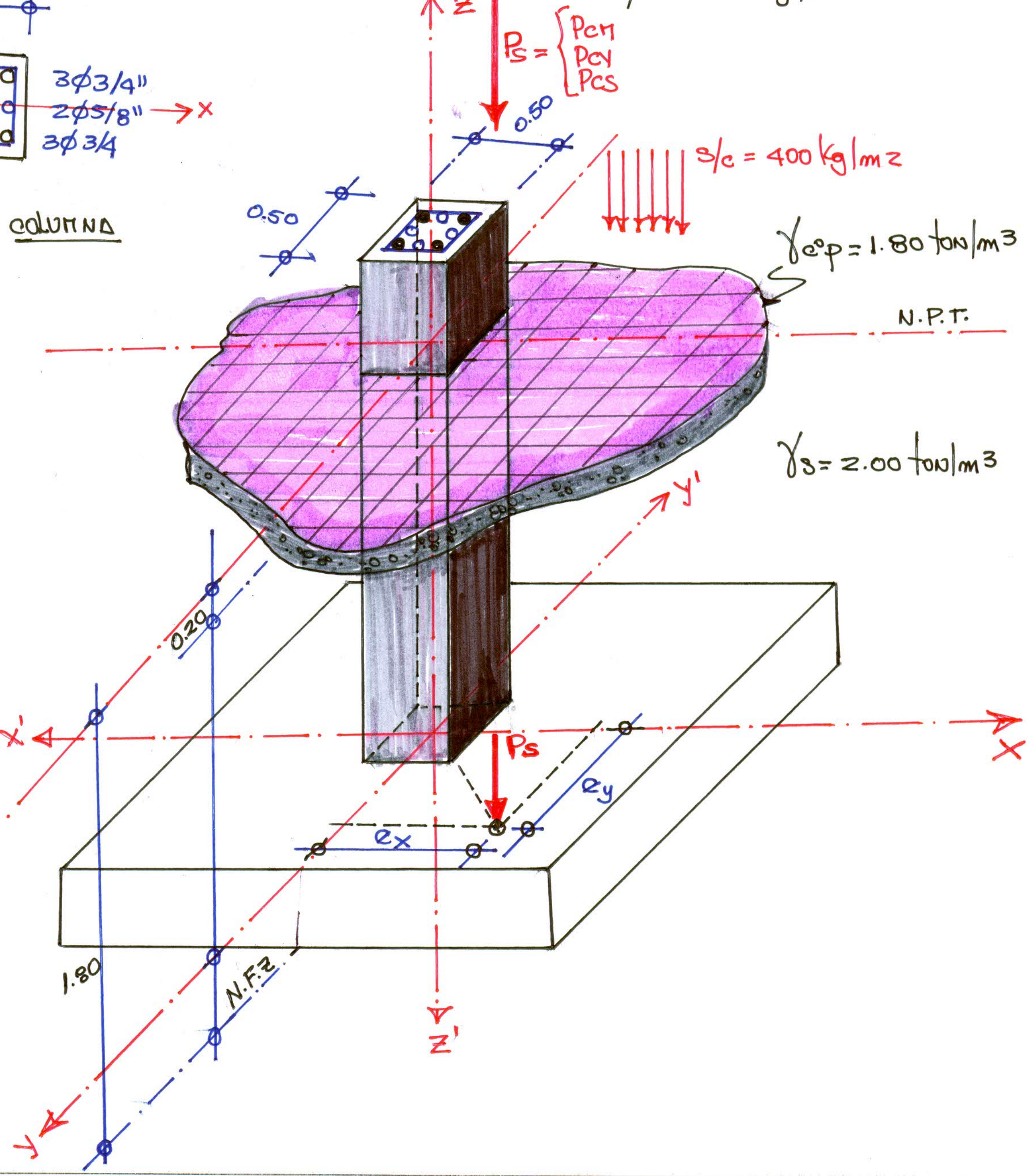
$\sigma_t = 2.50$ kg/cm2  $f'c = 210$ kg/cm²  $\gamma_s = 2.00$ ton/m3

$f'y = 4200$ kg/cm²  $\gamma_{cºp} = 1.80$ ton/m3

$S/c = 400$ kg/m2




SECCIÓN COLUMNA



# A: DIMENSIONAMIENTO DE LA ZAPATA

## PERALTE DE LA ZAPATA

CONSIDERACIONES NORMATIVAS

: As col: 6Ø3/4" + 4Ø5/8 ⇒ Ø3/4 { db = 1.905 cm. ; Ab = 2.84 cm4 }

$$ld = 0.08\, db\, fy/\sqrt{f'c} = 44.170$$
$$ld = 0.004\, db\, fy = 32.004$$
$$ld \geq 20\ cm. = 20.00$$

} ld = 44.17 cm. ⇒ ld = 45 cm.

∴ d = ld + 10 cm ⇒ d = 55.00 cm.   h = d + 10 cm ⇒ h = 65.00 cm.

## CAPACIDAD PORTANTE NETA DEL TERRENO ($q_e$)

$$q_e = \sigma_t - (\gamma_{c^\circ z} * h_z) - (\gamma_s * h_s) - (\gamma_{c^\circ p} * h_p) - s/c$$
$$= 25.00 - (2.40*0.65) - (2.00*0.95) - (1.80*0.20) - 0.40$$

$$q_e = 20.78\ ton/m^2 = 2.078\ kg/cm^2$$

## AREA DE LA ZAPATA

$$A = \frac{P_T}{q_e} \Rightarrow A = \frac{P_{cm} + P_{cv} + P_{cs}}{q_e} \Rightarrow A = \frac{125+65+\emptyset}{20.78} \Rightarrow A = 9.143\ m^2$$

∴ Columna F/cuadra ⇒ Zapata cuadrada $B = \sqrt{A} \Rightarrow B = 3.024\ m$

∴ $B_x = 3.00$, $B_y = 3.00$

$A = 9.00\ m^2$

# VERIFICACION DE PRESIONES: $\sigma_{max} < \sigma_t$

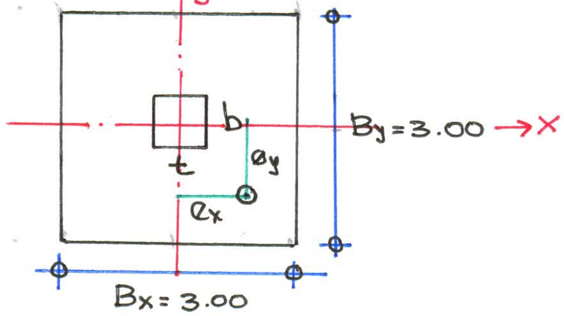
## A-1: ANALISIS ESTATICO

### CARGAS DE SERVICIO:

$$P_s = P_{cm} + P_{cv} \Rightarrow P_s = 125 + 65 \Rightarrow P_s = 190.00\ ton.$$

### MOMENTOS DE SERVICIO:

$$M_x = M_{cmx} + M_{cvx} \Rightarrow M_x = 2.75 + 1.65 \Rightarrow M_x = 4.40\ ton\text{-}m.$$
$$M_y = M_{cmy} + M_{cvy} \Rightarrow M_y = 2.45 + 1.25 \Rightarrow M_y = 3.70\ ton\text{-}m.$$



## DIRECCION : X–X

$$\frac{B_x}{6} = \frac{3.00}{6} \Rightarrow \frac{B_x}{6} = 0.50\ m.$$

$$e_x = \frac{M_x}{P_s} \Rightarrow e_x = \frac{4.40}{190} \Rightarrow e_x = 0.023\ m.$$

$$\Rightarrow \frac{B_x}{6} < e_x \Rightarrow$$ PRESION DE CONTACTO FORMA TRAPEZOIDAL

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_x c}{I}$$

$P_s = 190.00$ ton  
$A = 9.00\ m^2$  
$M_x = 4.40$ ton.m  
$B = 3.00$ m.  
$c = \frac{B_x}{2} \Rightarrow c = 1.50$ m  
$I = \frac{b_y\, b_x^3}{12} \Rightarrow I = 6.75\ m^4$

$$\sigma_{max} = \frac{190}{9.00} + \frac{4.40(1.50)}{6.75} \Rightarrow \sigma_{max} = 22.089\ ton/m^2 < \sigma_t = 25\ ton/m^2$$

(CONFORME.)

## DIRECCIÓN : Y–Y

$M_y = 3.70$ ton-m

$$\frac{B_y}{6} = \frac{3.00}{6} \Rightarrow \frac{B_y}{6} = 0.50\ m.$$

$$e_y = \frac{M_y}{P_s} \Rightarrow e_y = \frac{3.70}{190} \Rightarrow e_y = 0.019\ m$$

$$\Rightarrow \frac{B_y}{6} < e_y \Rightarrow$$ PRESION DE CONTACTO FORMA TRAPEZOIDAL

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_y c}{I}$$

$$\sigma_{max} = \frac{190}{9.00} + \frac{3.70(1.50)}{6.75} \Rightarrow \sigma_{max} = 21.933\ ton/m^2 < \sigma_t = 25\ ton/m^2$$

(CONFORME)

## A.2 : ANALISIS SISMICO

- CARGAS DE SERVICIO

$$P_s = P_{cm} + P_{cv} + P_{cs} \Rightarrow P_s = 125 + 65 + \emptyset \Rightarrow P_s = 190\ ton.$$

- MOMENTOS DE SERVICIO

$$M_{sx} = M_{cmx} + M_{cvx} + M_{csx} \Rightarrow M_x = 2.75 + 1.65 + 4.15 \Rightarrow M_x = 8.55\ ton\text{-}m$$

$$M_y = M_{cmy} + M_{cvy} + M_{csy} \Rightarrow M_y = 2.45 + 1.25 + 6.55 \Rightarrow M_y = 10.25\ ton\text{-}m.$$

## DIRECCION : X–X

$$e_x = \frac{M_x}{P_s} \Rightarrow e_x = \frac{8.55}{190} \Rightarrow e_x = 0.045 \quad \frac{B_x}{6} = 0.50$$

PRESION DE CONTACTO FORMA TRAPEZOIDAL

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_x c}{I} \Rightarrow \sigma_{max} = \frac{190}{9.00} + \frac{8.55(1.50)}{6.75} \Rightarrow \sigma_{max} = 23.011\ ton/m^2 < \sigma_t$$

(CONFORME)

## Dirección : y-y

$e_y = \frac{M_y}{P_s} \Rightarrow e_y = \frac{10.25}{190.00} \Rightarrow e_y = 0.054 < \frac{L}{6}$ Presión de contacto forma trapezoidal

$\sigma_{max} = \frac{P_s}{A} + \frac{M_y(c)}{I}$

$\sigma_{max} = \frac{190}{9.00} + \frac{10.25(1.50)}{6.75} \Rightarrow \sigma_{max} = 23.389\ ton/m^2 < \sigma_q = 25\ ton/m^2$ (Conforme)

## Cargas de diseño : ($P_u$, $M_u$)

## Reacción amplificada del suelo :

## Analisis estatico :

$P_u = 1.40\,P_{cm} + 1.70\,P_{cv} \Rightarrow P_u = 1.40(125) + 1.70(65) \Rightarrow P_u = 285.50\ ton.$

$M_{ux} = 1.40\,M_{cmx} + 1.70\,M_{cvx} \Rightarrow M_{ux} = 1.40(2.75) + 1.70(1.65) \Rightarrow M_{ux} = 6.655\ ton\text{-}m$

$M_{uy} = 1.40\,M_{cmy} + 1.70\,M_{cvy} \Rightarrow M_{uy} = 1.40(2.45) + 1.70(1.25) \Rightarrow M_{uy} = 5.555\ ton\text{-}m$

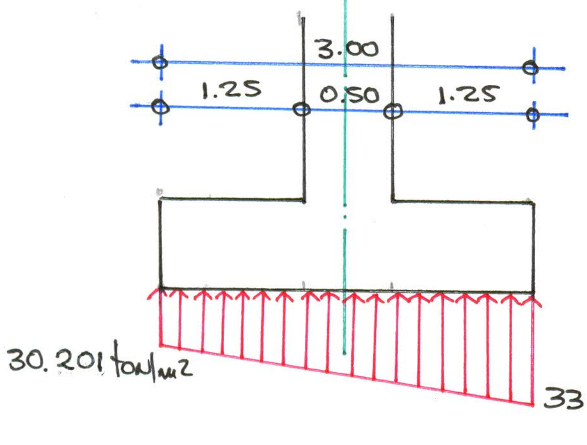
$\frac{B_x}{6} = \frac{B_y}{6} = 0.50$

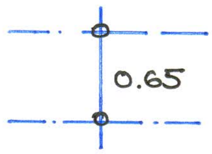
## Dirección : x-x

$e_x = \frac{M_{ux}}{P_u} \Rightarrow e_x = \frac{6.655}{285.50} \Rightarrow e_x = 0.023 < \frac{B_x}{6}$ (Conforme)

$\sigma_x(1,2) = \frac{P_u}{A} \pm \frac{M_{ux}(c)}{I} = \frac{285}{9.00} + \frac{6.655(1.50)}{6.75}$

$\sigma_x(1,2)$: $\sigma_{x1} = 33.201\ ton/m^2$; $\sigma_{x2} = 30.243\ ton/m^2$



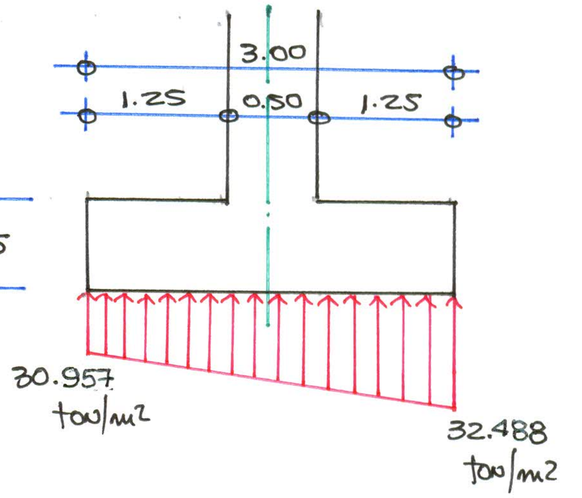




## Dirección : y-y

$e_y = \frac{M_{uy}}{P_u} = \frac{5.555}{285.5} \Rightarrow e_y = 0.019 < \frac{B_y}{6}$ (Conforme)

$\sigma_y(1,2) = \frac{P_u}{A} \pm \frac{M_{uy}(c)}{I} = \frac{285}{9.00} \pm \frac{5.555(1.50)}{6.75}$

$\sigma_y(1,2)$: $\sigma_{x1} = 32.957\ ton/m^2$; $\sigma_{x2} = 30.488\ ton/m^2$



# Análisis Sísmico :

$P_{CM} = 125$ ton $\qquad M_{CMx} = 2.75$ ton-m $\qquad M_{CMy} = 2.45$ ton-m

$P_{CV} = 65$ ton $\qquad M_{CVx} = 1.65$ ton-m $\qquad M_{CVy} = 1.25$ ton-m

$P_{CS} = \varnothing$ $\qquad M_{CSx} = 4.65$ ton-m $\qquad M_{CSy} = 6.55$ ton-m

## Combinaciones de carga:

$$U = 1.25(CM + CV) \pm CS$$
$$U = 0.90\,CM \pm CS$$

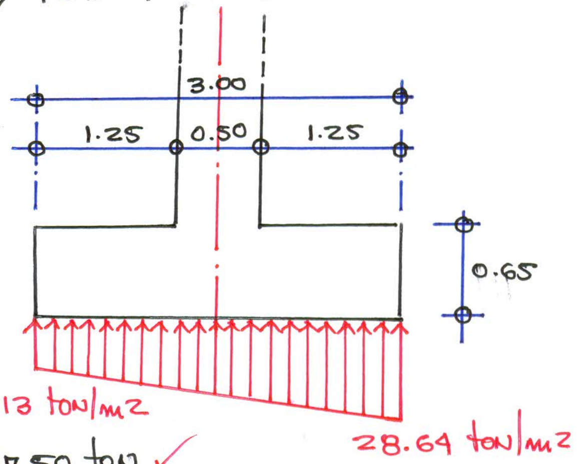
## Dirección : X-X

$$P_U: \begin{cases} P_U = 1.25(125+65)+0 \Rightarrow P_U = 237.50 \text{ ton} \checkmark \\ P_U = 0.90(125)+0 \Rightarrow P_U = 112.50 \text{ ton} \end{cases}$$

$$M_{Ux}: \begin{cases} M_{Ux} = 1.25(2.75+1.65)+4.65 \Rightarrow M_{Ux} = 10.15 \text{ ton-m} \checkmark \\ M_{Ux} = 0.90(2.75)+4.65 \Rightarrow M_{Ux} = 7.125 \text{ ton-m} \end{cases}$$

$$\sigma_{x1,2} = \frac{P_U}{A} \pm \frac{M_{Ux}\,c}{I}$$

$$\sigma_{x1,2} \rightarrow \begin{cases} \sigma_{x1} = 28.64 \text{ ton/m}^2 \\ \sigma_{x2} = 24.13 \text{ ton/m}^2 \end{cases}$$



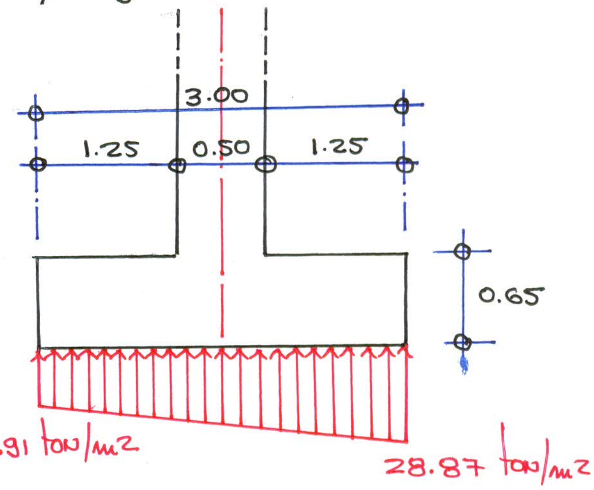

## Dirección : Y-Y

$$P_U = \begin{cases} P_U = 1.25(125+65)+0 \Rightarrow P_U = 237.50 \text{ ton} \checkmark \\ P_U = 0.90(1.25)+0 \Rightarrow P_U = 112.50 \text{ ton} \end{cases}$$

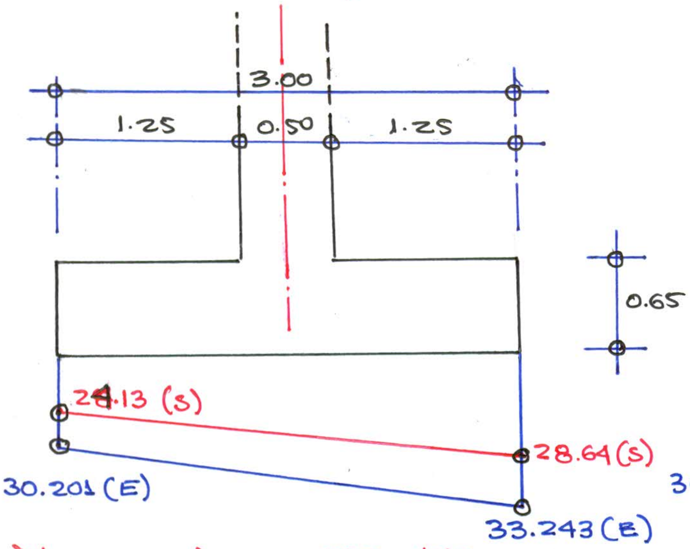
$$M_{Uy} = \begin{cases} M_{Uy} = 1.25(2.45+1.25)+6.55 \Rightarrow M_{Uy} = 11.175 \text{ ton-m} \checkmark \\ M_{Uy} = 0.90(2.45)+6.55 \Rightarrow M_{Uy} = 8.755 \text{ ton-m} \end{cases}$$

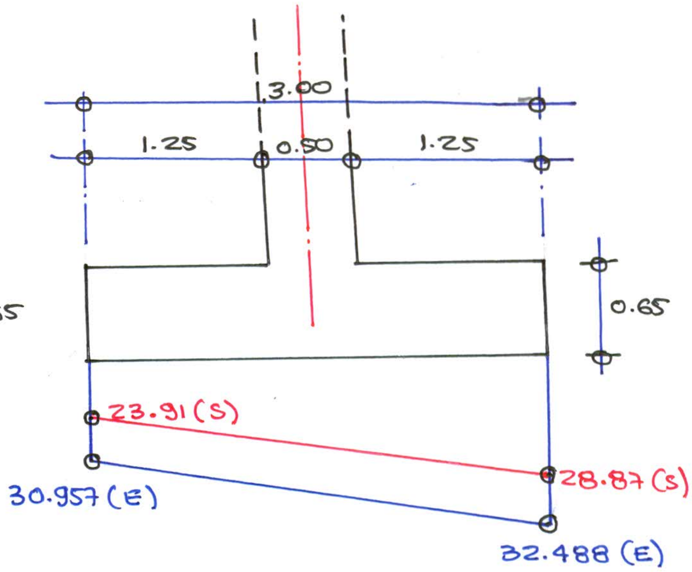
$$\sigma_{y1,2} = \frac{P_U}{A} \pm \frac{M_{Uy}\,c}{I}$$

$$\sigma_{y1,2} = \begin{cases} \sigma_{y1} = 28.87 \text{ ton/m}^2 \\ \sigma_{y2} = 23.91 \text{ ton/m}^2 \end{cases}$$



# RESUMEN DE PRESIONES (ESTATICO - SISMICO)

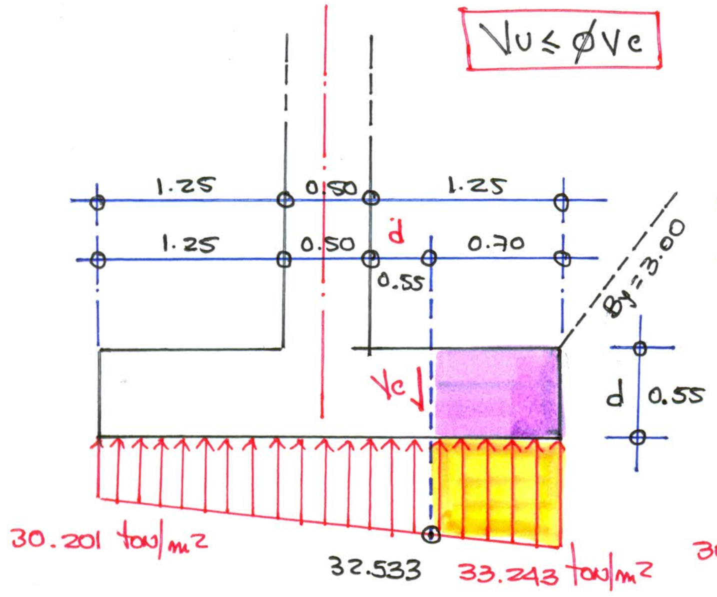


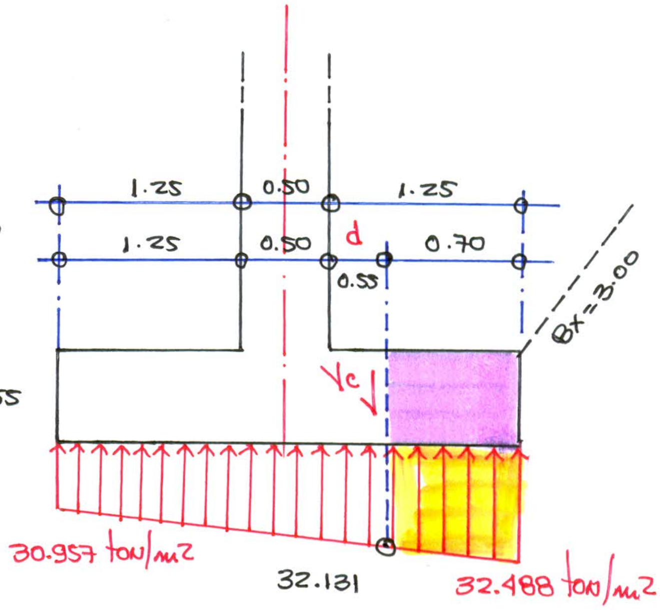

## VERIFICACION CORTE - FLEXION

**$V_u \leq \phi V_c$**

### DIRECCION : X-X




### DIRECCION : Y-Y




**Dirección X-X:**

$$V_u = \left[\frac{(33.243 + 32.533)0.70}{2}\right]3.00$$

$V_u = 69.065$ ton $= 69064.800$ kg

$\phi V_c = \phi\, 0.53 \sqrt{f'c}\; B_y\, d$

$\phi V_c = 0.85 * 0.53 * \sqrt{210} * 300 * 55$

$\phi V_c = 107.718$ ton $= 107\,718.00$ kg

CONFORME : $V_u < \phi V_c$

**Dirección Y-Y:**

$$V_u = \left[\frac{(32.488 + 32.131)0.70}{2}\right]3.00$$

$V_u = 67.850$ ton $= 67849.95$ kg.

$\phi V_c = \phi\, 0.53 \sqrt{f'c}\; B_x\, d$

$\phi V_c = 0.85 * 0.53 * \sqrt{210}\; 300 * 55$

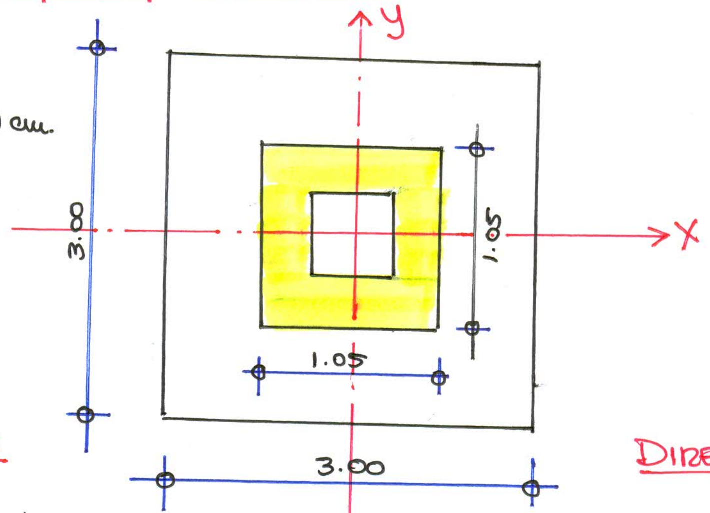
$\phi V_c = 107.718$ ton $= 107\,718.00$ kg

CONFORME : $V_u < \phi V_c$

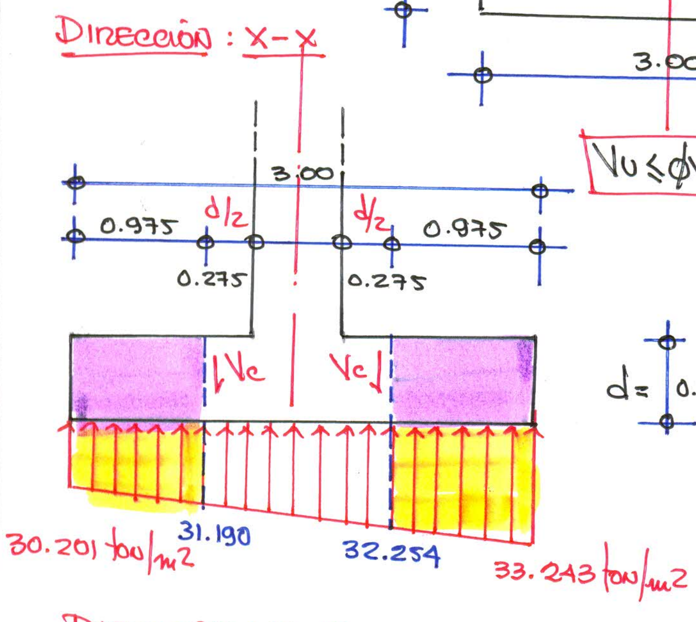
# Verificación por punzonamiento:

$b_o = 4(1.05) \Rightarrow b = 420$ cm.

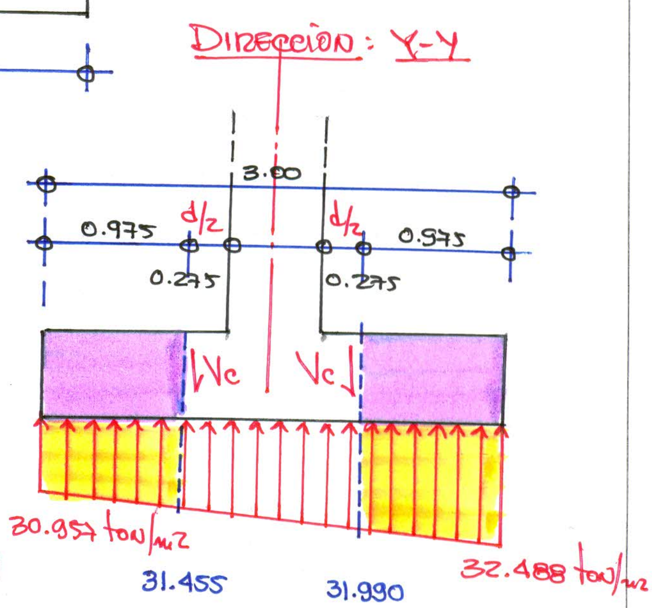
$\beta_o = \frac{0.50}{0.50} \Rightarrow \beta_o = 1$




$Vu \leq \phi Vc$




d = 0.55




## Dirección : X-X

$$Vu_x = \left[\frac{(33.243 + 30.201)}{2} 3.00\right] 3.00 - \left[\frac{(32.254 + 31.190)}{2} 1.05\right] 1.05$$

$$Vu = 250.524 \text{ ton} = 250\,524.495 \text{ Kg.}$$

$$\phi Vc = \phi\left(0.53 + \frac{1.10}{\beta o}\right)\sqrt{f'c}\, b_o\, d$$

$$\phi Vc = 0.85\left(0.53 + \frac{1.10}{1}\right)\sqrt{210}\; 420 * 55 \Rightarrow \phi Vc = 463.797 \text{ ton} = 463\,797.237 \text{ Kg}$$

## Dirección : Y-Y

$$Vu = \left[\frac{(32.488 + 30.957)}{2} 3.00\right] 3.00 - \left[\frac{(31.99 + 31.455)}{2} 1.05\right] 1.05$$

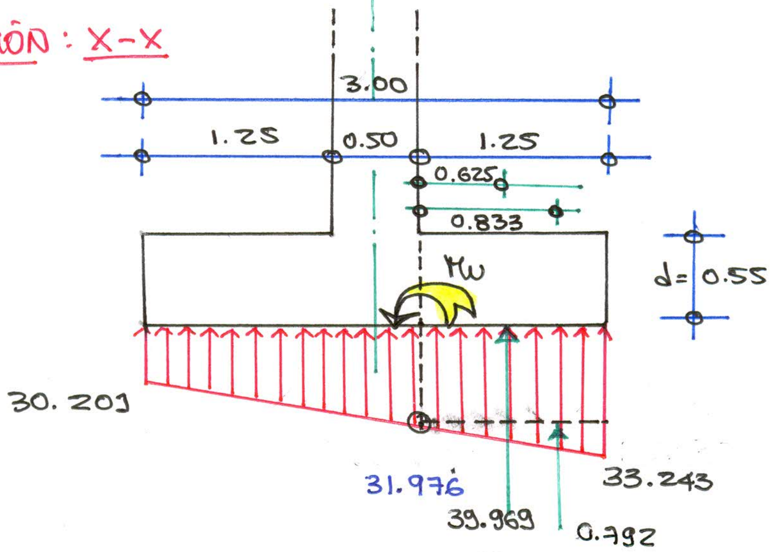
$$Vu_y = 250.528 \text{ ton} = 250\,528.444 \text{ Kg}$$

$\therefore Vu_x, Vu_y < \phi Vc \Rightarrow$ Conforme

## DISEÑO DE REFUERZO POR FLEXIÓN

$f'c = 210\ kg/cm^2$
$fy = 4200\ kg/cm^2$

### DIRECCIÓN : X-X




$Mu = 39.969\ (0.625) + 0.792\ (0.833) \Rightarrow Mu = 25.640\ ton\text{-}m$

DATOS DE DISEÑO: $Mu = 26.135\ ton\text{-}m.$ $b = 100\ cm.$ $d = 55\ cm,$ $f'c = 210\ kg/cm^2,$ $fy = 4200\ kg/cm^2$

$a = \frac{As\, fy}{0.85\, f'c\, b}$ $\qquad Mu = \phi\, As\, fy\, (d - a/2)$

$\rho_{min} = 0.70 \sqrt{f'c}/fy \Rightarrow \rho_{min} = 0.00242 \Rightarrow As = \rho_{min}\, bd \Rightarrow As_{min} = 13.284\ cm^2$

$\rho_b = 0.85\, \beta\, \frac{f'c}{fy} \left(\frac{6000}{6000 + fy}\right) \Rightarrow \rho_b = 0.02125 \Rightarrow As_b = \rho_b\, bd \Rightarrow As_b = 116.875$

$\rho_{MAX} = 0.50\, \rho_b \Rightarrow \rho_{max} = 0.01063 \Rightarrow As_{max} = \rho_{max}\, bd \Rightarrow As_{max} = 58.465$

$\rho_d = \frac{\omega\, f'c}{fy} \Rightarrow \rho_d = 0.00231 \Rightarrow As_d = \rho_d\, bd \Rightarrow As_d = 12.677\ cm^2$

$As\ \phi 5/8''$: $db\ \phi 5/8 = 1.588\ cm \Rightarrow \phi 5/8 = 2.00\ cm^2$
$0.016\ m.$

\# DE VARILLAS: $Astd = Asd * By = 13.284\ (3.00) \Rightarrow Astd = 39.852\ cm^2$

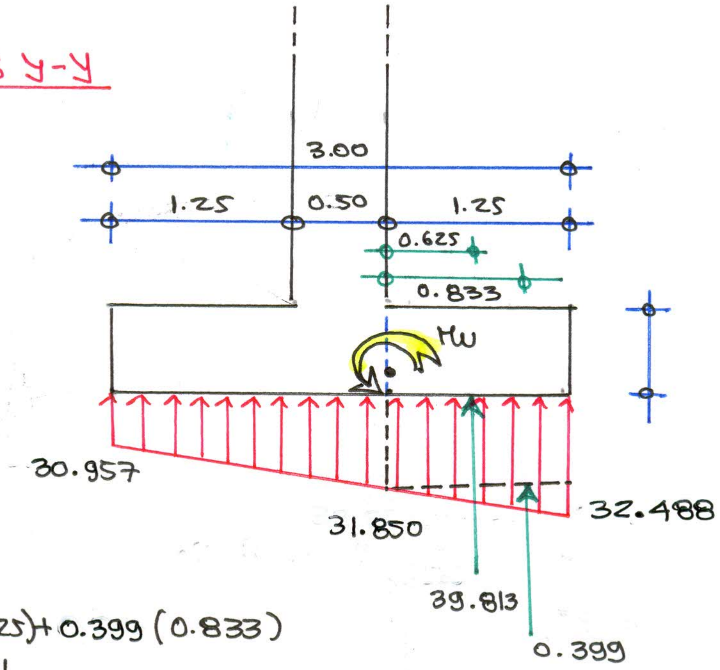
$N = \frac{Astd}{A\phi} \Rightarrow N = \frac{39.852}{2.00} \Rightarrow N = 20$ UNIDADES.

### DISTRIBUCIÓN DE ACERO

$S = \frac{Bx - 2r - \phi - 0.10}{N - 1} \Rightarrow S = \frac{3.00 - 0.016 - 1.588 - 0.10}{19} \Rightarrow S = 144\ m \approx 0.15$

**19 ϕ5/8" @ 0.15**

## DIRECCION : Y-Y




$M_u = 39.813(0.625) + 0.399(0.833)$

$M_u = 25.215$ ton-m.

**DATOS:** $M_u = 26.37$ ton-m, $b = 100$ cm, $d = 55$ cm, $f'c = 210$ kg/cm², $f_y = 4200$ kg/cm²

$\rho_{min} = 0.70\sqrt{f'c}/f_y \Rightarrow \rho_{min} = 0.00242$ $\qquad As_{min} = 13.284$ cm²

$\rho_b = 0.85\beta_1 \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right) \Rightarrow \rho_b = 0.02125$ $\qquad As_b = 116.875$ cm²

$\rho_d = \omega \frac{f'c}{f_y} \Rightarrow \rho_d = 0.00227$ $\qquad As_d = 12.462$ cm²

$\rho_{max} = 0.50\rho_b \Rightarrow \rho_{max} = 0.01063$ $\qquad As_{max} = 58.4375$ cm²

$As_{\phi 5/8} = 2.00$ cm² $\quad d_b = 0.016$ cm.

**# VARILLAS:** $As_{td} = As_d(B_y) \Rightarrow As_{td} = (13.284)(3) \Rightarrow As_{td} = 39.852$ cm²

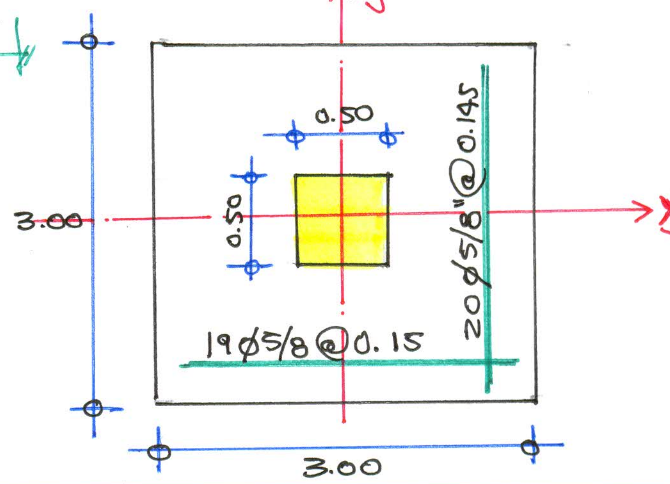
$N = \frac{As_{td}}{A_\phi} = \frac{39.852}{2.00} \Rightarrow N = 20$ varillas

**ESPACIAMIENTO DE ACEROS**

$s = \frac{B_x - 2r - \phi - 0.10}{N-1} = \frac{3.00 - 0.15 - 0.016 - 0.10}{19} \Rightarrow S = 0.145$ m.

∴ $20\phi 5/8'' @ 0.145$ ✓

DETALLE EN PLANTA



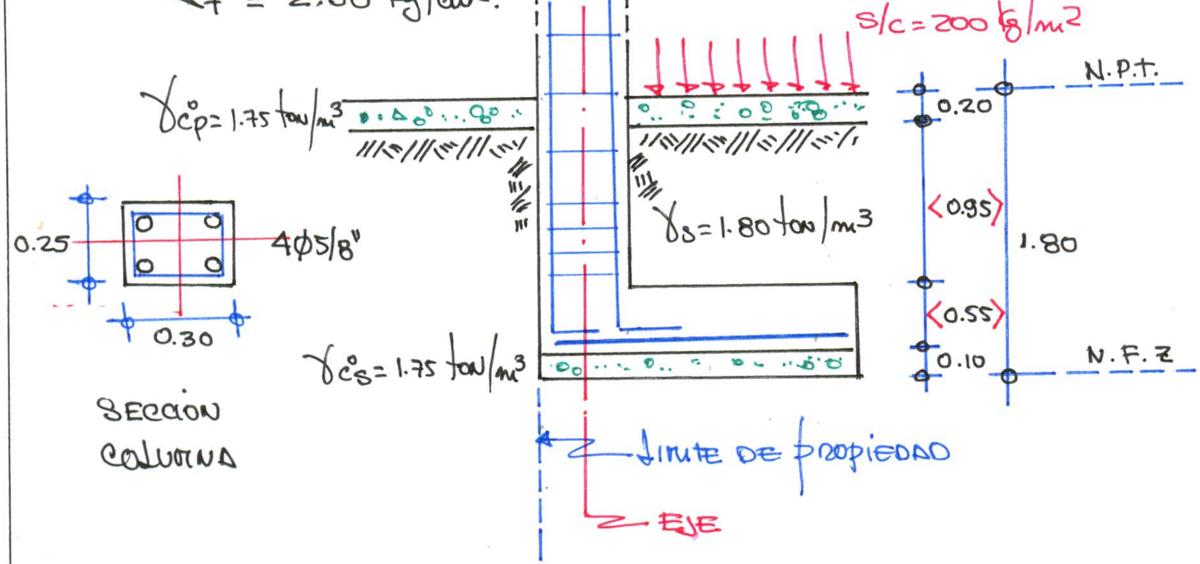
## PROBLEMA Nº 05:

DIMENSIONAR, VERIFICAR, DISEÑAR LA ZAPATA EXCENTRICA DE LA FIGURA ADJUNTA, PARA LAS SOLICITACIONES QUE SE INDICAN.

$P_{CM} = 32$ ton $\quad$ md: $M_{CM} = 6.00$ ton-m $\quad$ $f'c = 210$ kg/cm²

$P_{CV} = 12$ ton $\quad$ $M_{CV} = 4.00$ ton-m $\quad$ $f_y = 4200$ kg/cm²

$\sigma_t = 2.00$ kg/cm².




## DIMENSIONAMIENTO:

**- PERALTE:** $As_{col} = 4\phi 5/8" \Rightarrow \phi 5/8" \{ d_b = 1.588$ cm, $A_b = 2.00$ cm²

CONSIDERACION NORMATIVAS

$$ld = 0.08\, d_b\, f_y / \sqrt{f'c} \Rightarrow ld = 36.82 \text{ cm.} \qquad ld = 36.82 \text{ cm}$$

$$ld = 0.004\, d_b\, f_y \Rightarrow ld = 26.678 \text{ cm} \Rightarrow \quad ld = 35 \text{ cm.}$$

$$ld \geq 20 \text{ cm.} \Rightarrow ld = 20 \text{ cm.}$$

$$\therefore d = ld + 10\text{cm} \Rightarrow d = 45\text{cm} \Rightarrow h = d + 10\text{cm} \Rightarrow h = 55 \text{ cm.}$$

**- CAPACIDAD PORTANTE NETA DEL TERRENO ($q_e$)**

$$q_e = \sigma_t - (\gamma_{cs} * h_s) - (\gamma_{cz} * h_z) - (\gamma_s * h_s) - (\gamma_{cp} * h_p) - s/c$$

$$q_e = 20.00 - (1.75 * 0.10) - (2.40 * 0.55) - (1.80 * 0.95) - (1.75 * 0.20) - 0.20$$

$$q_e = 16.245 \text{ ton/m}^2 = 1.6245 \text{ kg/cm}^2$$

## SOLICITACIONES:

↳ CARGAS DE SERVICIO: $P_S = P_{CM} + P_{CV} \Rightarrow P_S = 32+12 \Rightarrow P_S = 44.00$ ton.
$M_S = M_{CM} + M_{CV} \Rightarrow M_S = 6+4 \Rightarrow M_S = 10.00$ ton-m.

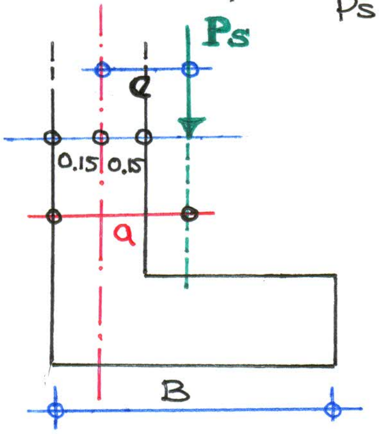
↳ CARGAS ULTIMAS: $P_U = 1.40 P_{CM} + 1.70 P_{CV} \Rightarrow P_U = 1.40(32)+1.70(12) \Rightarrow P_U = 65.20$ ton
$M_U = 1.40 M_{CM} + 1.70 M_{CV} \Rightarrow M_U = 1.40(6)+1.70(4) \Rightarrow M_U = 15.20$ ton-m.

## ZAPATAS SIN EXCENTRICIDAD

$$\boxed{A = \frac{P_S}{q_e}} \Rightarrow A = \frac{44.00}{1.625} \Rightarrow A = 2.709\ m^2$$

∴ TENDER ZAPATA EXCENTRICIDAD $A > 2.709\ m^2$

$$\text{EXCENTRICIDAD} \Rightarrow e = \frac{M_S}{P_S} \Rightarrow e = \frac{10.00}{44.00} \Rightarrow e = 0.227\ m.$$




$B_{MIN} = 3e \Rightarrow B_{MIN} = 0.681\ m$

$B_{MAX} = 2a \Rightarrow B_{MAX} = 0.754\ m.$

$BL = A \ :\ L = 2B \ :\ B = \sqrt{\frac{A}{2}}$

$B = \sqrt{\frac{2.709}{2}} \Rightarrow B = 1.164 \sim B = 1.20\ m.$

∴ $B = 1.20$, $L = 2.40 \Rightarrow A = 2.88\ m^2$

## VERIFICACIÓN DE PRESIÓN $\sigma_{MAX} < \sigma_t$

$B = 1.20\ m$
$L = 2.40\ m$
$A = 2.88\ m^2$
$I = 0.346\ m^4$
$c = 0.60\ m.$

$$\sigma_{MAX} = \frac{P_S}{A} + \frac{M_S\, c}{I} = \frac{44.00}{2.88} + \frac{10(0.60)}{0.346} \Rightarrow \sigma_{MAX} = 32.619\ ton/m^2 > \sigma_t$$

(NO CUMPLE)
REDIMENSIONAR AREA

$B = 1.50\ m$
$L = 3.00\ m$
$A = 4.50\ m^2$
$I = 0.844$
$c = 0.75\ m.$

$$\sigma_{MAX} = \frac{44.00}{4.50} + \frac{10(0.75)}{0.844} \Rightarrow \sigma_{MAX} = 18.664 < \sigma_t$$

(CONFORME)

## CARGAS DE DISEÑO ($P_U$, $M_U$)

$P_U = 65.20$ ton  $M_U = 15.20$ ton-m.

## REACCION AMPLIFICADA DEL SUELO:

$e_U = M_U / P_U \Rightarrow e_U = 15.20 / 65.20 \Rightarrow e_U = 0.233 < B/6 = 0.25\,m$

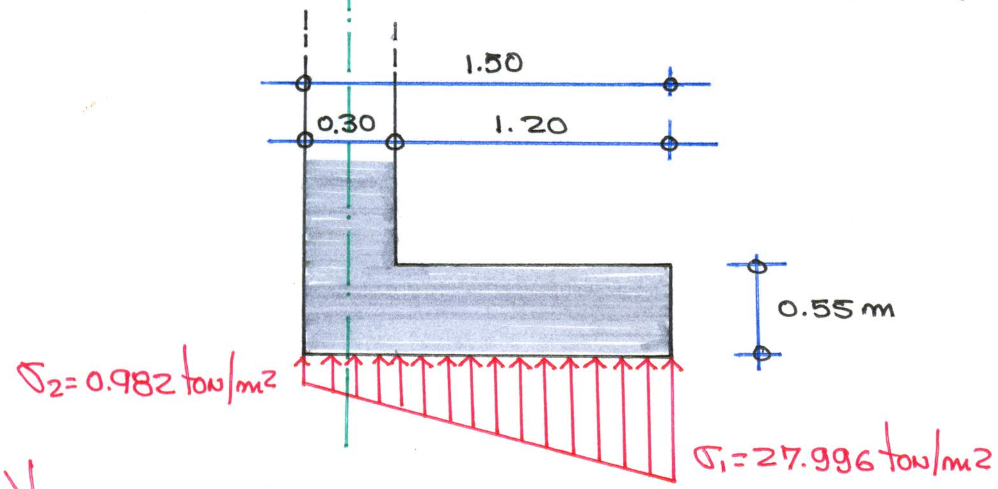
PRESION DE CONTACTO F/TRAPEZOIDAL

$$\sigma_{1,2} = \frac{P_U}{A} \pm \frac{M_U (c)}{I}$$

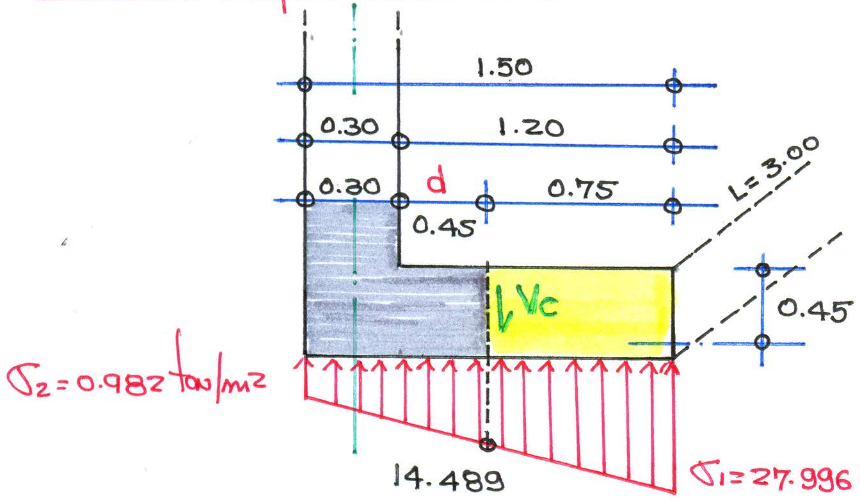
$$\sigma_{1,2} = \frac{65.20}{4.50} \pm \frac{15.20(0.75)}{0.844}$$

$\sigma_1 = 27.996$ ton/m²

$\sigma_2 = 0.982$ ton/m²




## VERIFICACION POR CORTANTE:



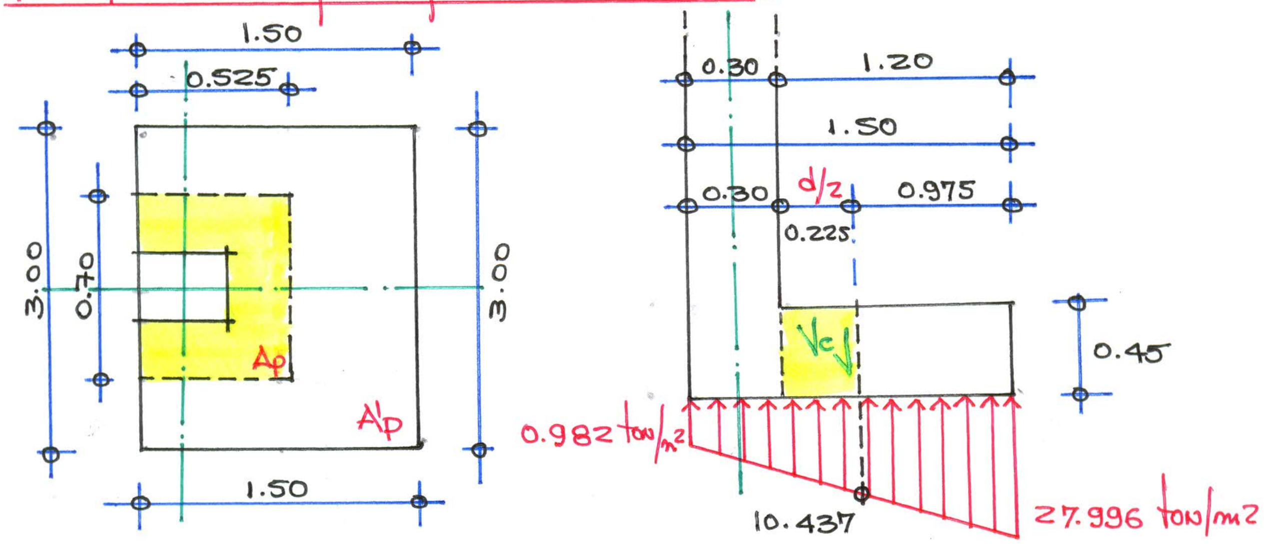

$V_U \leq \phi V_c$

$$V_U = \left[\frac{(27.996 + 14.489)\,0.75}{2}(3.00)\right] \Rightarrow V_U = 47.796 \text{ ton} = 47\,795.625 \text{ Kg}$$

$$\phi V_c = \phi\, 0.53 \sqrt{f'c} * L * d \Rightarrow \phi V_c = 0.85 * 0.53 \sqrt{210} * 300 * 45 \Rightarrow \phi V_c = 88.133 \text{ ton}$$

$\therefore V_U = 47.796$ ton $< \phi V_c = 88.133 \Rightarrow$ (CONFORME)

# VERIFICACION POR PUNZONAMIENTO:




PERIMETRO DE PUNZONAMIENTO

$$b_o = 2(0.525) + 0.70 \Rightarrow b_o = 1.75\ m.$$

RELACION DE LADOS DE LA COLUMNA

$$\beta_o = \frac{\text{LADO MAYOR}}{\text{LADO MENOR}} \Rightarrow \beta_o = \frac{30}{25} \Rightarrow \beta_o = 1.20$$

$$V_u \leq \phi V_c$$

$$V_u = \left[\frac{(27.996 + 0.982)}{2} 1.50\,(3.00)\right] - \left[\frac{(10.437 + 0.982)}{2} 0.525\,(0.70)\right]$$

$$V_u = 63.102\ ton = 63\,102.259\ Kg$$

$$\phi V_c = \phi\left(0.53 + \frac{1.10}{\beta_o}\right)\sqrt{f'c}\ b_o\, d$$

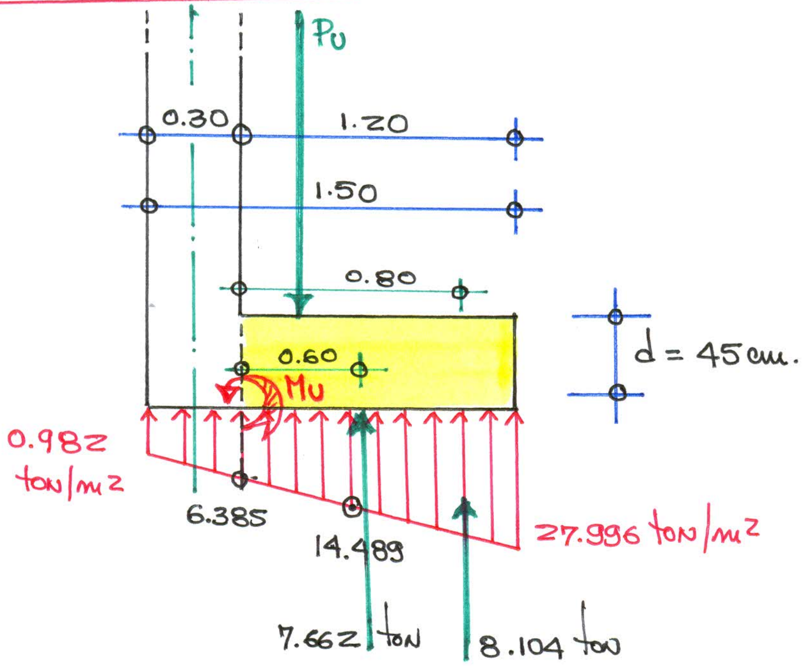
$$= 0.85\left(0.53 + \frac{1.10}{1.20}\right)\sqrt{210} * 175 * 45$$

$$\phi V_c = 140\,329.058\ Kg = 140.329\ ton.$$

$$\phi V_c = 140.329\ ton > V_u = 63.102\ ton$$

(CONFORME)

## DISEÑO DE REFUERZO




## DISEÑO DE REFUERZO LONGITUDINAL

$M_u = 11.080$ ton-m, $b = 100$ cm, $d = 45$ cm., $f'c = 210$ kg/cm², $f_y = 4200$ kg/cm²

$\rho_{min} = 0.70\sqrt{f'c}/f_y \Rightarrow \rho_{min} = 0.00242 \Rightarrow A_{smin} = \rho_{min}\, b d \Rightarrow A_{smin} = 10.868\ cm^2$

$\rho_b = 0.85\beta \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right)$ $\quad \rho_b = 0.02125 \Rightarrow A_{sb} = \rho_b\, b d \Rightarrow A_{sb} = 95.625\ cm^2$

$\rho_{max} = 0.75\,\rho_b$ $\quad \rho_{max} = 0.01594 \Rightarrow A_{smax} = \rho_{max}\, b d \Rightarrow A_{smax} = 71.719\ cm^2$

$\rho_{dis} = \omega \frac{f'c}{f_y}$ $\quad \rho_d = 0.00147 \Rightarrow A_{sd} = \rho_d\, b d \Rightarrow A_{sd} = 6.629\ cm^2$

#aceros $N = \frac{A_{st}}{A_{s\phi}}$ ∴ $\phi 5/8 = 2.00\ cm^2$ $\quad A_{st} = 32.604\ cm^2$

$N = \frac{32.604}{2.00} \Rightarrow N = 16.302 \sim N = 16$ UNIDADES.

DISTRIBUCCIÓN:

$S = \frac{3.00 - 0.15 - 0.01588 - 0.10}{15} \Rightarrow S = 0.18\ m.$

**16 φ5/8 @ 0.18**

## DISEÑO DE REFUERZO TRANSVERSAL

$M_u = \frac{14.489(1.375)^2}{2} \Rightarrow M_u = 13.697$ ton-m.

$b = 100$ cm, $d = 45.00$ cm, $f'c = 210$ kg/cm², $f_y = 4200$ kg/cm²

$\rho_{min} = 0.00242$ $As_{min} = 10.868$ cm²

$\rho_b = 0.02125$ $As_b = 95.625$ cm²

$\rho_{max} = 0.01594$ $As_{max} = 71.718$ cm²

$\rho_{dis} = 0.00183$ $As_d = 8.23$ cm²

∴ Acero de Diseño Transversal $Asd = 10.868$ cm²

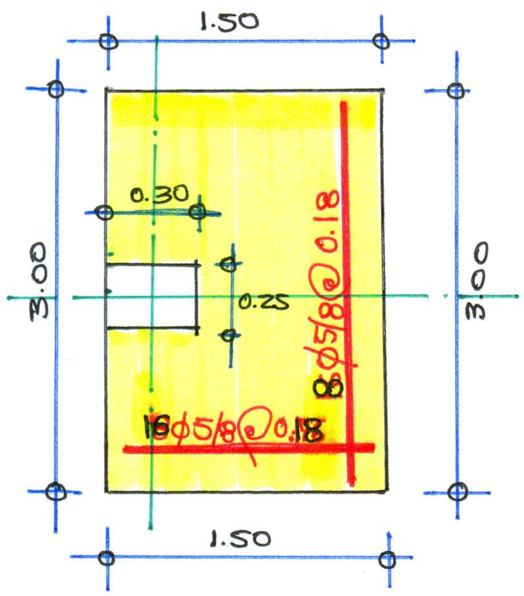
\# DE ACEROS : $Ast = 10.868(1.50) \Rightarrow Astd = 16.302$ $As\phi 5/8 = 2.00$

$N = \frac{Astd}{As\phi} \Rightarrow N = \frac{16.302}{2.00} \Rightarrow N = 8.15 \sim N = 8$ UNIDADES

DISTRIBUCION DE ACEROS (s)

$S = \frac{1.50 - 0.15 - 0.01588 - 0.10}{7} \Rightarrow S = 0.176$ m.

ACERO TRANSVERSAL: 8Ø5/8 @ 0.176 m. ~ 8Ø5/8" @ 0.18



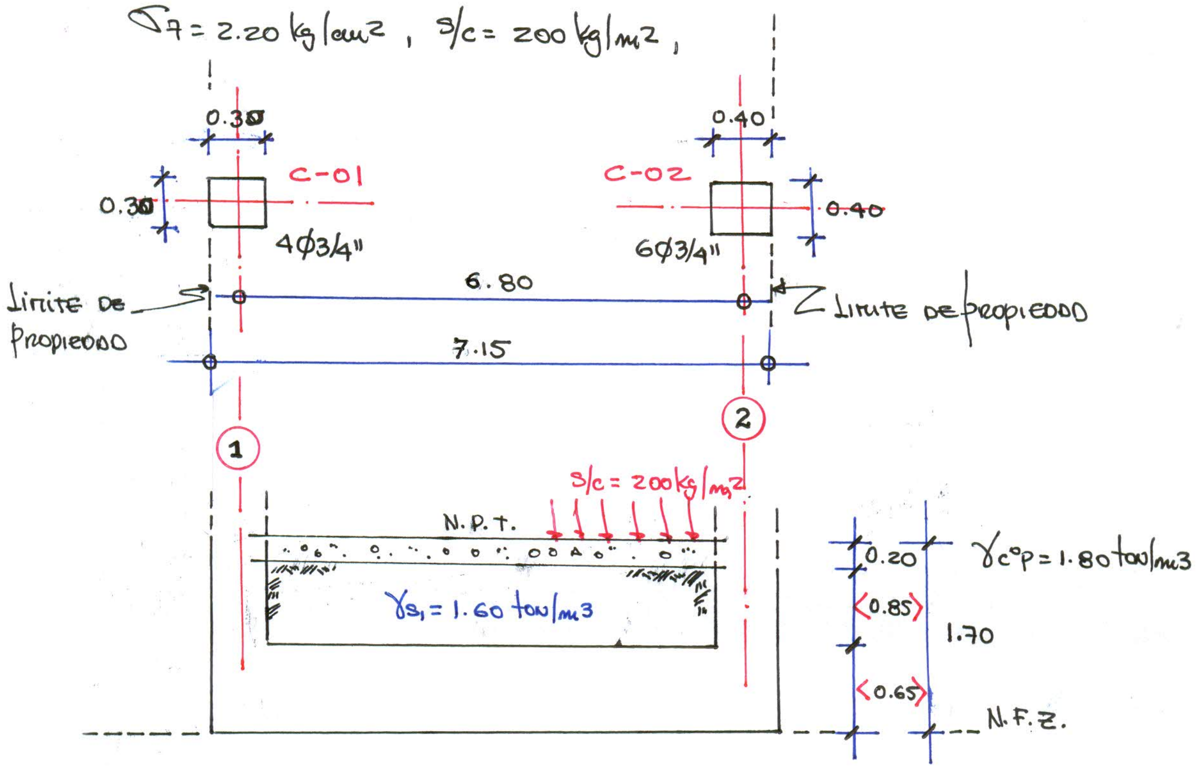

DETALLE : EN PLANTA

**PROBLEMA #02:** DISEÑAR LA ZAPATA COMBINADA PARA LA SECCIÓN DE MOMENTO MAXIMO.

$Pd_1 = 35$ ton $\quad Pd_2 = 48$ ton $\quad f'c = 210$ kg/cm2

$PL_1 = 14$ ton $\quad PL_2 = 18$ ton $\quad fy = 4200$ kg/cm2

$\sigma_t = 2.20$ kg/cm2 , s/c = 200 kg/m2 ,




**DIMENSIONAMIENTO:**

- **PERALTE:** ACERO EN COLUMNA $\phi 3/4 \Rightarrow db = 1.905$ cm $= 0.01905$ m, $Ab = 2.84$ cm2.

- Consideraciones normativas: ld por compresión

$ld = 0.08\, db\, fy/\sqrt{f'c}$ $\qquad ld = 44.17$ cm.

$ld = 0.004\, db\, fy$ $\qquad ld = 32.004$ cm. $\Rightarrow ld = 45$ cm.

$ld \geq 20$ cm. $\qquad d = 20$ cm.

$d = 55$ cm.

$h = 65$ cm.

**CAPACIDAD PORTANTE NETA DEL TERRENO ($q_e$)**

$$q_e = \sigma_t - (\gamma_{c^oz} * h_z) - (\gamma_{s1} * h_{s1}) - (\gamma_{c^op} * h_p) - s/c$$

$$= 22.00 - (2.40 * 0.65) - (1.60 * 0.85) - (1.80 * 0.20) - 0.20$$

$$q_e = 18.52 \text{ ton/m2} = 1.852 \text{ kg/cm2}$$

## Solicitaciones:

CARGAS DE SERVICIO: $P_{S1} = P_{d1} + P_{L1} \Rightarrow P_{S1} = 35 + 14 \Rightarrow P_{S1} = 49$ ton

$P_{S2} = P_{d2} + P_{L2} \Rightarrow P_{S2} = 48 + 18 \Rightarrow P_{S2} = 66$ ton

$P_S = 115$ ton

CARGAS ULTIMAS: $P_{U1} = 1.70 P_{L1} + 1.40 P_{d1} \Rightarrow P_{U1} = 1.70(14) + 1.40(35) \Rightarrow P_{U1} = 72.80$ ton

$P_{U2} = 1.70 P_{L2} + 1.40 P_{d2} \Rightarrow P_{U2} = 1.70(18) + 1.40(48) \Rightarrow P_{U2} = 97.80$ ton

$P_U = 170.60$ ton

## Area Requerida (A)

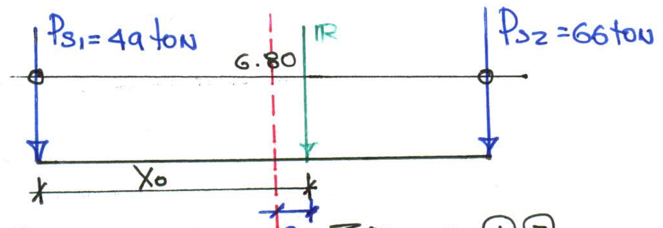
$$A = \frac{P_S}{q_a} \Rightarrow A = \frac{115.00}{18.52} \Rightarrow A = 6.21\ m^2$$

L = 7.15 m.

= 0.90 m

A = 6.44 m²

## Magnitud y ubicacion de la resultante:




$\Sigma F_Y = 0$

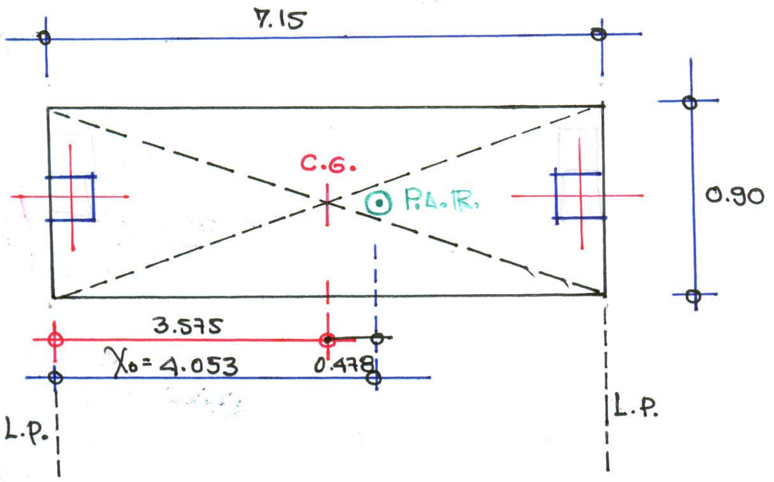
$-49 - 66 - R = 0$

$-R = 115$ ton

$\Sigma M_1 = 0$ (+)

$-R(X_0) - 66 * 6.80 = 0$

$X_0 = 3.903$ m




$$e_s = X_0 - \frac{L}{2} \Rightarrow e_s = 4.053 - 3.575 \Rightarrow e = 0.478 < \frac{L}{6} = 1.192\ m$$

Presión de contacto F/ trapezoidal

$$M_S = P_S * e_S \Rightarrow M_S = 115.00 * 0.478 \Rightarrow M_S = 54.97\ \text{ton-m}.$$

## Verificación de Presión $\sigma_{max} < \sigma_t$

$P_s = 115.00$ ton , $M_s = 54.97$ ton-m., $A = 6.435\ m^2$

$$\sigma_{max} = \frac{P_s}{A} + \frac{M_s\, c}{I}$$

$c = L/2 \Rightarrow C = 3.575\ m$

$I = \frac{B L^3}{12} \Rightarrow I = 27.414\ m^4$

$$\sigma_{max} = \frac{115}{6.435} + \frac{54.97(3.575)}{27.414}$$

$\sigma_{max} = 25.040\ ton/m^2 > \sigma_t = 22.00$ Redimensionamos B =

L = 7.15 m.
B = 1.05 m.
$A = 7.508\ m^2$
C = 3.575 m.
$I = 31.984\ m^4$

$\Rightarrow \sigma_{max} = 21.461\ ton/m^2 < \sigma_t = 22.00\ ton/m^2$

∴ Conforme

## Cargas de Diseño $P_u$, $M_u$

$\Sigma F_y = 0$
$-P_{u1} - P_{u2} - R = 0$
$-72.80 - 97.80 = R$
$R = 170.60$ ton

$\Sigma M_1 = 0$ (+) (-)
$-R(X_0) - P_{u2}(6.80) = 0$

$$X_0 = \frac{97.80\,(6.80)}{170.60} \Rightarrow X_0 = 3.898\ m$$

$\Rightarrow e_u = X_0 - \frac{L}{2} \Rightarrow e_u = 3.898 - \frac{7.15}{2} \Rightarrow e_u = 0.323\ m. < \frac{L}{6} = 1.192\ m$

$M_u = P_u * e_u \Rightarrow M_u = 170.60 * 0.323 \Rightarrow M_u = 55.104$ ton-m.

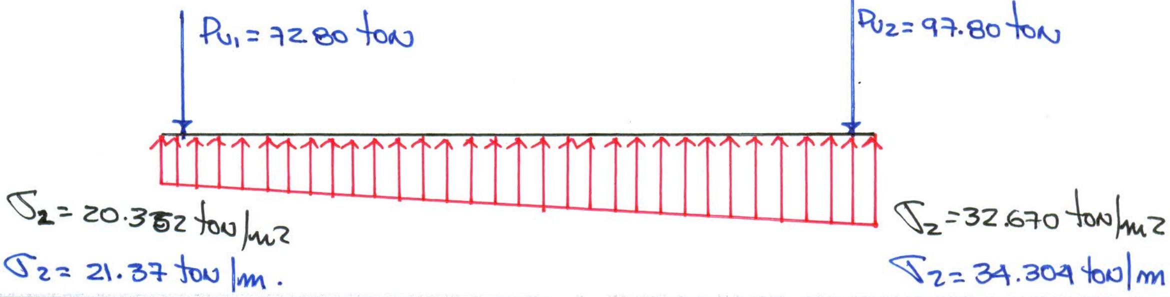
## Reacción Amplificada del suelo

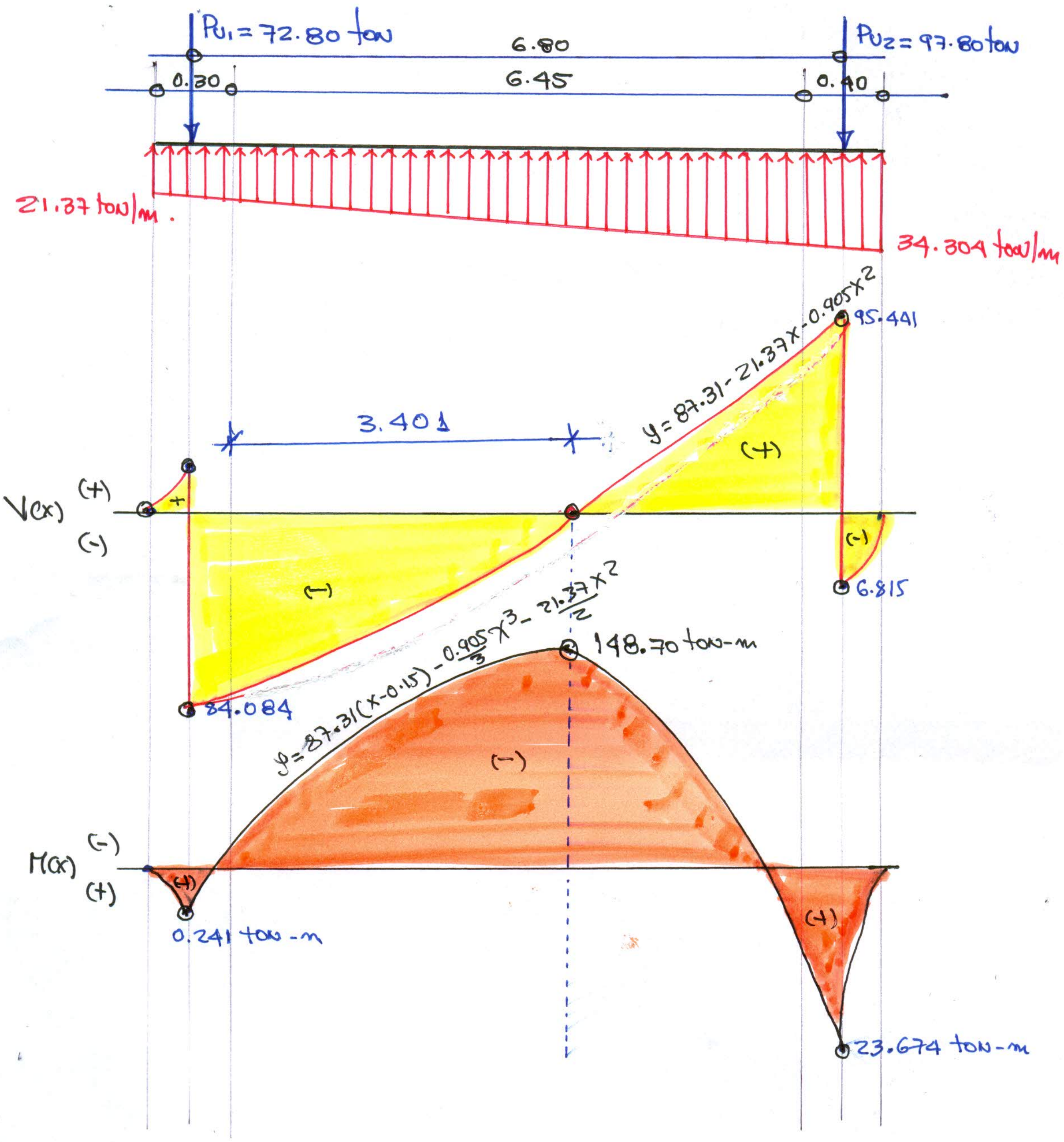
$P_u = 170.60$ ton , $M_u = 55.104$ ton-m
$A = 6.435\ m^2$, $B = 1.05\ m$, $L = 7.15\ m$
$C = 3.575\ m$, $I = 31.984\ m^4$

$$\sigma_{1,2} = \frac{P_u}{A} \pm \frac{M_u(c)}{I}$$

$\sigma_1 = 32.670\ ton/m^2$

$\sigma_2 = 20.352\ ton/m^2$

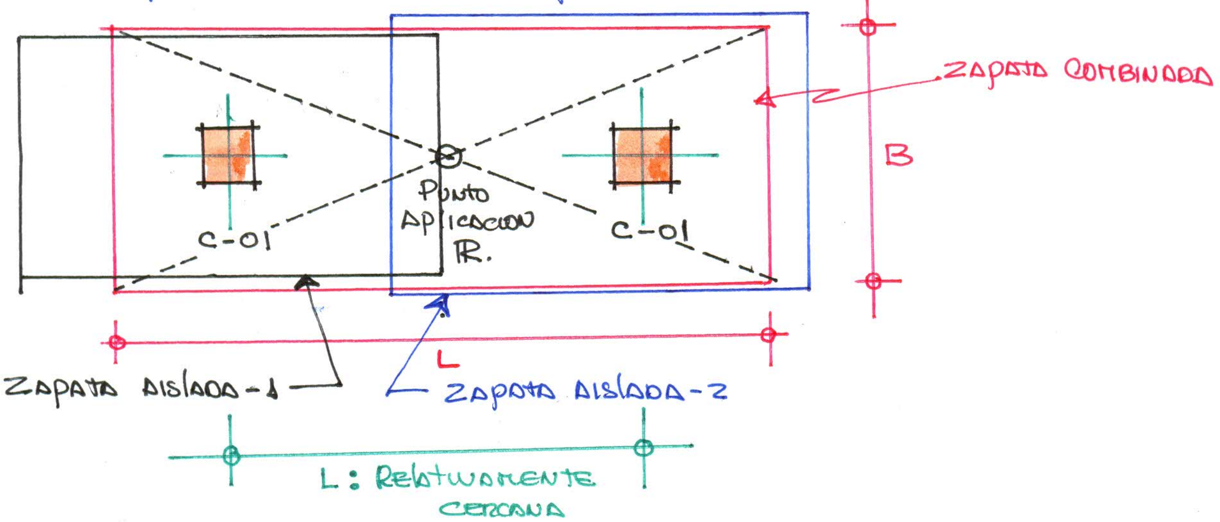



Pu1 = 72.80 ton
Pu2 = 97.80 ton
6.80
0.30
6.45
0.40
21.37 ton/m
34.304 ton/m
95.441
y = 87.31 - 21.37X - 0.905X2
3.401
V(x)
(+)
(-)
(-)
(+)
(-)
6.815
84.084
y = 87.31(X-0.15) - 0.905/3 X3 - 21.37/2 X2
148.70 ton-m
M(x)
(-)
(+)
(-)
(+)
(+)
0.241 ton-m
23.674 ton-m

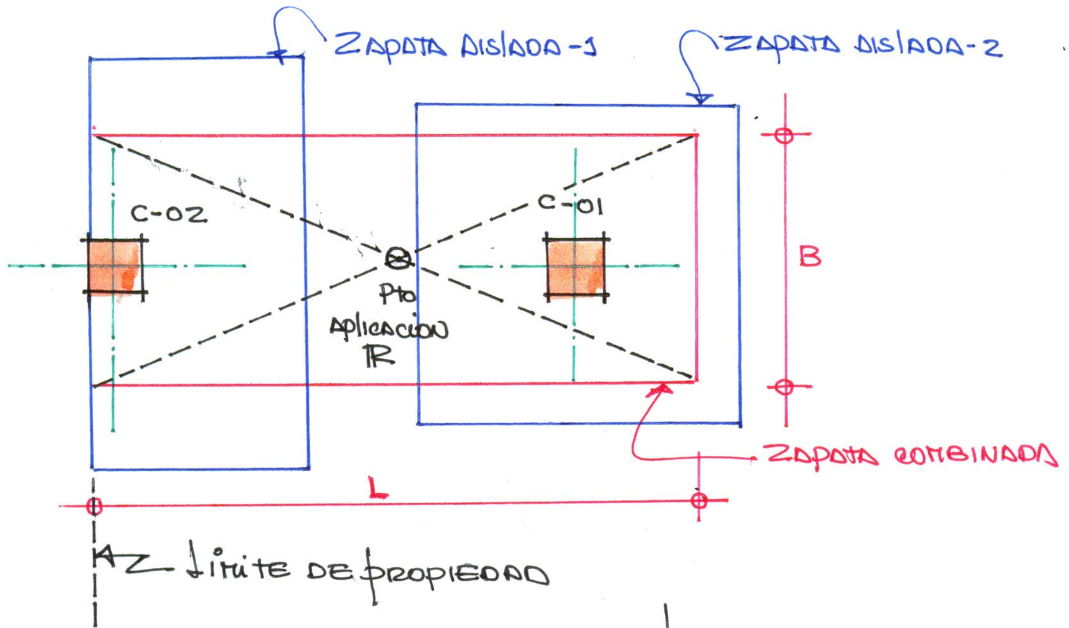
## ZAPATAS COMBINADAS

UNA CIMENTACIÓN COMBINADA RECIBE LAS CARGAS PROVENIENTES DE LA SUPER ESTRUCTURA ATRAVEZ DE 2 OMAS COLUMNAS, SE USA PRINCIPALMENTE EN LOS SIGUIENTES CASOS:

a) CUANDO DOS COLUMNAS ESTAN RELATIVAMENTE CERCANA ENTRE SI, DE MODO QUE SE UNIRAN LAS ZAPATAS AISLADAS ESTAS PODRAN TRANSFORMARSE EN UNA ZAPATA COMBINADA.




b) CUANDO UNA COLUMNA EXTERIOR ESTA EN EL LIMITE DE PROPIEDAD O MUY CERCANA DE EL, DE MODO QUE SE UNIRA UNA ZAPATA AISLADA ESTA RESULTARIA CON CARGA EXCENTRICA EXCESIVA.



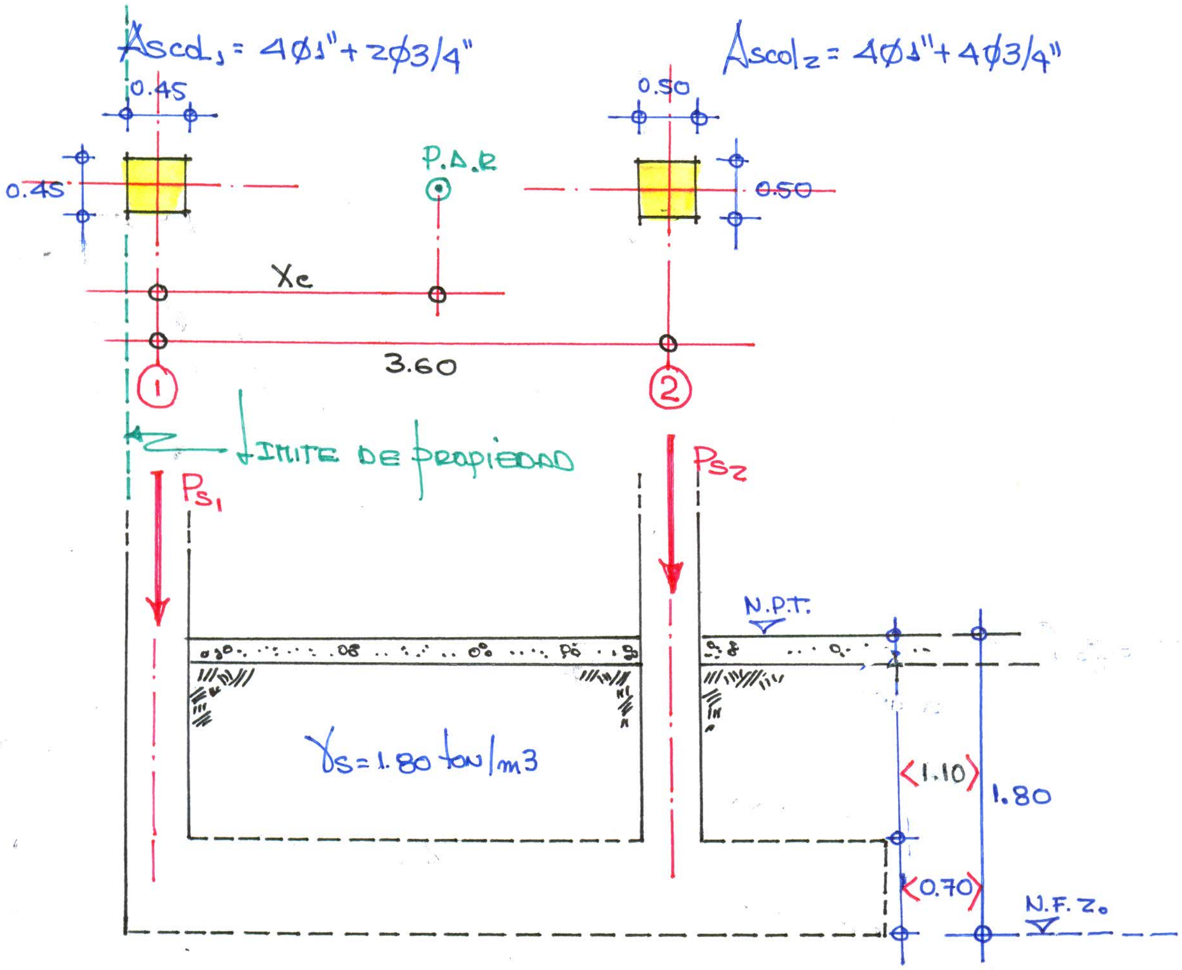

EN AMBOS CASOS EL FACTOR ECONOMICO TAMBIEN ES DETERMINANTE

## PROBLEMA N° 01:

DISEÑAR LA ZAPATA COMBINADA DE LA FIG. MOSTRADA PARA LAS SOLICITACIONES INDICADAS:

$P_{CM_1} = 55$ ton  $P_{CM_2} = 90$ ton  $f'c = 280$ kg/cm²
$P_{CV_1} = 45$ ton  $P_{CV_2} = 70$ ton  $f'y = 4200$ kg/cm²

$\sigma_t = 2.40$ kg/cm²  NF = -1.80 m.




## DIMENSIONAMIENTO:

4 PERALTE: Acero columna C-02: 4Ø1" + 4Ø3/4" ⇒ Ø1"   db = 2.54 cm.   Ab = 5.10 cm²

CONSIDERACIONES NORMATIVAS

$Ld = 0.08\, db\, fy / \sqrt{f'c}$   Ld = 51.003 cm.
$Ld = 0.004\, db\, fy$   Ld = 42.672 cm. ⇒ Ld = 50 cm.
$Ld \geq 20$ cm.   Ld = 20.00 cm.

$ld = 50\,cm \Rightarrow d = 60\,cm, \therefore h = 70\,cm.$

▲ **Capacidad portante neta del terreno :** $(q_e)$

$$q_e = \sigma_t - (\gamma_{c^o z} * h_z) - (\gamma_s * h_s)$$

$$= 24.0 - (2.40 * 0.70) - (1.80 * 1.10) \Rightarrow q_e = 20.34\ ton/m^2$$

$$q_e = 2.034\ kg/cm^2$$

▲ **Solicitaciones**

↳ Cargas de Servicio : $P_s = P_{cm_1} + P_{cv_1} \Rightarrow P_{s_1} = 55+45 \Rightarrow P_{s_1} = 100\ ton$

$P_{s_2} = P_{cm_2} + P_{cv_2} \Rightarrow P_{s_2} = 90+70 \Rightarrow P_{s_2} = 160\ ton$

$P_s = 260\ ton$

↳ Cargas ultimas

$$P_{u_1} = 1.40\,P_{cm_1} + 1.70\,P_{cv_1} \Rightarrow P_{u_1} = 1.40(55) + 1.70(45) \Rightarrow P_{u_1} = 153.50\ ton$$

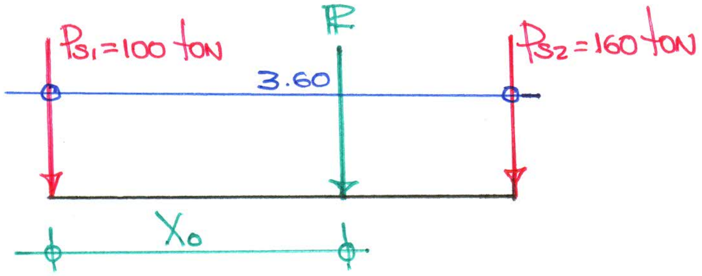
$$P_{u_2} = 1.40\,P_{cm_2} + 1.70\,P_{cv_2} \Rightarrow P_{u_2} = 1.40(90) + 1.70(70) \Rightarrow P_{u_2} = 245.00\ ton$$

$P_u = 398.50\ ton$

▲ **Area Requerida :**

$$A = \frac{P_s}{q_e} \Rightarrow A = \frac{260.00}{20.34} \Rightarrow A = 12.783\ m^2$$

▲ **Magnitud de la Resultante**




$\Sigma F_V = 0$

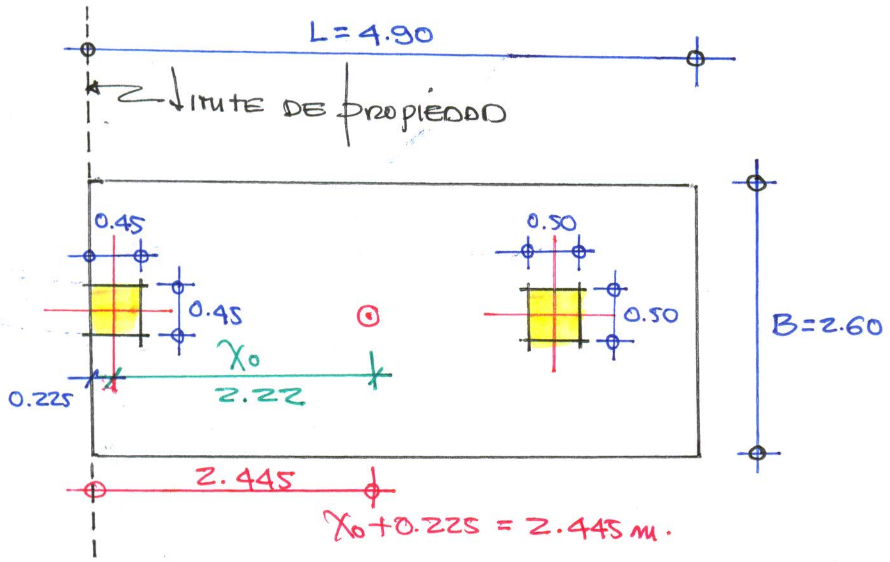
$-100 - 160 - R = 0$

$R = -260\ ton$

$\Sigma M_b = 0$ (+) (-)

$-R(X_o) - 160(3.60) = 0$

$X_o = 2.22$




Longitud de la zapata $L = 2(2.445) \Rightarrow L = 4.89 \Rightarrow L = 4.90\ m$

$\therefore\ B = \frac{A}{L} \Rightarrow B = \frac{12.783}{4.90} \Rightarrow B = 2.609\ m \longrightarrow B = 2.60\ m$

$A = 12.74\ m^2$

## Presiones de diseño:

$P_{U1} = 153.50$ ton
$P_{U2} = 245.00$ ton

$P_U = 398.50$ ton

### Cargas distribuidas:

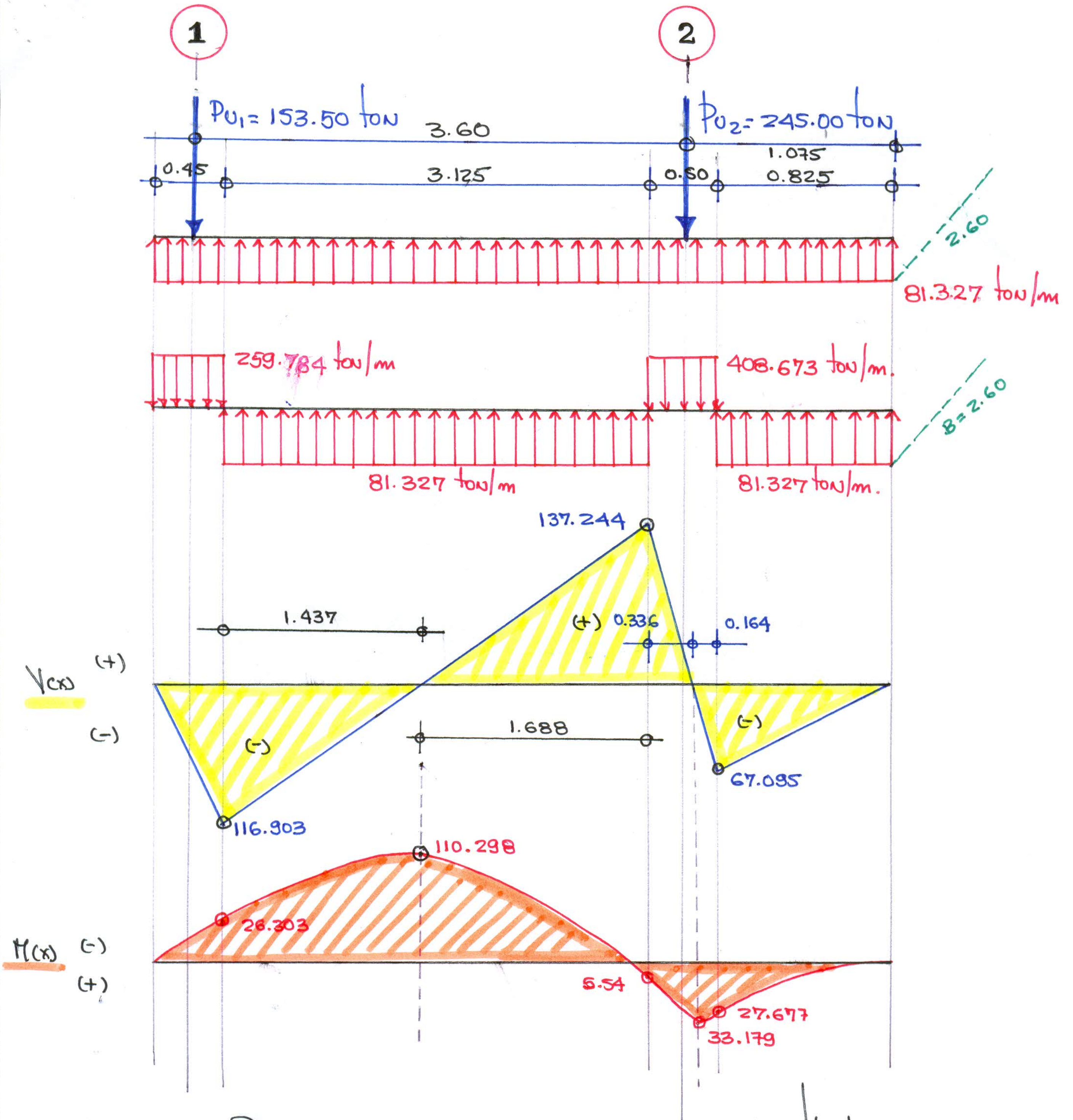
$A = 12.74\ m^2,\quad L = 4.90\ m,\quad B = 2.60\ m.$

$q'_U = \frac{P_U}{A} \Rightarrow q'_U = \frac{398.50}{12.74} \Rightarrow q'_U = 31.279\ ton/m^2$

$\therefore\ q_U = 31.279\,(B)$

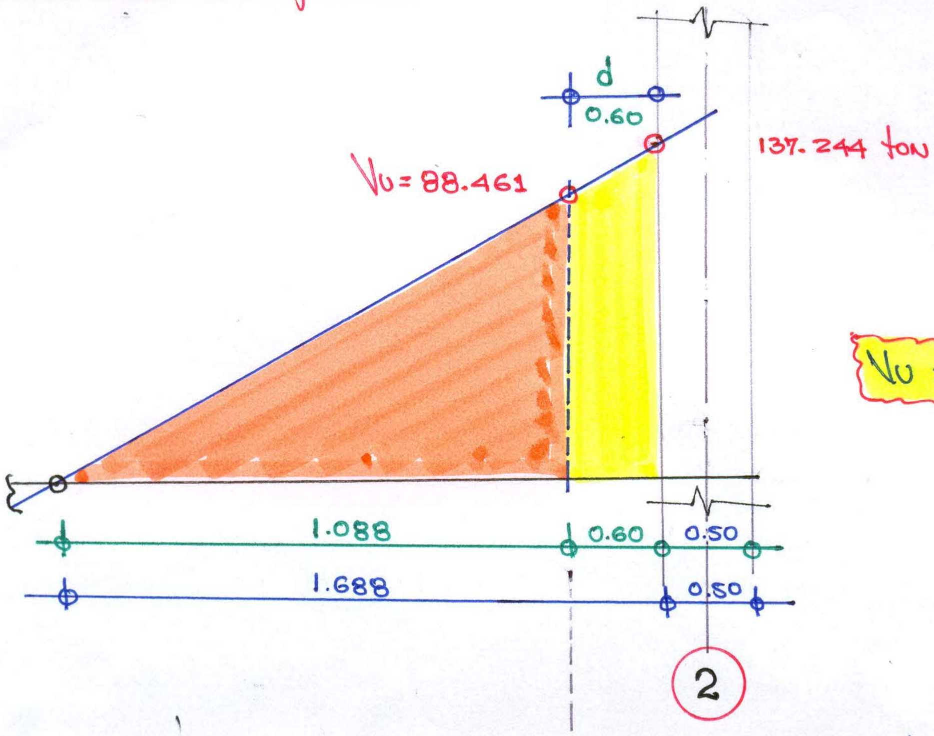
$q_U = 31.279\,(2.60)$

$q_U = 81.327\ ton/m$




Diagramas esfuerzo cortante y momento flector

## VERIFICACION CORTE-FLEXION: $B = 2.60$ , $L = 4.90$ , $A = 12.74\ m^2$ $d = 60\ cm.$

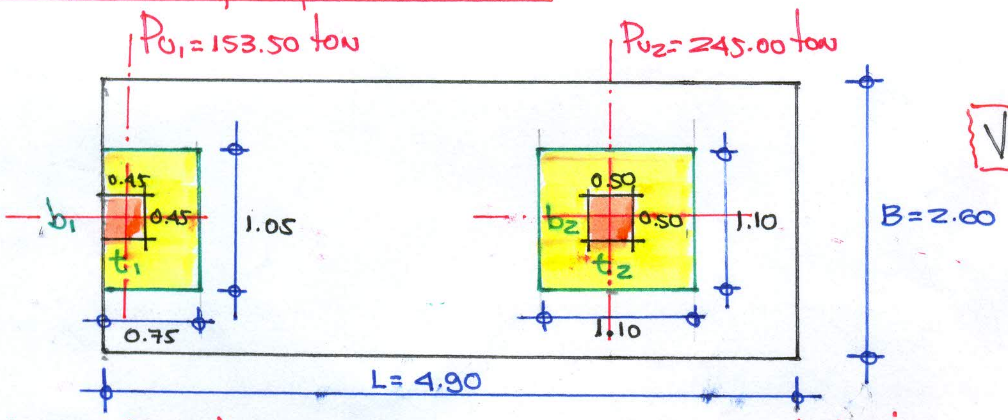



$V_u \leq \phi V_c$

$V_u = 88.461\ ton$ $\phi V_c = \phi\, 0.53 \sqrt{f'c}\, B\, d = 0.85 * 0.53 \sqrt{280} * 260 * 60 = 117.597\ ton$

$V_u = 88.461\ ton < \phi V_c = 117.597\ ton$ (CUMPLE) CONFORME

## VERIFICACION POR PUNZONAMIENTO




$V_u \leq \phi V_c$

**COLUMNA EXTERIOR**

$V_u = P_{u1} - q'_u\left[\left(t_1 + \frac{d}{2}\right)(b_1 + d)\right]$

$V_u = 153.50 - 31.279[(.45 + 0.30)(.45 + 0.60)]$

$V_u = 128.868\ ton$

$\phi V_c = \phi\, 1.10 \sqrt{f'c}\, b_o d$

$\phi V_c = 0.85 * 1.10 \sqrt{280} * 240 * 60$

$\phi V_c = 225.296\ ton$

$V_u < \phi V_c$ (Conforme)

**COLUMNA INTERIOR**

$V_u = P_{u2} - q'_u[(t_2 + d)(b_2 + d)]$

$V_u = 101.842 - 31.279[(.50 + .60)(.50 + .60)]$

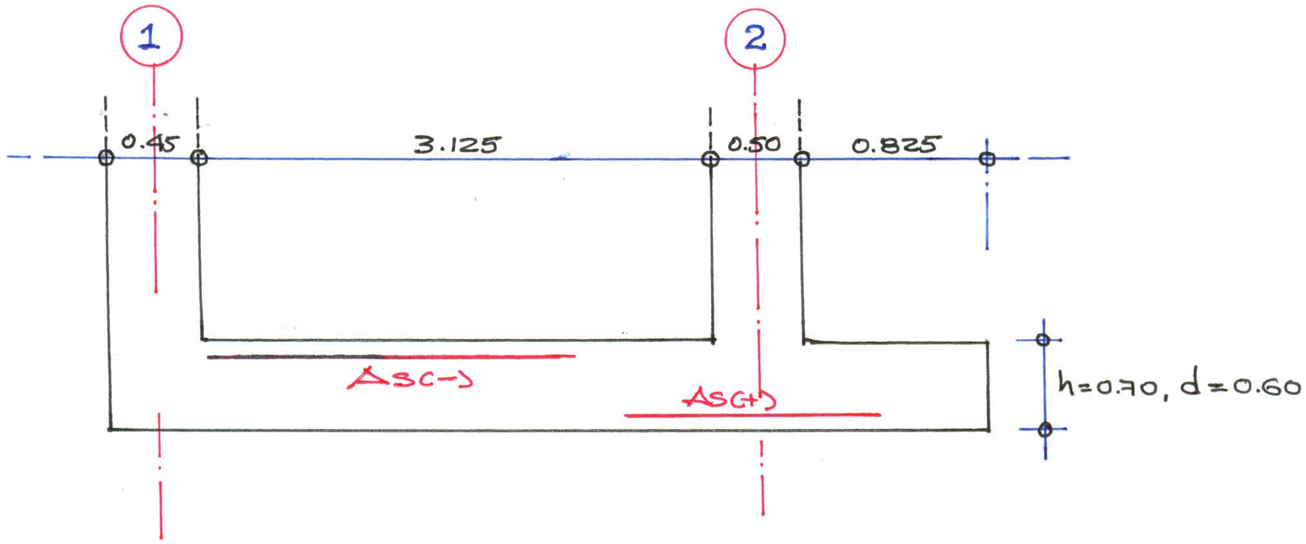
$V_u = 207.152\ ton$

$\phi V_c = \phi\, 1.10 \sqrt{f'c}\, b_o d$

$\phi V_c = 0.85 * 1.10 \sqrt{280} * 440 * 60$

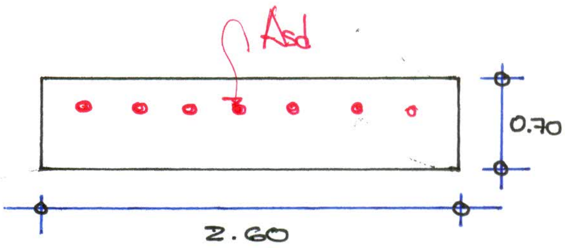
$\phi V_c = 413.042\ ton$

$V_u < \phi V_c$ (Conforme)




## Diseño Refuerzo Longitudinal:

### ① Tramo: 1-2 Acero Negativo




Datos de Diseño:

$M_u = 110.298$ ton-m  $f'c = 280\ kg/cm^2$

$b = 260$ cm, $d = 60$ cm.  $f_y = 4200\ kg/cm^2$

$$a = \frac{A_s f_y}{0.85 f'c\, b}$$

$$M_u = \phi A_s f_y (d - a/2)$$

$\rho_{min} = \frac{0.70\sqrt{f'c}}{f_y}$  $\rho_{min} = 0.00279 \Rightarrow A_{smin} = \rho_{min} bd \Rightarrow A_{smin} = 43.506\ cm^2$

$\rho_b = 0.85\beta_1 \frac{f'c}{f_y}\left(\frac{6000}{6000+f_y}\right)$  $\rho_b = 0.02833 \Rightarrow A_{sb} = \rho_b bd \Rightarrow A_{sb} = 441.948$

$\rho_d = w\, f'c/f_y$  $\rho_d = 0.00321 \Rightarrow A_{sd} = \rho_d bd \Rightarrow A_{sd} = 50.054$

$\rho_{max} = 0.75\rho_b$  $\rho_{max} = 0.02125 \Rightarrow A_{smax} = \rho_{max} bd \Rightarrow A_{smax} = 331.50$

## Distribución de Refuerzo:

$\phi 3/4 = 2.84\ cm^2$, $d_b = 0.01905$ cm.

⇒ **Acero Mínimo:** $A_{smin} = 43.506\ cm^2$, $m = \frac{A_{smin}}{A_{s\phi}} \Rightarrow m = \frac{43.506}{2.84}$ (50.054) $\Rightarrow m = 15$ Unidades

$\therefore S = \frac{2.60 - 0.15 - 0.01905 - 0.10}{14} \Rightarrow S = 0.166$ (0.14) $\Rightarrow S = 0.17$ cm.

⇒ **Acero de Refuerzo:** $A_{sr} = A_{sd} - A_{smin} \Rightarrow A_{sr} = 6.548\ cm^2$

$m = \frac{A_{sr}}{A_{s\phi}} \Rightarrow m = \frac{6.548}{2.84} \Rightarrow m = 2$ Unidades. $\Rightarrow S = 0.75$

$\therefore$ $A_{smin}$: 15 $\phi$ 3/4 @ 0.17 , $A_{sr}$: 2 $\phi$ 3/4 @ 0.75

## ② Apoyo 2: Acero positivo

$Mu = 33.179$ ton-m

Datos de Diseño: $b = 260$ cm, $d = 60$ cm, $f'c = 280$ kg/cm², $fy = 4200$ kg/cm²

$$a = \frac{As\,fy}{0.85\,f'c\,b} \Rightarrow Mu = \phi\,As\,fy\,(d - a/2)$$

$\rho_{min} = 0.70\sqrt{f'c}/fy \Rightarrow \rho_{min} = 0.00279$ $\quad As_{min} = \rho_{min}\,b\,d \Rightarrow As_{min} = 43.506$ cm²

$\rho_b = 0.85\beta\frac{f'c}{fy}\left(\frac{6000}{6000+fy}\right) \Rightarrow \rho_b = 0.02833$ $\quad As_b = \rho_b\,b\,d \Rightarrow As_b = 441.948$ cm²

$\rho_d = w\,f'c/fy \Rightarrow \rho_d = 0.00095$ $\quad As_d = \rho_d\,b\,d \Rightarrow As_d = 14.753$ cm²

$\rho_{max} = 0.75\,\rho_b \Rightarrow \rho_{max} = 0.02125$ $\quad As_{max} = \rho_{max}\,b\,d \Rightarrow As_{max} = 331.50$ cm²

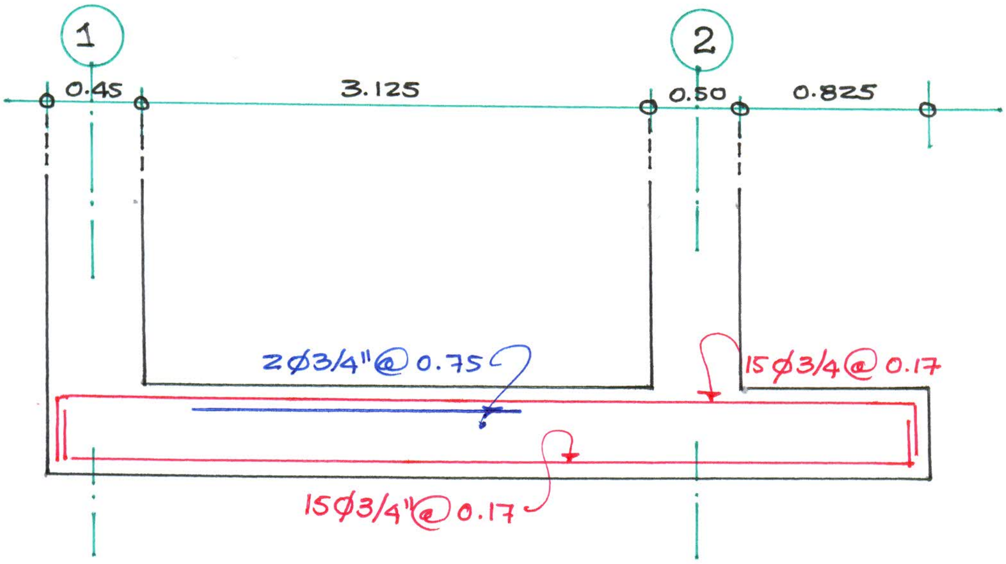
$\therefore As_d = As_{min} = 43.506$ cm²

**Distribución de Refuerzo:** $\phi 3/4" = 2.84$ cm², $d_b = 0.01905$ cm.

$$n = \frac{As_d}{As_\phi} \Rightarrow n = \frac{43.506}{2.84} \Rightarrow n = 15.319 \Rightarrow n = 15 \text{ unidades.}$$

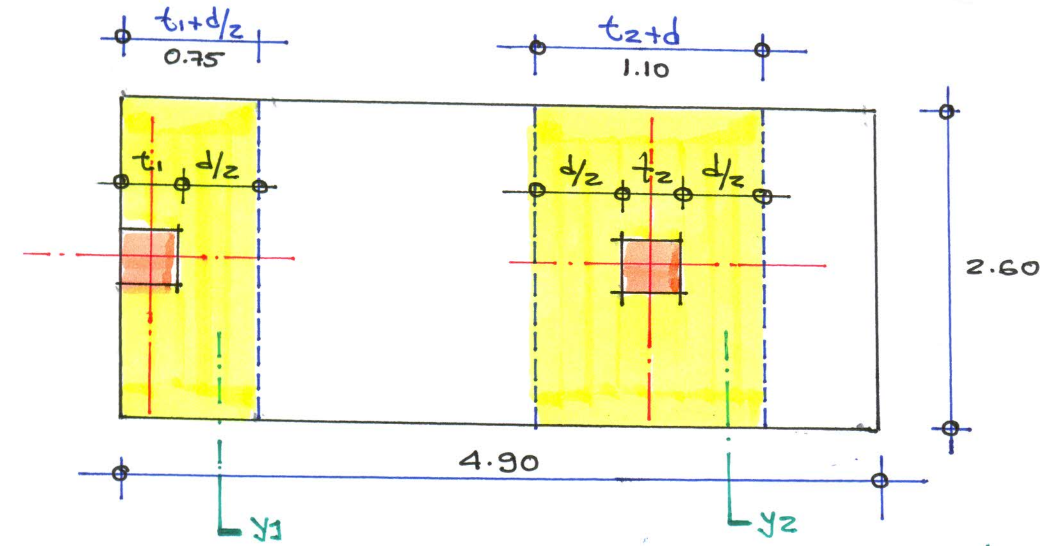
$$S = \frac{2.60 - 0.15 - 0.01905 - 0.10}{14} \Rightarrow S = 0.1665 \Rightarrow S = 0.17 \text{ m.}$$

15 ∅3/4 @ 0.17

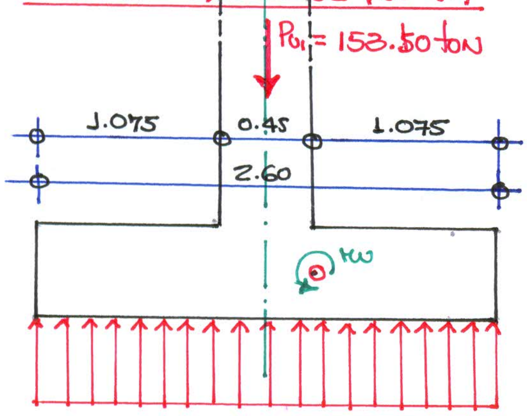



Detalle: Refuerzo Longitudinal

# DISEÑO REFUERZO TRANSVERSAL



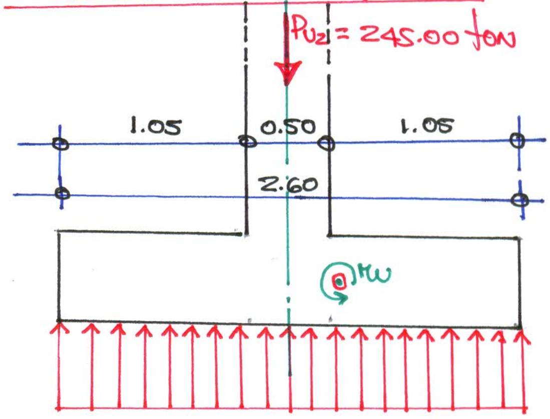

## COLUMNA EXTERIOR (y1-y1)




$$\frac{153.50}{2.60} = 59.038 \text{ ton/m}$$

$$M_u = \frac{\omega L^2}{2} \Rightarrow M_u = 34.113 \text{ ton-m}$$

## COLUMNA INTERIOR (y2-y2)




$$\frac{245}{2.60} = 94.231 \text{ ton/m}$$

$$M_u = \frac{\omega l^2}{2} \Rightarrow M_u = 51.945 \text{ ton-m}$$

$b = 100$ cm, $d = 60$ cm, $f'c = 280$ kg/cm², $f_y = 4200$ kg/cm²

**Columna exterior:**

$\rho_{min} = 0.00279$ — $As_{min} = 16.733$ cm²

$\rho_b = 0.02833$ — $As_b = 169.98$ cm²

$\rho_d = 0.00257$ — $As_d = 15.39$ cm²

$\rho_{max} = 0.02125$ — $As_{max} = 127.50$ cm²

$\Rightarrow As_{td} = As_d(0.75) \Rightarrow As_{td} = 11.54$ cm²

$n = 4.06$ Und, $n = 4$ Und.

$$S = \frac{0.75 - 0.075 - 0.01905 - 0.10}{4} \Rightarrow S = 0.185 \text{ m}$$

4 Ø 3/4 @ 0.185 m.

**Columna interior:**

$\rho_{min} = 0.00279$ — $As_{min} = 16.733$ cm²

$\rho_b = 0.02833$ — $As_b = 169.98$ cm²

$\rho_d = 0.00396$ — $As_d = 23.734$ cm²

$\rho_{max} = 0.02125$ — $As_{max} = 127.50$ cm²

$As_{td} = As_d(1.10) \Rightarrow As_{td} = 26.107$ cm²

$n = 9.19$ Und. $\Rightarrow n = 9$ Und.

$$S = \frac{1.10 - 0.01905 - 0.10}{8} \Rightarrow S = 0.12 \text{ m.}$$

9 Ø 3/4 @ 0.12 m.

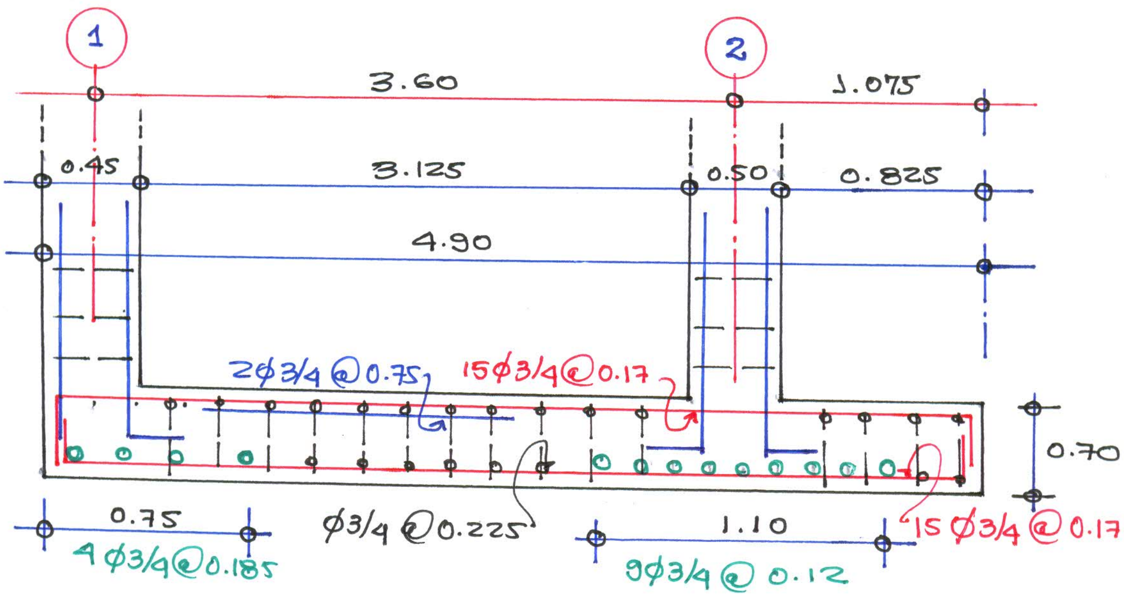
ACERO DE MONTAJE: $b = 100\ cm$, $h = 70\ cm$, $f'c = 280\ kg/cm^2$, $f_y = 4200\ kg/cm^2$

$$A_{SR} = 0.0018\ b\ h$$

$A_{SR} = 0.0018 * 100 * 70 \Rightarrow A_{SR} = 12.60\ cm^2$

$$S = \frac{b * A_{S\phi}}{A_{SR}} \Rightarrow S = \frac{100 * 2.84}{12.60} \Rightarrow S = 22.50\ cm.$$

∴ $A_{SR}$ : $\phi 3/4$ @ 0.225




DETALLE DE REFUERZO LONGITUDINAL TRANSVERSAL