Universidad Nacional Autónoma de México

FACULTAD DE INGENIERIA

DISEÑO DE UNA NAVE INDUSTRIAL DE 25 M. DE CLARO POR 50 M. DE LARGO CON ELEMENTOS DE CONCRETO PRESFORZADO

TESIS PROFESIONAL

Que para obtener el Título de

INGENIERO CIVIL

presenta

DAVOR MILTON VARGAS POL

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AUTONOMA

Al Pasante señor VARGAS POL DAVOR,
P r e s e n t e .

En atención a su solicitud relativa, me es grato transcribir a usted a continuación el tema que aprobado por esta Dirección propuso el Profesor Ing. Constancio Rodríguez Cabello, para que lo desarrolle como tesis en su Examen Profesional de Ingeniero CIVIL.

"DISEÑO DE UNA NAVE INDUSTRIAL DE 25 M. DE CLARO POR 50 M. DE LARGO CON ELEMENTOS DE CONCRETO PRESFORZADO"

1. Introducción.
2. Diseño de largueros.
3. Diseño de trabes portantes.
4. Diseño de columnas.
5. Conclusiones.

Ruego a usted se sirva tomar debida nota de que en cumplimiento de lo especificado por la Ley de Profesiones, deberá prestar Servicio Social durante un tiempo mínimo de seis meses como requisito indispensable para sustentar Examen Profesional; así como de la disposición de la Dirección General de Servicios Escolares en el sentido de que se imprima en lugar visible de los ejemplares de la tesis, el título del trabajo realizado.

A t e n t a m e n t e
"POR MI RAZA HABLARA EL ESPIRITU"
Cd. Universitaria, a 19 de febrero de 1982
EL DIRECTOR

ING. JAVIER JIMENEZ ESPRIU

"DISEÑO DE UNA NAVE INDUSTRIAL DE 25 M. DE CLARO POR 50 M. DE LARGO CON ELEMENTOS DE CONCRETO PRESFORZADO"

C O N T E N I D O .

I. INTRODUCCION

El objetivo de la presente tesis o trabajo escrito, es la de mostrar el procedimiento para diseñar una nave industrial con elementos de concreto presforzado.

La nave cubre un área de 1250 metros cuadrados, 25 metros de claro por 50 metros de largo. La cubierta esta formada por losas concreto celular para techo, que estan apoyadas en largueros de concreto presforzado, los que a su vez estan apoyadas en trabes portantes presforzadas y estas descansan en columnas de concreto reforzado.

La cubierta consta de losas prefabricadas de concreto ligero de 10 cm de espesor y un peso de 65 kg/m^2.

Los largueros son de concreto presforzado de 5 metros de claro y una sección transversal rectangular de 15 por 30 cm.

Las trabes portantes son también de concreto presforzado de 25 metros de claro y de sección transversal I variable.

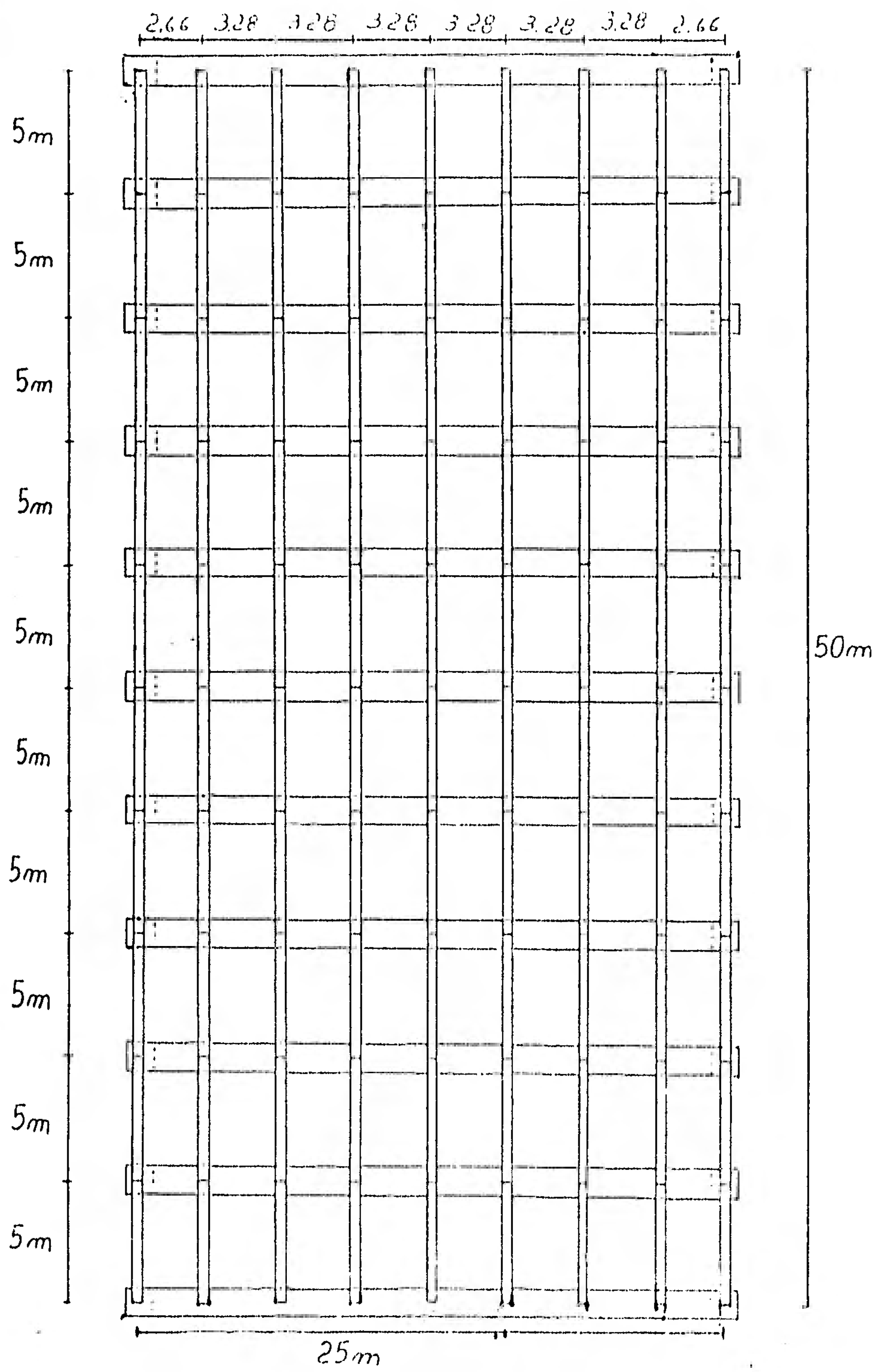
Las columnas son de 4.5 m de altura, de concreto reforzado y una sección rectangular de 35 por 50 cm.

A continuación se dibuja un croquis en planta de la nave en que:

Largueros de 5 m de claro.

Columnas de 35 por 50 cm.

Trabes portantes de 25m de claro y sección I variable.



2,66
3,28
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2,66
5m
5m
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5m
5m
5m
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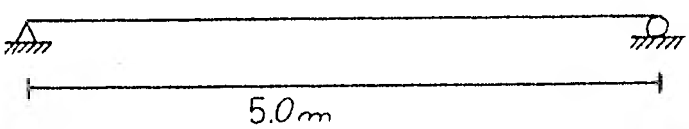
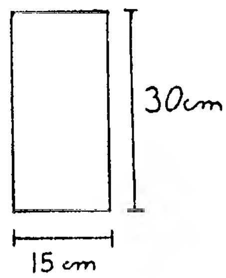
5m
5m
5m
5m
50m
25m

II. DISEÑO DE LARGUEROS

II.1. Datos para el diseño.





DATOS:

w_{cv} = 60 Kg/m^2

w_1 = 65 Kg/m^2 (peso de la cubierta)

w_i = 15 Kg/m^2 (impermeabilizante)

l = 500 cm (claro del larguero)

f'_c = 350 Kg/cm^2

f_{sr} = 1,800 Kg/cm^2

b = 15 cm (ancho del larguero)

h = 30 cm (altura del larguero)

Separación de los largueros de 328 cm

Se emplearán torones de $\phi \frac{5"}{16}$

II.2. Cálculo de las características geométricas

$A = bh$

$A = (15)\ (30)$

$A = 450\ cm^2$

$I = \frac{bh^3}{12}$

$I = \frac{(15)(30)^3}{12}$

$I = 33750\ cm^4$

$y_i = 15\ cm$

$y_s = 15\ cm$

II.3. Determinación de los esfuerzos permisibles.

II.3.1. En el concreto

- Inmediatamente después de la transferencia

$f'_{ci} = 0.8\ f'_c = (0.8)(350) = 280\ kg/cm^3$

. Compresión

$0.6\ f'_{ci} = (0.6)(280) = 168\ kg/cm^3$

. Tensión

$f'_{ci} = 280 = 16.73\ Kg/cm^2$

- Después de las pérdidas.

. Compresión.

$0.45\ f'_c = (0.45)\ (350) = 157.5\ Kg/cm^2$

. Tensión

$2\ f'_c = 2\ 350 = 37.42\ Kg/cm^2$

III.3.2. En el acero de presfuerzo

- Presfuerzo inicial

$0.7\ f_{sr} = (0.7)(18000) = 12600\ Kg/cm^2$

$P_i = (0.372)(12600) = 4687.2\ Kg$ (por cada toron de $\phi\ \frac{5"}{16}$)

Suponiendo un 20% de perdidas

$0.8\ (0.7f_{sr}) = (0.8)(0.7)(18000) = 10080\ Kg/cm^2$

$P = (0.372)(10080) = 3749.76\ Kg$ (por cada toron de $\phi\ \frac{5"}{16}$)

II.4. Esfuerzos actuantes en secciones críticas

La sección crítica que se presenta inmediatamente después de la transferencia se localiza en el apoyo; y la correspondiente a largo plazo, es decir después de las pérdidas se encuentra al centro del claro.

II.4.1. Apoyo

$M_a = 0$

$f_i = 0$

$f_s = 0$

II.4.2. Centro del claro

Cargas:

Carga viva	60 Kg/m^2
Impermeabilizante	15 Kg/m^2
Losa	65 Kg/m^2
	140 Kg/m^2

$$140 \frac{Kg}{m^2} \times 3.28m = 459.2 \ Kg/m$$

$$w_{pp} = \text{Peso propio/m} = A \times \gamma_{concreto} = (0.045 \ m^2)(2400 \ \frac{Kg}{m^2})$$

$$= 108 \ Kg/m$$

$$w_{total} = 459.2 + 108 = 1672 \ Kg/m$$

$$M_a = \frac{w_t \ l^2}{8} = \frac{(567.?)(5)^2}{} = 1772.5 \ Kg\text{-}m$$

$$M_a = 177250 \ Kg\text{-}cm$$

$$f_i = \frac{M_a}{I} y_i = - \frac{177250}{33750}(15) = -78.78 \ Kg/cm^2 \ \text{(tensión)}$$

$$f_j = \frac{M_a}{I} y_s = \frac{177250}{33750}(15) = 78.78 \ Kg/cm^2 \ \text{(compresión)}$$

II.5. Capacidad de presfuerzo de la sección

$$f_i = 0.6 \ kf'_{ci} = (0.6)(0.8)(280) = 134.4 \ Kg/cm^2 \ \text{(impresión)}$$

$$f_s = k \ \ f'_{ci} = 0.8 \ \ 280 = -13.39 \ Kg/cm^2 \ \text{(tensión)}$$

II.6. Comparación de esfuerzos

Sumando los esfuerzos actuantes con los esfuerzos debidos a la capacidad de presfuerzo se obtiene:

$$f_i = 078.78 + 134.4 = 55.62 \ Kg/cm^2 \ \text{(compresión)}$$

$$55.62 < 157.5$$

$$f_s = +78.78 - 13.39 = 65.39 \ Kg/cm^2 \ \text{(compresión)}$$

$$65.39 < 157.5$$

En consecuencia se nota que no es necesario dar la capacidad máxima de presfuerzo a la sección.

II.7. Reducción del presfuerso en la sección:

f_i = 41.36 Kg/cm^2 (compresión)

f_s = 13.39 Kg/cm^2 (tensión)

II.8. Suma de los esfuerzos actuantes y los esfuerzos debidos al presfuerzo reducido; y compararlos con los esfuerzos permisibles.

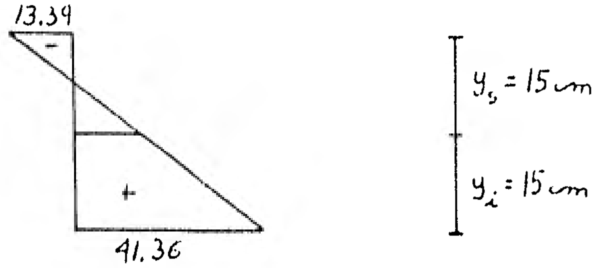
f_i = 78.78 + 41.36 = -37.42 Kg/cm^2 (tensión)

37.42 = 37.42

f_s = +178.78 - 13.39 = 65.39 Kg/cm^2

65.39 < 157.5

II.9. Determinación de la fuerza de presfuerzo (P), número de torones (n) y la colocación.



$$\frac{(\frac{P}{A}) + 13.39}{15} = \frac{13.39 + 41.36}{30}$$

$\frac{P}{A} = \frac{15}{30}\,(13.39 + 41.36) = 19.39$

$P = (13.985)(450)$

$P = 6293.25$ Kg.

$n = \frac{6293.25}{3749.76} - 1.68$

Consecuentemente se emplearán 2 torones de $\phi\ \frac{5"}{16}$

$e_t = \frac{I}{P y_i}\,[f_i - \frac{P}{A}] \;\; \frac{33\ 750}{(6293.25)(15)}[41.36 - 13.985]$

$e_t' = y_i - e_t = 15 - 9.79 = 5.21$ cm

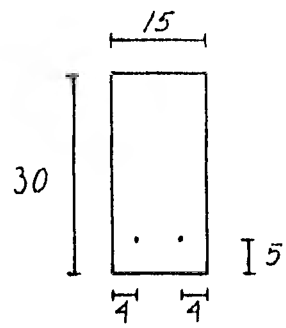
Colocación:

$r_e \geq 2$ cm

$r_{toron} = r_e + \frac{\phi}{2} + \frac{0.7938}{2} = 2.397$ cm $= 2.5$ cm

$S_e \geq 3\phi = (3)\,(0.7938) = 2.38$ cm

$s_f = S_e + \phi = 2.38 + 0.7938 = 3.17$ cm $= 3.5$ cm



$e_r = 10$ cm

II.10. Revisión de esfuerzos

II.10.1. Sección crítica inmediatamente después de la transferencia (apoyo).

$f_i = \frac{P_o}{} - \frac{P_o\,e_r}{}\,y_i\;\frac{(2)(4687.2)}{450} + \frac{(2)(4687.2)(10)}{33750}\,(15)$

$= 62.5$ Kg/cm^2

62.5 < 168

$\therefore$ está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, er}{I} y_s = \frac{(2)(4687.2)}{450} - \frac{(2)(4687.2)(10)}{33750}(15)$$

$$= 20.83\ Kg/cm^2$$

20.83 > 16.73

$\therefore$ se deberá colocar acero de refuerzo ordinario para tomar las tensiones (II.11).

II.10.2. Sección crítica después de las pérdidas (al centro del claro).

$$f_i = \frac{P}{A} + \frac{P_{er}}{I} y_i - \frac{M_a}{I} y_i$$

$$f_s = \frac{P}{A} - \frac{P_{er}}{I} y_s + \frac{M_a}{I} y_s$$

$$P = (2)(3749.76)$$

$$P = 7499.52\ Kg.$$

$$f_i = \frac{7499.52}{450} + \frac{(7499.52)(10)}{33750}(15) - \frac{177250}{33750}(15)$$

$$f_i = -28.78\ Kg/cm^2 \text{ (tensión)}$$

28.78 < 37.42

$\therefore$ está correcta

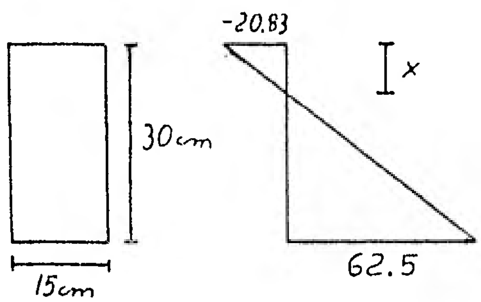
$$f_s = \frac{7499.52}{450} - \frac{(7499.52)(10)}{33750}(15) + \frac{177250}{33750}(15)$$

$$f_s = 62.11\ Kg/cm^2 \text{ (compresión)}$$

62.11 < 157.5

$\therefore$ está correcto

II.11. Cálculo de la cantidad de acero de refuerzo ordinario necesario para tomar las tensiones; correspondiente a la etapa inmediatamente después de la transferencia.



$$\frac{62.5 + 20.83}{30} = \frac{20.83}{x}$$

$$x = 7.5 \text{ cm}$$

$$F = \frac{1}{2}(20.83)(7.5)(15)$$

$$F = 1171.69 \text{ Kg.}$$

Datos del acero de refuerzo ordinario:

$f_y = 4200 \text{ Kg/cm}^2$

$\phi = \frac{5''}{16}$

$a_s = 0.49 \text{ cm}^2$

$f_e = 0.6\ f_y$

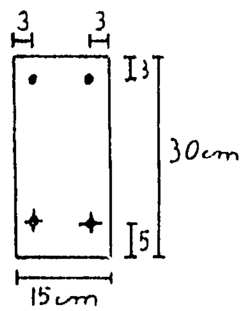
$f_e = 2520 \text{ Kg/cm}^2$

El área de acero necesario será:

$$A_s = \frac{F}{f_p} = \frac{1171.69}{2520} = 0.46 \text{ cm}^2$$

Por lo que una barra de $\phi \frac{5''}{16}$ sería suficiente. Sin-embargo para facilitar el armado del acero transversal necesario para cortante; se colocarán 2 barras de $\phi \frac{5''}{16}$.

Finalmente quedará:



II.12. Revisión por resistencia.

La sección que se debe revisar, es decir la sección - crítica, es la que se encuentra al centro del claro.

II.12.1. Cálculo del momento último actuante.

$M_a = 177250$ Kg-cm

$M_{ua} = F.C.\ M_a$

$M_{ua} = (1.4)(177250)$

$M_{ua} = 248150$ Kg-cm

II.12.2. Cálculo de f_{sp}

$$f_{sp} = f_{sr}\ (1 - 0.5\ P_p \frac{f_{sr}}{f'_c})$$

$$p_p = \frac{A_{sp}}{bd}$$

$$A_{sp} = 2(0.372) = 0.744 \text{ cm}^2$$

$$b = 15 \text{ cm}$$

$$d = 25 \text{ cm}$$

$$p_p = \frac{0.744}{(15)(25)}$$

$$p_p = 0.002$$

$$f_{sr} = 18000 \text{ Kg/cm}^2$$

$$f'_c = 350 \text{ Kg/cm}^2$$

$$f_{sp} = 18000 \left[1 - (0.5)(0.003) \frac{18000}{350}\right]$$

$$f_{sp} = 17081.69 \text{ Kg/cm}^2$$

II.12.3. Cálculo de a.

$$a = \frac{A_{sp} \, f_{sp}}{bf''_c}$$

$$f^*_c = 0.8F'_c = (0.8)(350) = 280 \text{ Kg/cm}^2$$

$$f''_c = (1.05 - \frac{f^*_c}{1250}) \, f^*_c = (1.05 - \frac{280}{1250}) \, 280 = 231.28 \text{ Kg/cm}^2$$

$$a = \frac{(0.744)(17081.69)}{(15)(231.28)}$$

$$a = 3.66 \text{ cm}$$

II.12.4. Cálculo de M_{uR}

$$M_{uR} = F_R \left[A_{sp} \cdot f_{sp}\right] (d - \frac{a}{2})]$$

$M_{uR} = 0.9\ [(0.744)(17081.69)(25 - \frac{3.66}{2})]$

$M_{uR} = 264997.17$ Kg-cm

$M_{uR} = 264997.17$ Kg-cm $> M_{ua} = 248150$ Kg-cm

.'. está correcto por resistencia.

II.13. Verificación del tipo de falla

Se deberá cumplir que:

$$E_{sp} + E_i > E_{yp}$$

II.13.1. Cálculo de E_{sp}

$$c = \frac{a}{0.8}$$

$$c = \frac{3.66}{0.8}$$

$$c = 4.575 \text{ cm}$$

$$E_{sp} = \frac{(d-c)(0.003)}{c}$$

$$E_{sp} = \frac{(25-4.575(0.003)}{4.575}$$

$$E_{sp} = 0.0134$$

II.13.2. Cálculo de E_i

$$E_i = \frac{f_i}{E_s} = \frac{12600}{1.9\times10^6}$$

$$E_i = 0.0066$$

II.13.3.

$E_{sp} + E_i = 0.0134 + 0.0066$

$E_{sp} + E_i = 0.02$

$E_{yp} = 0.01$

$E_{sp} + E_i = 0.02 > E_{yp} = 0.01$

.'. El tipo de falla es dúctil.

III.14. Revisión del acero mínimo

$M_{uR} \geq 1.2\ M_{agriet.}$

$$M_{agriet} = \frac{I}{y_i} \left[\frac{P}{A} + \frac{P_e}{J} y_i + 2 \quad f'_c \right]$$

$$M_{agriet} = \frac{33750}{15} \left[\frac{(2)(3749.76)}{450} + \frac{(2)(3749.76)}{33750}(15) + 350 \right]$$

$M_{agrieg} = 196680.09$ Kg-cm

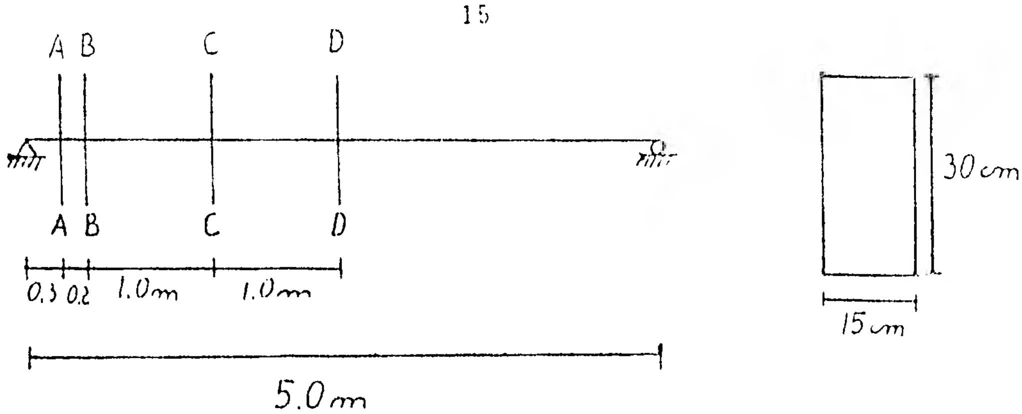
$M_u R = 264891.3$ Kg-cm $> 1.2\ M_{agriet} = 236016.1$ Kg-cm

.'. cumple con el requisito de acero mínimo

II.15. Revisión por cortante.

Se colocarán estribos de 5/16"; con fy = 4200 Kg/cm^2

- Las secciones críticas que se deben revisar son:



$x_A = 30$ cm

$x_B = 50$ cm

$x_C = 150$ cm

$x_D = 250$ cm

- Cálculo del cortante y momento actuante en cada sección.

$V_x = R - wx$

$M_x = Rx - \frac{wx^2}{2}$

$R = \frac{wl}{2} = \frac{(567.2)(5)}{2} = 1418$ Kg

$V_x = 1418 - 5.672x$

$M_x = 1418x - 5.672\ \frac{x^2}{2}$

Para $x_A = 30$ cm

$V_A = 1418 - (5.672)(30) = 1247.84$ Kg

$M_A = (1418)(30) - (5.672)\ \frac{(30)^2}{2} = 39987.6$ Kg-cm

Para x_B = 50 cm:

$$V_B = 1418 - (5.672)(50) = 1134.4 \text{ Kg}$$

$$M_B = (1418)(50) - (5.672)\frac{(50)^2}{2} = 63810 \text{ Kg-cm}$$

Para x_C = 150 cm:

$$V_C = 1418 - (5.672)(150) = 567.2 \text{ Kg}$$

$$M_C = (1418)(150) - (5.672)\frac{(150)^2}{2} = 148890 \text{ Kg-cm}$$

Para x_D = 250 cm:

$$V_D = 1418 - (5.672)(250) = 0$$

$$M_D = (1418)(250) - (5.672)\frac{(250)^2}{2} = 177250 \text{ Kg-cm}$$

Obtención de V_c

$$V_c = F_R bd(0.15 \quad f_c^* + 50 \frac{Va}{Ma} d_t)$$

$$= (0.8)(15)(25)[0.15 \quad 280 + (50)(25)\frac{Va}{Ma}]$$

$$V_c = 752.99 + 375000 \frac{Va}{Ma}$$

$$V_{c\ máximo} = F_R\ 1.3\ bd \quad f_c^*$$

$$V_{c\ máx} = (0.8)(1.3)(15)(25) \quad 280$$

$$V_{c\ máx} = 2509.98 \text{ Kg}$$

-Fuerza cortante máxima permisible:

$$V_{ua\ perm.} = (2.5)(0.8)(15)(25) \quad 280$$

$V_{ua\ perm.} = 12549.9$ Kg.

- Separación por área mínima:

$$S \leq \frac{F_R\ A_v\ f_y}{3.5\ b} = \frac{(0.8)(0.98)(4200)}{(3.5)\ (15)} = 62.72 \text{ cm}$$

- Por separación máxima:

Como: $V_{ua} \leq 1.5\ F_R\ bd\ \ f_c^* = (1.5)(0.8)(15)(25)\ \ 280$

$= 7529.94$

$$S_{máx} = 0.75\ h = (0.75)(30) = 22.5 \text{ cm}$$

	secciones / conceptos	A	B	C	D	Observaciones
1	Va	1247.84	1134.4	567.2	0	Kg
2	Ma	39987.6	63810	148890	177230	Kg-cm
3	$375000 \frac{Va}{Ma}$	11702.13	6666.67	1428.57	0	
4	$V_c = 752.99 + 37500 \frac{Va}{Ma}$	12455.12	7419.66	2161.56	751.99	
5	V_c definitivo	6525.95	6525.95	2509.98	2509.98	$V_{c\,máx}$ =6525.95 $V_{c\,mín}$ =2509.98
6	V_{ua}					$V_{ua\,máx}$ =125499 ∴ no se cambia sección
7	$V' = V_{ua} - V_c$					
8	$S_{req.} = \frac{F_R A_v f_{yd}}{V'}$					se requieren estribos para especificación.
9	$S_{sm} = \frac{F_R A_v f_{yd}}{3.5b}$	62.72	62.72	62.72	62.72	Separación por área mínima
10	$S_{máx} = 0.75$	22.5	22.5	22.5	22.5	
11	S	22.5	22.5	22.5	22.5	
12	$S_{def.}$	20	20	20	20	
Revisión						
13	$V' = \frac{F_R A_v f_{yd}}{S}$	4116	4116	4116	4116	
14	$V_{uR} = V_c + V'$	10641.95	10641.95	6625.98	6514.98	
15	$V_{uR} > V_{ua}$	Correcto	Correcto	Correcto	Correcto	

II.16. Refuerzo vertical en zonas de anclaje de presfuerzo.

Empleando el procedimiento para reforzar los extremos de las vigas para

$$\frac{e}{h} = \frac{10}{30}$$

$$\frac{e}{h} = 0.33$$

Pe = (2)(3849.76)(10) = 74995.2 Kg-cm.

y	$\frac{2}{h}$	$\frac{M}{Pe}$	M Kg-cm
0	0	0	0
3	0.1	0.04	2999.8
6	0.2	0.1	7499.52
9	0.3	-0.01	-749.95
12	0.4	-0.09	-6749.57
15	0.5	-0.11	-8249.47
18	0.6	-0.1	-7499.52
21	0.7	-0.08	-5999.62
24	0.8	-0.03	-2249.86
27	0.9	0	0
30	1.0	0	0

$M_{máx}$ = 8249.47 Kg-cm

$$T = \frac{M}{h-z} = \frac{8249.47}{30 - 7.5} = 366.64 \text{ Kg}$$

$$f_s = 1.67 \left[\frac{E_s \quad f'_c \quad w}{d_s} \right]^{\frac{1}{2}} \leq 0.6 \text{ fy}$$

$$f_s = 1.67 \left[\frac{(x10^6) \quad (350) \quad (0.01)}{0.71} \right]^{\frac{1}{2}}$$

$$f_s = 1212 \text{ Kg/cm}^2 < 2520 \text{ Kg/cm}^2 = 0.6 \text{ fy}$$

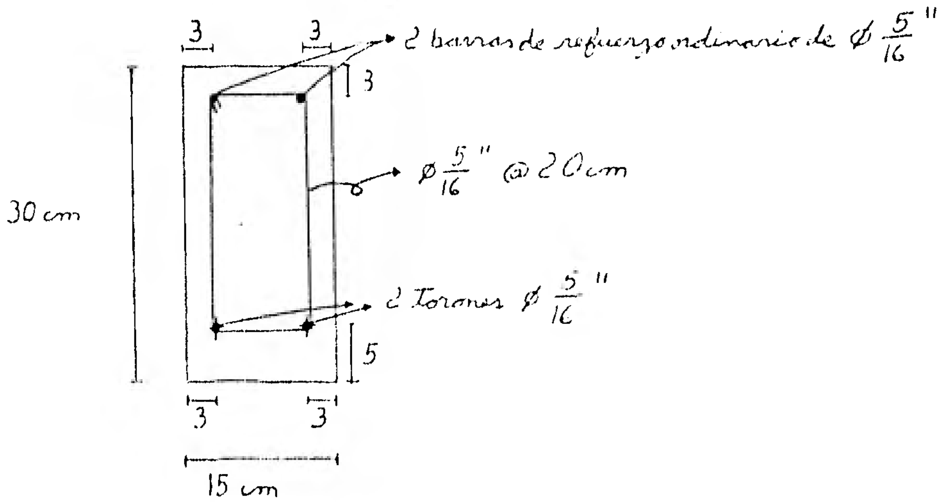
$$A_s = \frac{T}{f_s} = \frac{366.64}{1212}$$

$$A_s = 0.3 \text{ cm}^2$$

$$n = \frac{A_s}{a_s} = \frac{0.3}{(2)(0.71)} = 0.21$$

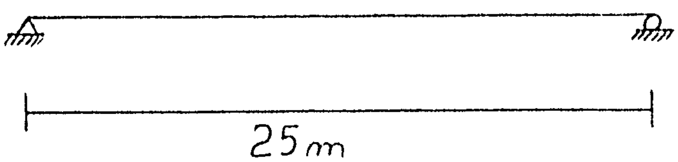
.'. Prácticamente no es necesario colocar refuerzo vertical- adicional al que se necesita por cortante en las zonas - de anclaje de presfuerzo.

II.17. Armado propuesto.



III. DISEÑO DE TRABES PORTANTES

III.1. Datos para el diseño.



- Datos:

l = 25 m

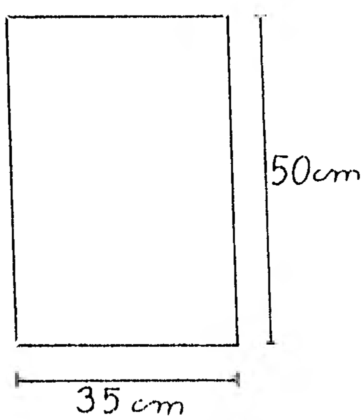
f'_c = 350 Kg/cm^2

f_{sr} = 18000 Kg/cm^2

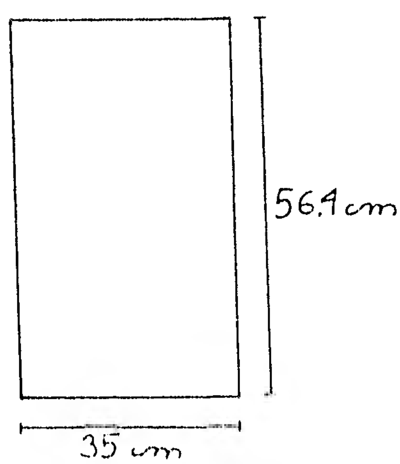
Se emplearon torones de $\phi \frac{3"}{8}$

- La sección transversal varía de la siguiente forma:

. De 0 m (apoyo) a 0.8 m, la sección es rectangular.

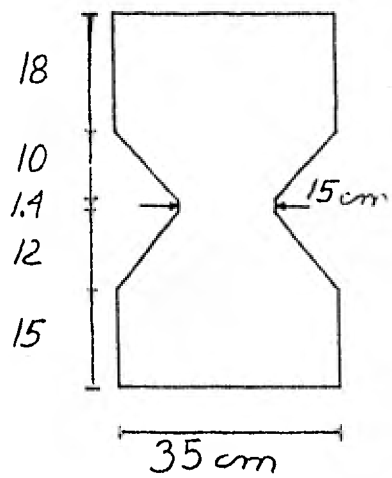


Extremo

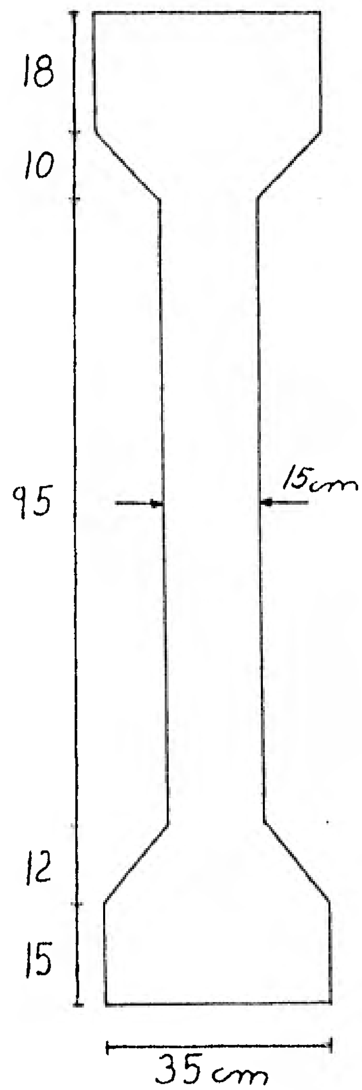


a 80 cm del extremo

- De 0.8 m a 12.5 (centro del claro), la sección es I.



a 0.8 m del extremo



al centro del claro

- Cálculo de las cargas.

$w_{cubierta} = 65\ Kg/m^2$

$w_{cv} = 60\ Kg/m^2$

$w_I = \underline{15}\ Kg/m^2$

$\Sigma w\ \ 140\ Kg/m^2$

$(140\ Kg/m^2)(5m)(3.28m) + 540\ Kg = 2836\ Kg.$

$(140\ Kg/m^2)(5m)(1.64m + 1.33m) + 540\ Kg. = 2619\ Kg.$

$(140\ Kg/m^2)(5m)(1.33m) + 540\ Kg = 1471\ Kg.$

Vol. larguero $\gamma_{correcto} = (0.225\ m^3)(2400\ \frac{Kg}{m^3}) = 540\ Kg$

Cálculo de las áreas transversales en el extremo, a 80 cm - del extremo; y al centro del claro.

$A_0 = 1750\ cm^2$ (extremo de la trabe)

$A_{80I} = 1974\ cm^2$ (izquierda)

$A_{80D} = 1726\ cm^2$ (derecha)

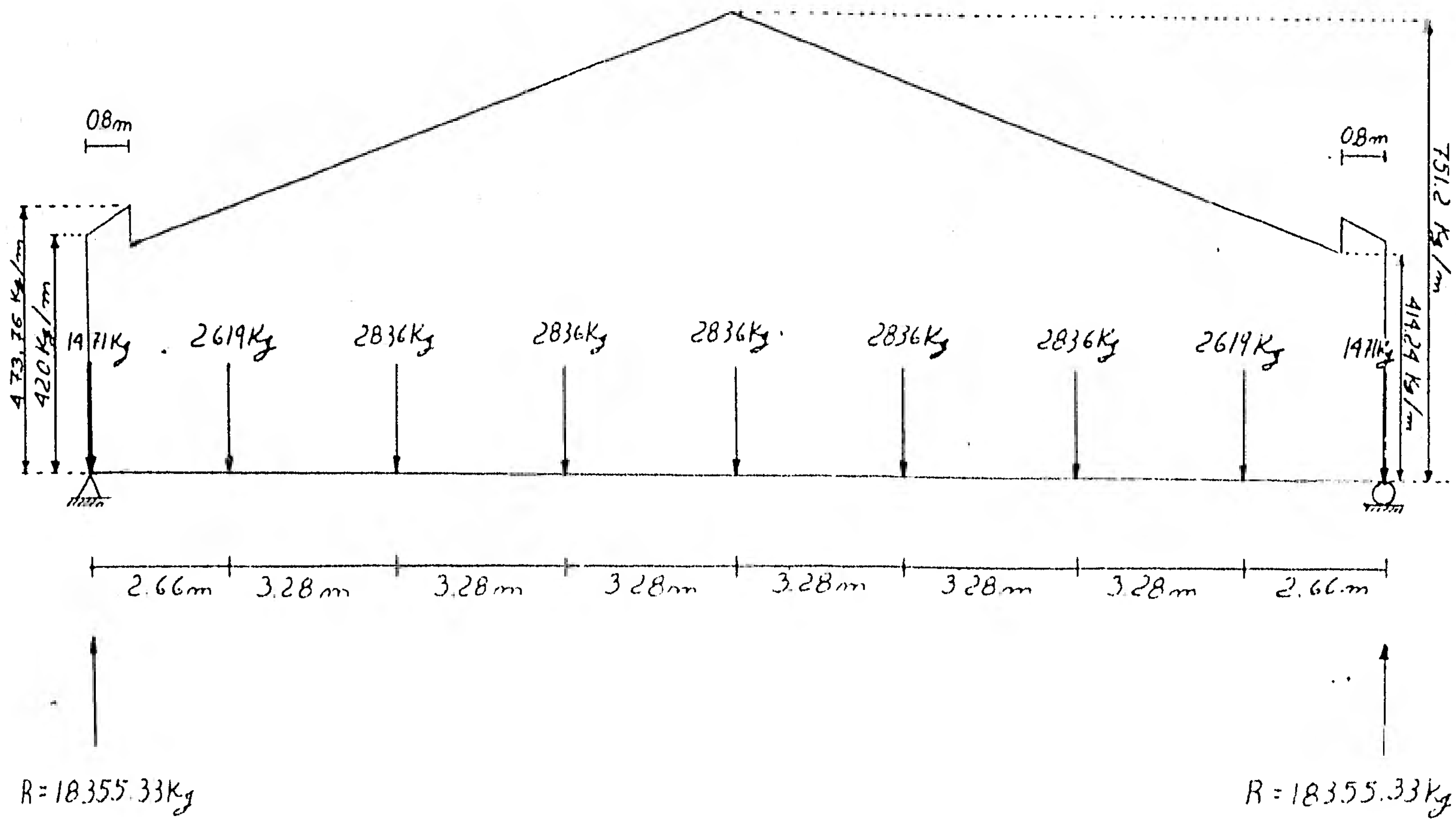
$A = 3130\ cm^2$ (centro del claro)

$A_o\gamma_{concreto} = (0.175)(2400) = 420\ Kg/m$

$A_{80I}\ \gamma_{concreto} = (0.1974)(2400) = 473.76\ Kg/m$

$A_{80D}\ \gamma_{concreto} = (0.1+26)(2400) = 414.24\ Kg/m$

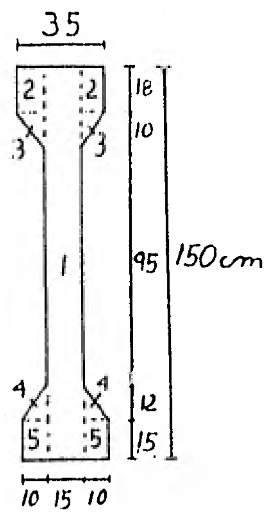
$A\ \ \gamma_{concreto} = (0.3130)(2400) = 751.2\ Kg/m$



08m
08m
473.76 Kg/m
420 Kg/m
751.2 Kg/m
414.24 Kg/m
1471Kg
2619Kg
2836Kg
2836Kg
2836Kg
2836Kg
2836Kg
2619Kg
1471Kg
2.66m
3.28m
3.28m
3.28m
3.28m
3.28m
3.28m
2.66m
R=18355.33Kg
R=18355.33Kg

III.2 Cálculo de las características geométricas

- Al centro del claro.



Elementos	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	2250	75	168750	-0.69	0.4761	1071.23	4218750
2	360	141.67	50760	65.31	4265.4	1535542.6	9720
3	100	128.67	12867	52.98	2806.88	280688.04	555.56
4	120	19	2280	-56.69	3213.76	385650.73	960
5	300	7.5	2250	-68.19	4644.88	1394962.83	5625
Σ	3130		236907			3597915.43	4235610.56

$A = 3130 \text{ cm}^2$

$$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{236907}{3130} = 75.69 \text{ cm.}$$

$y_i = 75.69$ cm

$y_s = 74.31$ cm

$I = \Sigma I + \Sigma Ad^2$

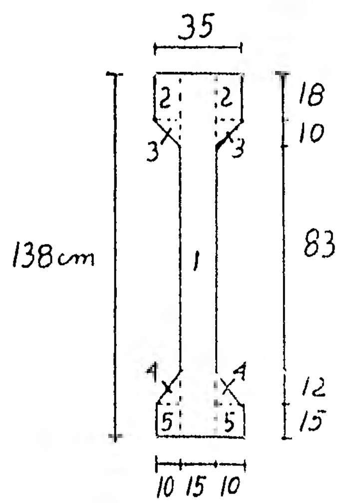
$I = 4235610.56 + 3597915.43$

$I = 7833525.99\ cm^4$

$e_r = 75.69 - 15.3 = 60.39\ cm$

$e_r = 60.39\ cm$

- A 11 m del extremo de la trabe.



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	2070	69	142830	-0.65	0.4225	874.58	3285090
2	360	129	46440	49.35	3522.42	1268072.1	9720
3	100	116.67	1666.7	47.02	2210.88	221088.04	555.56
4	120	19	2280	-50.65	2565.42	3078850.7	960
5	300	7.5	2250	-62.15	3862.62	1158786.35	5625
Σ	2950		205466.7			2956672.17	3301950.56

$A = 2950\ cm^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{205466.7}{2950} = 69.65$

$y_i = 69.65\ cm$

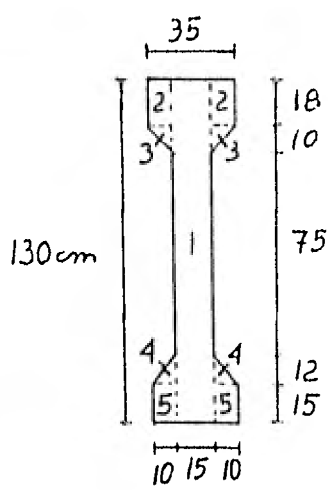
$y_s = 68.35\ cm$

$I = \Sigma I + \Sigma Ad^2 = 3301950.56 + 2956672.17$

$I = 6258622.73\ cm^4$

$e = 54.35\ cm$

- A 10 m del extremo de la trabe.



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1950	65	126750	-0.62	0.3844	749.58	2746250
2	360	12.1	43560	55.38	3066.94	1104019.98	9720
3	100	108.67	10867	43.05	1853.3	185330.25	555.56
4	120	19	2280	-46.62	2173.42	260810.93	960
5	300	7.5	2250	-58.12	3377.93	1013380.32	5625
	2830		185707			2564371.06	2763111.56

$A = 2830\ cm^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{185707}{28.30} = 65.62$

$y_i = 65.62\ cm$

$y_s = 64.38\ cm$

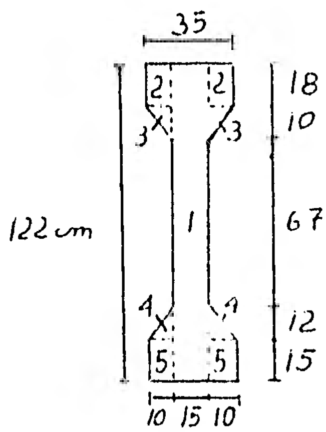
$I = \Sigma I + \Sigma Ad^2$

$I = 2763110.56 + 2569371.06$

$I = 5327481.62\ cm^4$

$e_r = 50.32\ cm.$

- A 9 m del extremo de la trabe.



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1830	61	111630	-0.59	0.35	63702	2269810
2	360	113	40680	51.41	2642.99	951475.72	9720
3	100	100.67	10067	39.08	1527.25	152724.64	555.36
4	120	19	2280	-42.59	1813.9	217668.97	960
5	300	7.5	2250	-54.09	2925.75	877718.43	5625
Σ	2710		166907			2200224.86	2286670.56

$A = 2710 \text{ cm}^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{166907}{2710} = 61.59 \text{ cm}$

$Y_i = 61.59 \text{ cm}$

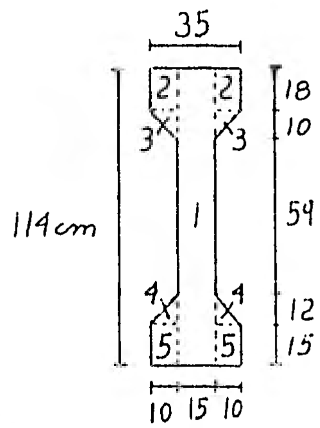
$y_s = 60.41 \text{ cm}$

$I = I + \Sigma Ad^2 = 2286670.56 + 2200224.86$

$I = 4486895.42 \text{ cm}^4$

$e_r = 46.20 \text{ cm}$

- A 8 m del extremo de la trabe.



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1710	57	97970	-0.55	0.3025	5172	1851930
2	360	105	37800	47.45	2251.5	810540.9	9720
3	100	92.67	9266.67	35.12	1233.41	123341.44	555.56
4	120	19	2280	-38.55	1486.1	178333.3	960
5	300	7.5	2250	-50.65	2565	751500.75	5625
Σ	2590		149066.67			1864332.67	1868790.56

$A = 2590\ cm^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{149066.67}{2590} = 57.55\ cm$

$y_i = 57.55\ cm$

$y_s = 56.45\ cm$

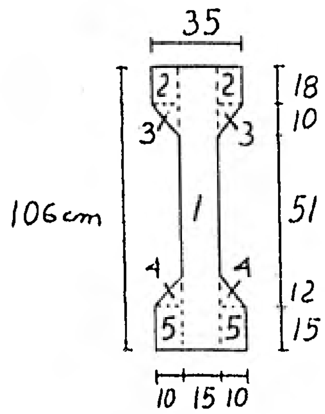
$I = \Sigma I + \Sigma Ad^2 = 1868790.56 + 864232.67$

$I = 3733023.22\ cm^4$

$e_r = 57.55 = 15.3 = 42.25\ cm$

$e_r = 42.25\ cm$

- A 7 m del extremo de la trabe



Elementos							
1	1590	53	84270	-0.52	0.2704	429.94	1488770
2	360	97	34920	43.48	1890.51	680583.71	9720
3	100	84.67	89667	31.15	970.32	97032.25	555.56
4	120	19	2280	-34.52	1191.63	142995.65	960
5	300	7.5	2250	046.02	2117.84	635358.72	5625
Σ	2470		132186.7			1556393.7	1505630.56

$A = 2470 \text{ cm}^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{132186.7}{2470} = 53.52 \text{ cm}$

$y_i = 53.52 \text{ cm}$

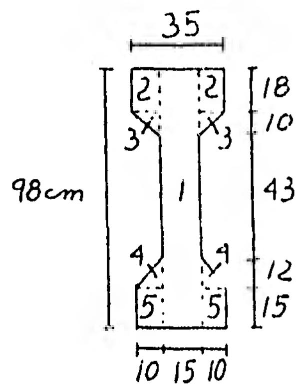
$y_s = 52.48 \text{ cm}$

$I = I + \Sigma A d^2 = 1505630.56 + 1556393.7$

$I = 3062024.26 \text{ cm}^4$

$e_r = 38.22 \text{ cm}$

- A 6 metros del extremo de la trabe



Elementos	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1470	49	72030	-0.48	0.23	21038.09	1176490
2	360	89	32040	39.52	1561.83	562258.44	9720
3	100	76.67	7666.7	27.19	739.3	73929.61	555.56
4	120	19	2280	-30.48	939.03	111483.65	960
5	300	7.5	2250	-41.98	1762.32	528696	5625
Σ			116766.7			1276707	1193350.56

$A = 2350\ cm^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{116266.7}{2350} = 49.48\ cm$

$y_i = 49.48\ cm$

$y_s = 48.52\ cm$

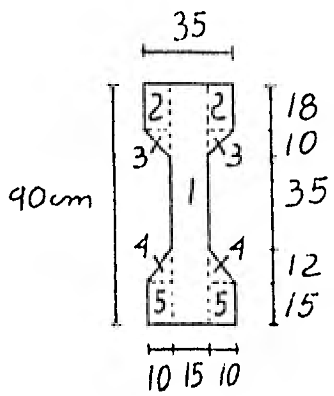
$I = \Sigma I + \Sigma Ad^2 = 1193350.56 + 1276707$

$I = 2470057.57\ cm^4$

$e = 49.48 - 15.3$

$e_r = 34.18\ cm$

- A 5 metros del extremo de la trabe



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1350	45	60750	-0.43	0.184	249.62	911250
2	360	81	29160	35.57	1265.22	455480.96	9720
3	100	68.67	6866.7	23.29	540.097	54009.76	555.56
4	120	19	2280	-26.43	698.5	83825.39	960
5	300	7.5	2250	-37.93	1438	431605.47	5625
Σ	2230		101306.67				928110.56

$A = 2230 \text{ cm}^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{101306.67}{2230} = 45.43 \text{ cm}$

$y_i = 45.43 \text{ cm}$

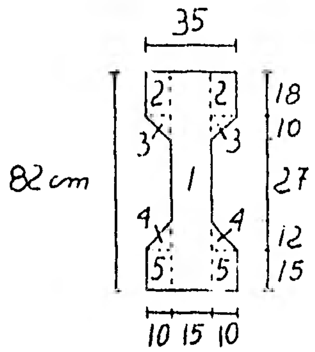
$y_s = 44.57 \text{ cm}$

$I = \Sigma I + \Sigma Ad^2 = 928110.56 + 1025171.197$

$I = 1953281.76 \text{ cm}^4$

$e_I = 30.13 \text{ cm}$

- A 4 metros del extremo de la trabe



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1230	41	50930	-0.38	0.1449	177.61	689210
2	360	73	26280	31.62	99982	359936.78	9720
3	100	60.67	6066	19.29	378.1	27810.41	555.56
4	120	19	2280	-22.38	500.86	60103.73	960
5	300	7.5	2250	-33.88	1147.85	344356.32	5625
Σ	2110		87306			801784.85	706070.56

$A = 2110 \text{ cm}^2$

$$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{87306}{2110} = 41.38 \text{ cm}$$

$y_i = 41.38 \text{ cm}$

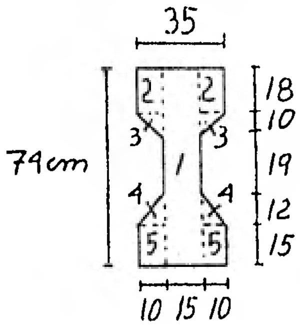
$y_s = 40.62 \text{ cm}$

$I = \Sigma I + \Sigma Ad^2 = 706070.56 + 801784.85$

$I = 1507855.41 \text{ cm}^4$

$e_r = 26.08 \text{ cm}$

- A 3 metros del extremo de la trabe.



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	1110	37	41070	-0.32	0.1024	113.66	506530
2	360	65	23400	27.68	766.18	275825.66	9720
3	100	52.67	5266.7	15.35	235.62	23562.25	555.56
4	120	1.9	2280	-18.32	335.62	40274.69	960
5	300	7.5	2250	-29.82	889.23	266769.72	5625
Σ	1990		74266.7			606545.99	523390.56

$A = 1990$ cm

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{74266.7}{1990} = 37.32$ cm

$y_i = 37.32$ cm

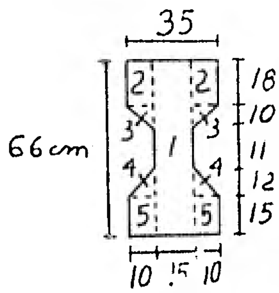
$y_s = 36.68$ cm

$I = \Sigma I + \Sigma Ad^2 = 523390.56 + 606545.99$

$I = 1129936.55$ cm^4

$e = 22.02$ cm

- A 2 metros del extremo de la trabe



Elementos.	A	$\bar{y}$	$A\bar{y}$	d	d^2	Ad^2	I
1	990	33	32670	-0.25	0.0614	61.88	359370
2	360	57	20520	23.75	564.06	203062.5	9720
3	100	44.67	4466.7	11.42	130.42	13041.64	555.56
4	120	19	2280	-14.25	203.06	24367.5	960
5	300	7.5	2250	-25.75	663.06	198918.75	5625
Σ	1870		62186.7			439952.26	376230.56

$A = 1870\ cm^2$

$$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{62186.7}{1870} = 33.25\ cm$$

$y_i = 33.25\ cm$

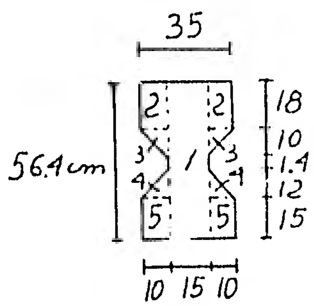
$y_s = 32.75\ cm$

$I = \Sigma I + \Sigma Ad^2 = 376230.56 + 439452.26$

$I = 815682.83\ cm^4$

$e = 17.95\ cm$

- A 80 centímetros del extremo de la trabe.



Elementos.							
1	846	28.2	23857.2	-0.17	0.0289	24.45	224257.68
2	360	47.4	17064	19.03	362.14	130370.72	9720
3	100	35.07	3506.67	6.7	44.89	4489	555.56
4	120	19	2280	-9.37	87.8	10535.63	960
5	300	7.5	2250	-20.87	435.56	130667.07	5625
Σ	1726		48957.87			276086.87	241118.24

$A = 1726 \text{ cm}^2$

$y_i = \frac{\Sigma A\bar{y}}{\Sigma A} = \frac{48957.87}{1726} = 28.37$

$y_i = 28.37 \text{ cm}$

$y_s = 28.03 \text{ cm}$

$I = \Sigma I + \Sigma Ad^2 = 241118.24 + 276086.87 = 51705.11$

$I = 517205.11 \text{ cm}^4$

$e = 13.07 \text{ cm}$

III.3. Determinación de los esfuerzos permisibles.

III.3.1. En el concreto.

- Inmediatamente después de la transferencia

$f'_{ci} = 0.8\ f'_c = (0.8)(350) = 280\ Kg/cm^2$

. Compresión.

$0.6\ f'_{ci} = (0.6)(280) = 168\ Kg/cm^2$

. Tensión.

$f'_{ci} = 280 = 16.73\ Kg/cm^2$

- Después de las pérdidas

. Compresión

$0.45\ f'_c = (0.45)(350) = 37.42\ Kg/cm^2$

III.3.2. En el acero de presfuerzo

- Presfuerzo inicial

$0.7\ f_{sr} = (0.7)(18000) = 12600\ Kg/cm^2$

$P_i = (0.516)(12600) = 6501.6$ Kg (por cada toron de $\phi\ \frac{3''}{8}$

- Presfuerzo efectivo

Suponiendo un 20% de pérdidas por relajación del acero de presfuerzo se tiene:

$0.8(0.7f_{sr}) + (0.8)(0.7)(18000) = 10080\ Kg/cm^2$

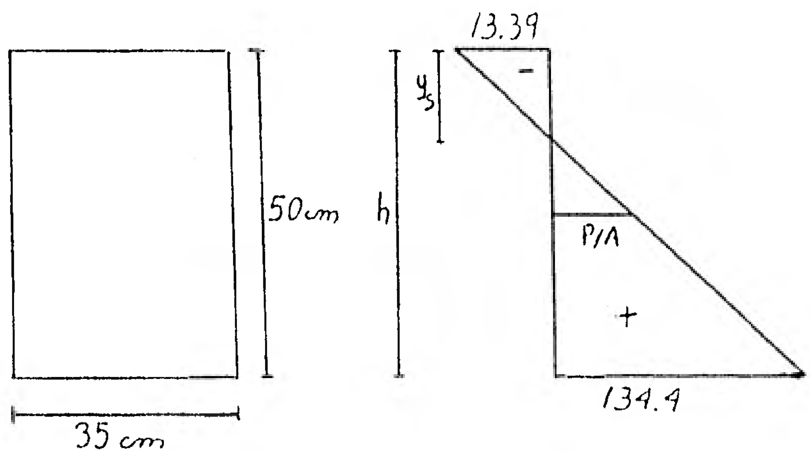
$P = (0.516)(10080) = 5201.28$ Kg (por cada toron de $\phi\ \frac{3''}{8}$

III.4. Cálculo de la capacidad de presfuerzo.

$f_i = 0.6 \; kf'_{ci} = (0.6)(0.8)(280) = 134.4$ Kg/cm^2 (compresión)

$f_s = k \;\; f'_{ci} \;\; = 0.8 \;\; 280 \;\; = -13.39$ Kg/cm^2 (tensión)

III.4.I. Capacidad de presfuerzo en el extremo de la trabe.



$$\frac{134.4 + 13.39}{h} = \frac{13.39 + \frac{P}{A}}{y_s}$$

$$\frac{P}{A} = \frac{y_s}{h} (134.4 + 13.39) - 13.39$$

$$\frac{P}{A} = \frac{25}{50} (134.9 + 13.39) - 13.39$$

$$\frac{P}{A} = 60.5 \;\; \text{Kg/cm}^2$$

$P = (60.5) \; A = (60.5) \; (35) \; (50)$

$P = 105883.75$ Kg

$$e_t = \frac{I}{Py_i}\left[f_i - \frac{P}{A} \right]$$

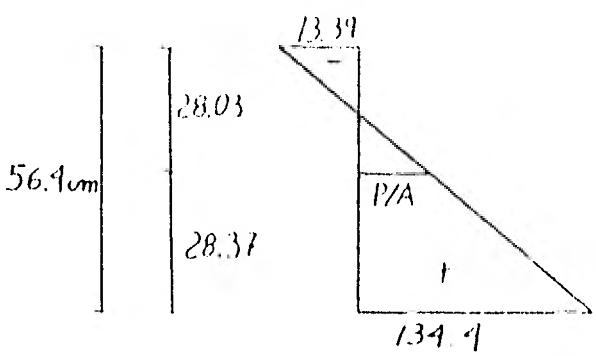
$$I = \frac{(35)(50)^3}{12} = 364583.33 \text{ cm}^4$$

$$e_t = \frac{3.64583.33}{(105883.75)(25)} [134.4 - 60.5]$$

$$e_t = 10.18 \text{ cm}$$

$e_t' = 14.82$ cm (distancia del centroide del presfuerzo a la fibra inferior)

III.4.2. Capacidad de presfuerzo en el extremo de la sección 1.



$A = 1726 \text{ cm}^2$

$I = 517205.11 \text{ cm}^4$

$$\frac{13.39 + 13.44}{56.4} = \frac{13.39 + \frac{P}{A}}{28.03}$$

$$\frac{P}{A} = \frac{28.03}{56.4} [13.39 + 134.4] - 13.39$$

$\frac{P}{A} = 60.06\ Kg/cm^2$

$P = (60.06)(1726)$

$P = 103662.76\ Kg$

$e_t = \frac{I}{Py_i}\ [\ f_i - \frac{P}{A}\ ]$

$e_t = \frac{517205.11}{(103662.76)(28.37)}\ [\ 134.4 - 60.06\ ]$

$e_t = 13.07\ cm$

$e_t' = 15.3\ cm$ (distancia del centroide del presfuerzo a la fi bra inferior)

III.4.3. En resumen en la sección rectangular se tiene:

$P_0 = 105883.75\ Kg$

$e_{t_0}' = 14.82\ cm$

y en la sección I se obtiene:

$P_I = 103662.76\ Kg.$

$e_{t_I}' = 15.3\ cm$

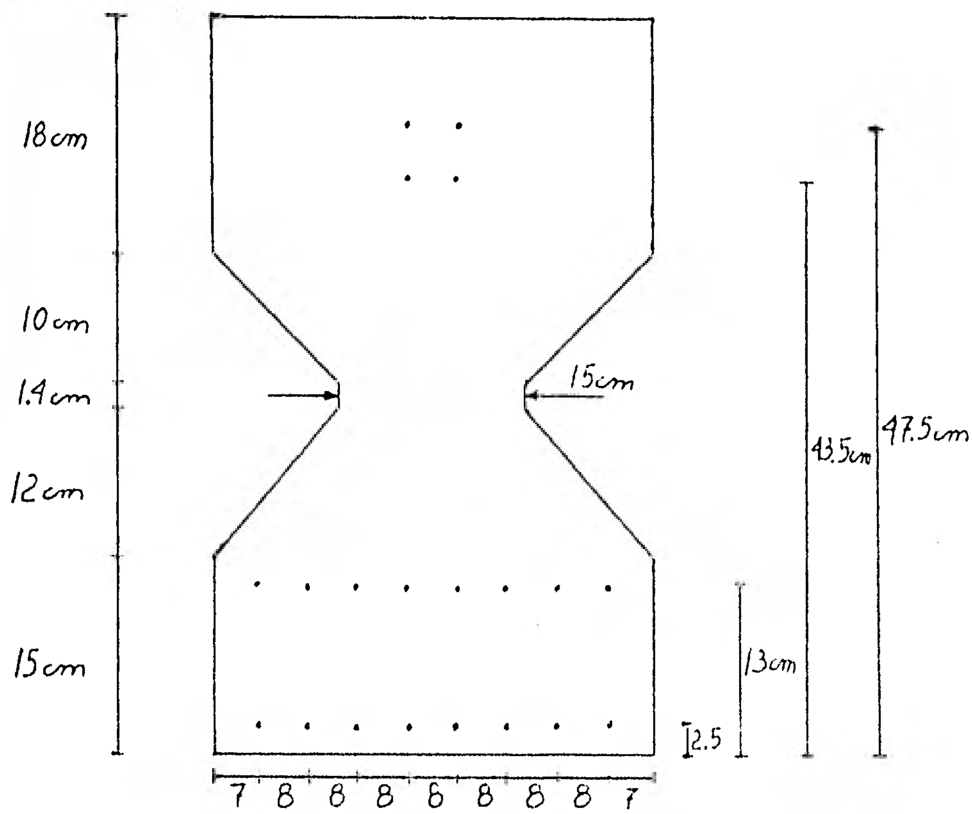
Consecuentemente como:

$P_I = 103662.76\ Kg < P_0 = 105883.75\ Kg$

$e_{t'_I} = 15.3\ cm > e_{t'_0} = 14.82\ cm$

el presfuerzo que rige en la trabe portante la define la sec ción crítica I, (a 80 cm del apoyo).

III.5. Determinación de la fuerza de presfuerzo (P), número de torones (n) y la colocación.



P = 103662.76 Kg

$$n = \frac{P_{efect}}{P_{toron}}$$

$$n = \frac{103662.76}{5201.28}$$

n = 19.93 ≐ 20 torones

La colocación de los torones deberá cumplir con:

$$r_t = 2\text{ cm} + \frac{\phi}{2} = 2 + \frac{0.9525}{2} = 2.476\text{ cm} \doteq 2.5\text{ cm}$$

r_t = 2.5 cm

$s_t = s_e + \phi = 3\phi + \phi = 3(0.9525)+0.9525 = 3.81$ cm $\doteq 4$ cm.

$s_t = 4$ cm

La distancia del centroide del presfuerzo a la fibra extrema inferior es de:

$$e'_r = \frac{(8)(2.5) + (8)(13) + (12)(43.5) + (2)(47.5)}{20}$$

$e'_r = 15.3$ cm

III.6. Revisión de esfuerzos

$P_o = n\ P_{o\ toron} = (20)(6501.6) = 130032$ Kg.

$P = n\ P_{toron} = (20)(5201.28) = 104025.6$ Kg.

$e'_{rese} = 15.3$ cm

III.6.1. Inmediatamente después de la transferencia

- Apoyo (Sección A)

$A = 1870\ cm^2$

$e_r = 25 - 15.3 = 9.7$ cm

$I = 364583.33\ cm^4$

$y_i = 25$ cm

$y_s = 25$ cm

$$f_i = \frac{P_o}{A} + \frac{P_o\ e_r}{I}\ y_i$$

$$f_i = \frac{130032}{1750} + \frac{(130032)(9.7)}{364583.33}\ (25)$$

$f_i = 160.79 \text{ Kg/cm}^2$ (compresión)

$160.79 < 168$

.·. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

$$f_s = \frac{130032}{1750} - \frac{(130032)(9.7)}{364583.33}(25)$$

$f_s = 12.19 \text{ Kg/cm}^2$ (tensión)

$12.19 < 16.73$

.·. está correcto

Sección C izquierda (a 80 cm del apoyo)

$A = 1974 \text{ cm}^2$

$e_r = 28.2 - 15.3 = 12.9 \text{ cm}$

$I = 523267.92 \text{ cm}^4$

$y_i = 28.2 \text{ cm}$

$y_s = 28.2 \text{ cm}$

$$f_i = \frac{P_o}{A} + \frac{P_o\, e_r}{I}\, y_i$$

$f_i = 156.27 \text{ Kg/cm}^2$ (con presión)

$156.27 < 168$

.·. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

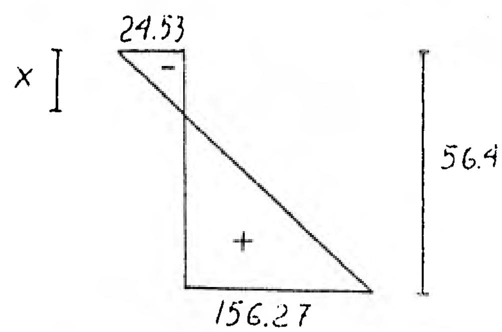
$$f_s = \frac{130032}{1974} - \frac{(130032)(12.9)}{523267.92}\,(28.2)$$

f_s = -24.53 Kg/cm^2 (tensión)

24.53 >16.73

∴ se necesita refuerzo ordinario para tomar - la tensión.

- Cálculo de la fuerza de tensión T_B en la sección B.



$$\frac{25.53}{x} = \frac{24.53 + 156.27}{56.4}$$

$$x = \frac{(24.53)\ (56.4)}{24.53 + 156.27}$$

x = 7.65 cm

$$T_B = \frac{(24.53)(7.65)(35)}{2}$$

T_B = 3284.84 Kg

- Sección C derecha (a 80 cm del apoyo)

A = 1726 cm^2

e_r = 28.37 - 15.3 = 13.07 cm

I = 517205.11 cm^4

y_i = 28.37 cm

$y_s = 28.03$ cm

$$f_i = \frac{P_o}{A} + \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{1726} + \frac{(130032)(13.07)}{517205.11}\,(28.37)$$

$f_i = 168.56$ Kg/cm^2 (compresión)

$168.56 \doteq 168$

.·. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

$$f_s = \frac{130032}{1726} - \frac{(130032)(13.07)}{517205.11}\,(28.03$$

$f_s = -16.77$ Kg/cm^2 (tensión)

$16.77 \doteq 16.73$

.·. está correcto

- Sección D (a 2 m del extremo)

$A = 1870$ cm^2

$e_r = 33.25 - 15.3 = 17.95$ cm

$I = 815682.83$ cm^4

$y_i = 33.25$ cm

$y_s = 32.75$ cm

$$f_i = \frac{P_o}{A} + \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{1870} + \frac{(130032)(17.95)}{815682.83}\,(33.25)$$

$f_i = 164.68$ Kg/cm^2 (compresión)

$164.68 < 168$

.·. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\ e_r}{I}$$

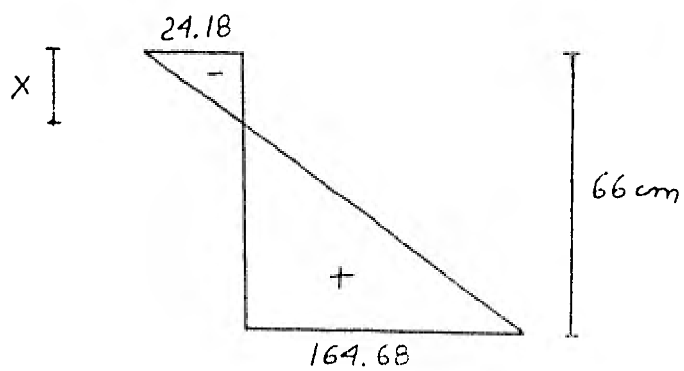
$$f_s = \frac{130032}{1870} - \frac{(130032)(17.95)}{815682.83}\ (32.75)$$

$$f_s = -24.28\ Kg/cm^2\ \text{(tensión)}$$

$$24.18 > 16.73$$

.˙. se deberá colocar acero de refuerzo ordinario pa.a tomar las tensiones.

. Cálculo de la fuerza de tensión T_C en la sección C.



$$\frac{24.18}{x} = \frac{24.18 + 164.68}{66}$$

$$x = 8.45\ cm$$

$$T_C = \frac{(24.18)(66)}{24.18 + 164.68}$$

$$T_C = 3575.65\ Kg$$

- Sección E (a 3 metros del extremo de la trabe).

$A = 1990\ cm^2$

$e_r = 37.32 - 15.3 = 22.02\ cm$

$I = 1129936.55\ cm^4$

$y_i = 37.32\ cm$

$y_s = 36.68\ cm$

$f_i = \frac{P_o}{A} + \frac{P_o\ e_r}{I}\ y_i$

$f_i = \frac{130032}{1990} + \frac{(130032)(22.02)}{1129936.55}\ (37.32)$

$f_i = 159.91\ Kg/cm^2$ (compresión)

$159.91 < 160$

.˙. está correcto

$f_s = \frac{P_o}{A} \quad \frac{P_o\ e_r}{I}\ y_s$

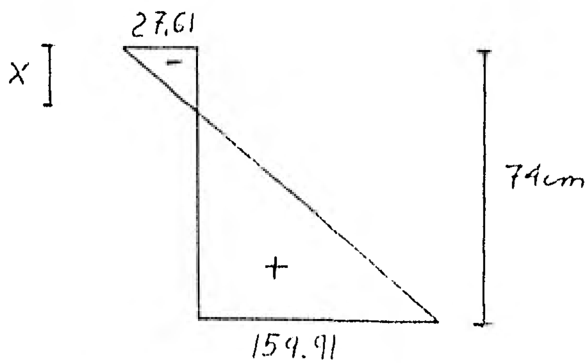
$f_s = \frac{130032}{1990} - \frac{(130032)(22.02)}{1129936.55}\ (36.68)$

$f_s = 27.6\ Kg/cm^2$ (tensión)

$27.61 > 16.73$

.˙. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza de tensión T_D en la sección D.



$$\frac{27.61}{x} = \frac{27.61 + 159.91}{74}$$

$$x = 10.9 \text{ cm}$$

$$T_D = \frac{(27.61)(10.9)\ (35)}{2}$$

$$T_D = 5264.47 \text{ Kg}$$

- Sección F (a 4 metros del extremo de la trabe)

$A = 2110 \text{ cm}^2$

$I = 1507855.41 \text{ cm}^4$

$e_r = 41.38 - 15.3 = 26.08 \text{ cm}$

$y_i = 41.38 \text{ cm}$

$y_s = 40.62 \text{ cm}$

$$f_i = \frac{P_o}{A} \quad \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{2110} + \frac{(130032)(26.08)}{1507855.41}\ (41.38)$$

$f_i = 154.69 \text{ Kg/cm}^2$ (compresión)

$154.69 < 168$

.˙. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

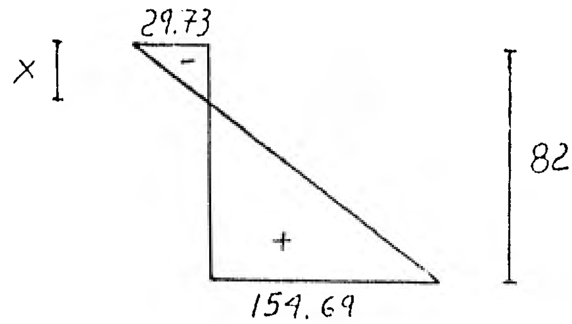
$$f_s = \frac{130032}{2110} \quad \frac{(130032)(26.08)}{1507855.41}\ (40.62)$$

$f_s = -29.73 \text{ Kg/cm}^2$ (tensión)

$29.73 > 16.73$

.˙. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza de tensión T_E en la sección E.



$$\frac{29.73}{x} + \frac{29.73 + 154.69}{82}$$

$$x = 13.22 \text{ cm}$$

$$T_E = \frac{(29.73)\ (13.22)(35)}{2}$$

$$T_E = 6878.04 \text{ Kg}$$

- Sección G (a 5 metros del extremo de la trabe)

$A = 2230 \text{ cm}^2$

$I = 1953281.76 \text{ cm}^4$

$y_i = 45.43 \text{ cm}$

$y_s = 44.57 \text{ cm}$

$e_r = 45.43 - 15.3 = 30.13 \text{ cm}$

$$f_i = \frac{P_o}{A} \quad \frac{P_o\ e_r}{I}\ y_i$$

$$f_i = \frac{130032}{2230} \quad \frac{(130032)(30.13)}{1953281.76}\ (45.43)$$

$f_i = 149.43 \text{ Kg/cm}^2$ (compresión)

149.43 < 168

.'. está correcto

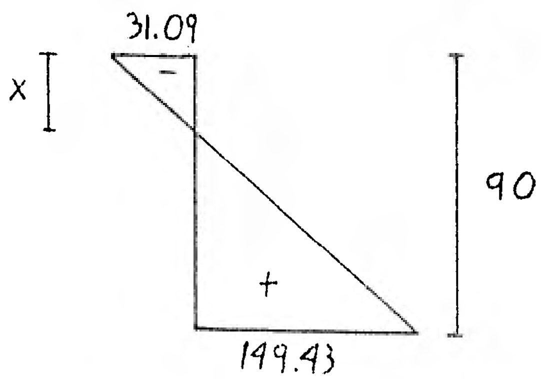
$$f_s = \frac{P_o}{A} - \frac{P_o\ e_r}{I}\ y_s$$

$$f_s = \frac{130032}{2230} \quad \frac{(130032)(30.13)}{1953281.76}\ (44.57)$$

f_s = -31.09 Kg/cm^2 (tensión)

31.09 > 16.73

.'. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.



$$\frac{31.09}{x} = \frac{31.09 + 149.43}{90}$$

$$x = \frac{(31.09)(90)}{31.09 + 149.43}$$

x = 15.5 cm

$$T_F = \frac{(31.09)(15.5)(35)}{2}$$

T_F = 8433.28 Kg

- Sección H (a 6 metros del extremo de la trabe)

A = 2350 cm^2

$I = 2470057.57\ cm^4$

$y_i = 49.48\ cm$

$y_s = 48.52\ cm$

$e_r = 49.48 - 15.3 = 34.18\ cm$

$$f_i = \frac{P_o}{A} + \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{2350} + \frac{(130032)(34.18)}{2470057.57}\,(49.48)$$

$f_i = 144.36\ Kg/cm^2$ (compresión)

$144.36 < 168$

∴ está correcto.

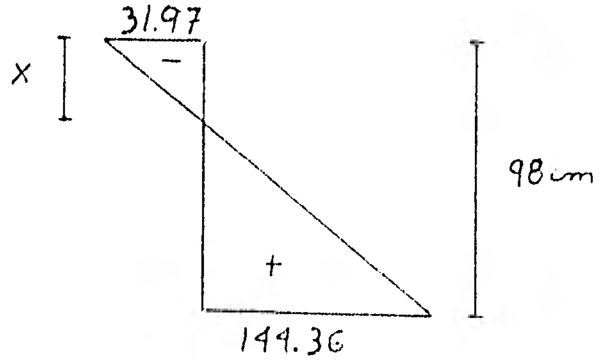
$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

$$f_s = \frac{130032}{2350} - \frac{(130032)(34.18)}{2470057.57}\,(48.52)$$

$f_s = 31.97\ Kg/cm^2$ (tensión)

$31.97 > 16.73$

∴ se deberá colocar acero de refuerzo ordinario para tomar las tensiones.



$$\frac{31.97}{x} + \frac{31.97 + 144.36}{98}$$

$$x = 17.77 \text{ cm}$$

$$T_G = \frac{(31.97)(17.77)(35)}{2}$$

$$T_G = 9940.84 \text{ Kg}$$

- Sección I (a 7 metros del extremo de la trabe)

$A = 2470$

$I = 3062034.26 \text{ cm}^4$

$y_i = 53.52$

$y_s = 52.48$

$e_r = 53.52 - 15.3 = 38.22 \text{ cm}$

$$f_i = \frac{P_o}{A} + \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{2470} \quad \frac{(130032)(38.22)}{3062034.26}\ (53.52)$$

$f_i = 139.51 \text{ Kg/cm}^2$ (compresión)

$139.51 < 168$

$\therefore$ está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

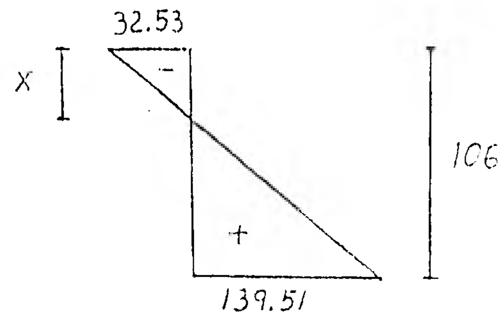
$$f_s = \frac{130032}{2470} - \frac{(130032)(38.22)}{3062024.26}\ (52.48)$$

$f_s = 32.53 \text{ Kg/cm}^2$ (tensión)

32.53 > 16.73

.˙. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

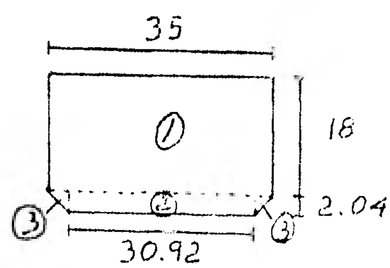
. Cálculo de la fuerza de tensión T_H en la sección H



$$\frac{32.53}{x} = \frac{32.53 + 139.51}{106}$$

$$x = \frac{(32.53)(106)}{32.53+139.51}$$

$$x = 20.04 \text{ cm}$$



- Cálculo del centroide

Elemento	Area	y	Ay
1	630	9	5670
2	63.08	19.02	1199.78
3	4.16	18.68	77.71
Σ	697.24		6947.49

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{6947.49}{697.24}$$

$$\bar{y} = 9.96 \text{ cm}$$

$$\frac{32.53}{20.04} = \frac{f\bar{y}}{9.96}$$

$$f\bar{y} = 16.17 \text{ kg/cm}^2$$

$$T_H = f\bar{y}(\Sigma A) = (16.17)(697.24)$$

$$T_H = 11277.5 \text{ Kg/cm}^2$$

- Sección J (a 8 metros del extremo de la trabe)

$$A = 2590 \text{ cm}^2$$

$$I = 3733023.22 \text{ cm}^4$$

$$y_i = 57.55 \text{ cm}$$

$$y_s = 56.45 \text{ cm}$$

$$e_r = 57.55 - 15.3 = 42.25 \text{ cm}$$

$$f_i = \frac{P_o}{A} \quad \frac{P_o\, e_r}{I}\, y_i$$

$$f_i = \frac{130032}{2590} + \frac{(130032)(42.25)}{3733023.22}(57.55)$$

$$f_i = 134.9 \text{ Kg/cm}^2$$

$134.9 < 168$

$\therefore$ está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\, e_r}{I}\, y_s$$

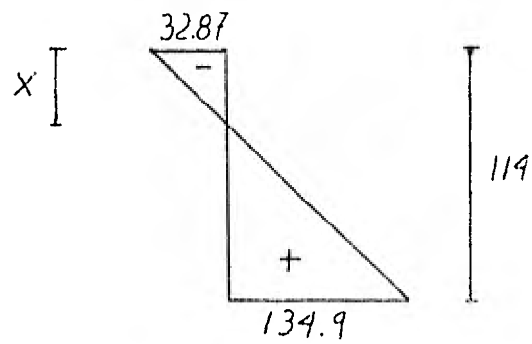
$$f_s = \frac{130032}{2590} - \frac{(130032)(42.25)}{3733023.22}(56.45)$$

$$f_s = -32.87\ Kg/cm^2$$

$$32.87 > 16.73$$

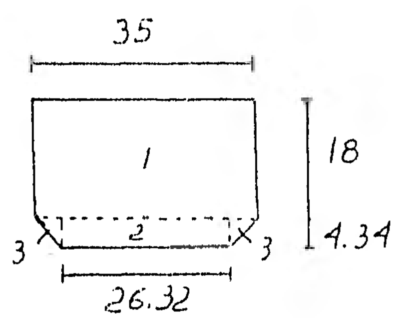
.˙. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza de tensión T_J en la sección J.



$$\frac{32.87}{x} = \frac{32.87 + 134.9}{114}$$

$$x = 22.34\ cm$$



+ Cálculo del centroide

Elemento	Area	y	Ay
1	630	9	5670
2	114.23	20.17	2304.02
3	18.84	19.45	366.44
Σ	763.07		8340.46

$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$

$\bar{y} = \frac{8340.46}{763.07}$

$\bar{y} = 10.93$ cm

$\frac{32.87}{22.34} = \frac{f\bar{y}}{10.95}$

$f\bar{y} = 16.08$ Kg/cm^2

$T_J = f\bar{y}\ (\Sigma A) = (16.08)(763.07)$

$T_J = 12271.75$ Kg

- Sección K (a 9 metros del extremo de la trabe)

$A = 2710$ cm^2

$I = 4486895.42$ cm^4

$y_i = 61.59$ cm

$y_s = 60.41$ cm

$e_r = 61.59 - 15.3 = 46.29$ cm

$$f_i = \frac{P_o}{A} + \frac{P_o\,er}{I}\,y_i$$

$$f_i = \frac{130032}{2710} + \frac{(130032)(46.29)}{4486895.42}\,(61.59)$$

$$f_i = 130.6 \text{ Kg/cm}^2$$

$130.6 < 168$

$\therefore$ está correcto

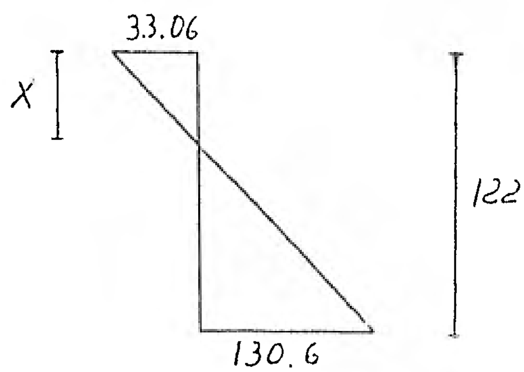
$$f_s = \frac{130032}{2710} - \frac{(130032(46.29)}{4486895.42}\,(60.41)$$

$$f_s = -33.06 \text{ Kg/cm}^2$$

$33.06 > 16.73$

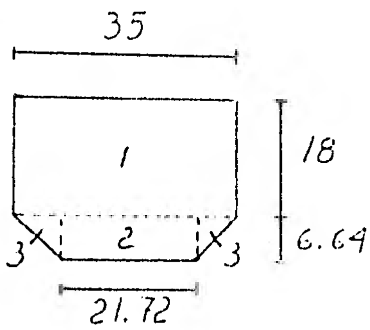
$\therefore$ se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza ce tensión T_K en la sección K.



$$\frac{33.06}{x} + \frac{33.06 + 130.6}{122}$$

$x = 24.64$ cm



+ Cálculo del centroide

Elemento	Area	y	Ay
1	630	9	5670
2	144.22	21.32	3074.79
3	44.09	20.21	891.06
Σ	818.31		9635.84

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = 11.77 \text{ cm}$$

$$\frac{32.87}{24.64} = \frac{f\bar{y}}{11.77}$$

$$f\bar{y} = 15.7 \text{ Kg/cm}^2$$

$$T_K = f\bar{y}(\Sigma A) = (15.7)(818.31)$$

$$T_K = 12848.53 \text{ Kg}$$

- Sección L (a 10 metros del extremo de la trabe)

$A = 2830\ cm^2$

$I = 5327481.62\ cm^4$

$y_i = 65.62\ cm$

$y_s = 64.38\ cm$

$e_r = 65.62 - 15.3 = 50.32\ cm$

$$f_i = \frac{P_o}{A} \quad \frac{P_o\ e_r}{I}\ y_i$$

$$f_i = \frac{130032}{2830} + \frac{(130032)(50.32)}{5327481.62}\ (65.62)$$

$f_i = 126.54\ Kg/cm^2$

$126.54 < 168$

.'. está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\ e_r}{I}\ y_s$$

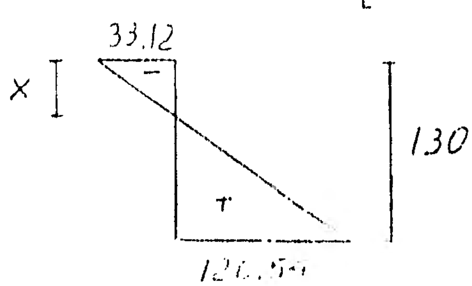
$$f_s = \frac{130032}{2830} - \frac{(130032)(50.32)}{5327481.62}\ (64.38)$$

$f_s = -33.12\ Kg/cm^2$

$33.12 > 16.73$

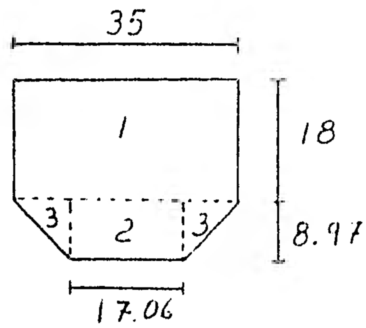
.'. se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza de tensión T_L en la sección L



$$\frac{33.12}{x} = \frac{(33.12 + 126.54}{130}$$

$$x = 26.97 \text{ cm}$$



+ Cálculo del centroide

Elemento	Area (A)	y	Ay
1	630	9	5670
2	153.03	22.48	3440.88
3	80.46	20.99	1688.85
Σ	863.49		10798.96

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{10799.73}{863.49}$$

$$\bar{y} = 12.5 \text{ cm}$$

$$\frac{33.12}{26.97} = \frac{f\bar{y}}{12.5}$$

$$f\bar{y} = 15.36 \text{ Kg/cm}^2$$

$$T_L = f\bar{y}(\Sigma A) = (15.36)\ (863.49)$$

$$T_L = 1326[illegible].41 \text{ Kg}$$

- Sección M (a 11 metros del extremo de la trabe)

$A = 2950\ cm^2$

$I = 6258622.73\ cm^4$

$y_i = 69.65\ cm$

$y_s = 68.35\ cm$

$e_r = 69.65 - 15.3 = 54.35\ cm$

$$f_i = \frac{P_o}{A} + \frac{P_o\ e_r}{I}\ y_i$$

$$f_i = \frac{130032}{2950} + \frac{(130032)(54.35)}{6258622.73}(69.65)$$

$f_i = 122.73\ Kg/cm^2$ (compresión)

$122.73 < 168$

∴ está correcto

$$f_s = \frac{P_o}{A} - \frac{P_o\ e_r}{I}\ y_s$$

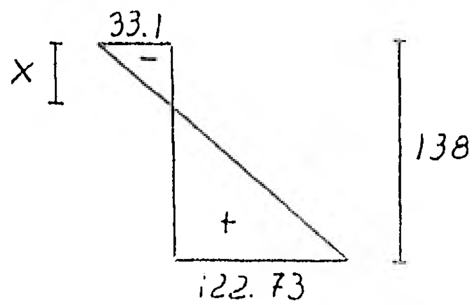
$$f_s = \frac{130032}{2950} - \frac{(130032)(54.35)}{6258622.73}(68.35)$$

$f_s = -33.1\ Kg/cm^2$ (tensión)

$33.1 > 16.73$

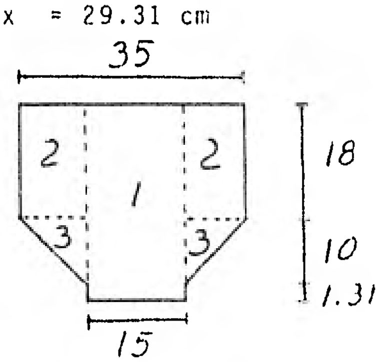
∴ se deberá colocar acero de refuerzo ordinario para tomar las tensiones.

. Cálculo de la fuerza de tensión T_M en la sección M.



$$\frac{33.1}{x} = \frac{33.1 + 122.73}{138}$$

$$x = 29.31 \text{ cm}$$



+ Cálculo del centroide

Elementos	Area (A)	y	Ay
1	439.65	14.65	644.07
2	360	9	3240
3	100	21.33	2133.33
Σ	899.65		11816.41

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{11816.41}{899.65}$$

$$\bar{y} = 13.13 \text{ cm}$$

$$\frac{33.1}{29.31} = \frac{f\bar{y}}{13.13}$$

$f\bar{y} = 14.83\ Kg/cm^3$

$T_M = f\bar{y}(\Sigma A) = (14.83)(899.65)$

$T_M = 13344.36\ Kg$

- Sección N (al centro del claro)

$A = 3130\ cm^2$

$I = 7833525.99\ cm^4$

$y_i = 75.69\ cm$

$y_s = 74.31\ cm$

$e_r = 75.69 - 15.3 = 60.39\ cm$

$$f_i = \frac{P_o}{A} + \frac{P_o\ e_r}{I}\ y_i$$

$$f_i = \frac{130032}{3130} + \frac{(130032)(60.39)}{7833525.99}\ (75.69)$$

$f_i = 117.42\ Kg/cm^2$ (compresión)

$117.42 < 168$

.'. está correcto

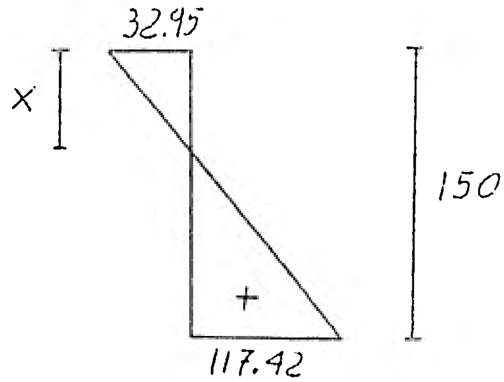
$$f_s = \frac{P_o}{A} - \frac{P_o\ e_r}{I}\ y_s$$

$$f_s = \frac{130032}{3130} - \frac{(130032)(60.39)}{7833525.99}\ (74.31)$$

$f_s = 32.95\ Kg/cm^2$ (tensión)

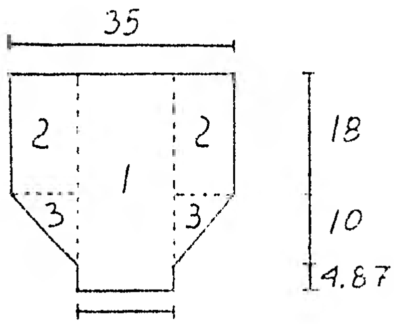
$32.95 > 16.73$

.'. se deberá colocar acero de refuerzo ordinario.



$$\frac{32.95}{x} + \frac{32.95 + 117.42}{150}$$

$x = 32.87$ cm



+ Cálculo del centroide

Elemento	Area (A)	y	Ay
1	493.05	16.435	8103.28
2	360	9	3240.00
3	100	21.33	3133.33
Σ	953.05		13476.61

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{13476.61}{953.05}$$

$\bar{y} = 14.14$ cm

$$\frac{32.95}{32.87} = \frac{f\bar{y}}{14.14}$$

$f\bar{y} = 14.175$ Kg/cm^2

$T_N = f\bar{y}(\Sigma A) = (14.175)(953.05)$

$T_N = 13509.41$ Kg

III.6.2. Cálculo de la cantidad de acero de refuerzo ordinario necesario para tomar las tensiones; correspondientes a la etapa inmediatamente después de la transferencia.

La fuerza de tensión crítica (F), en la trabe portante, es la que se presenta al centro del claro y vale:

$F = 13509.41$ Kg

Datos del acero de refuerzo ordinario:

$fy = 4200$ Kg/cm^2

$f_p = 0.6\ fy$

$f_p = (0.6)(4200)$

$f_p = 2520$ Kg/cm^2

El área de acero necesario será:

$$A_s = \frac{F}{f_p} = \frac{13509.41}{2520} = 5.36 \text{ cm}^3$$

Por lo que serán necesarias 3 barras de $\phi \frac{5}{8}$ que dan $5.94\ cm^2$.

Pero a los 6 metros del extremo de la trabe:

$F = 9940.84$ Kg

$\therefore\ A_s = \frac{9940.84}{2520} = 3.95\ cm^2$; por lo que serán necesarias 2 barras de $\phi \frac{5}{8}$ que dan $3.96\ cm^2$.

$l_d = 50$ cm (longitud de desarrollo)

De 0 a 5.60 m se emplearán 2 barras.

De 5.60 al   se emplearán 3 barras.

III.6.3. Revisión de esfuerzos después de las pérdidas.

$$f_i = \frac{P}{A} + \frac{P_{er}}{I} y_i - \frac{M_a}{I} y_i$$

$$f_s = \frac{P}{A} - \frac{P_{er}}{I} y_s + \frac{M_a}{I} y_s$$

$P = nP_{toron} = (20)(5201.28)$

$P = 104025.6$ Kg

+ Sección N (al centro del claro).

$$M_a = (18355.33)(12.5)-(1471)(12.5)-(2619)(9.84)-(2836)(6.56) - (2836)(3.28)-(357.5)\underbrace{(12.092)}_{x_1}-(6817.82)\underbrace{(5.286)}_{x_2}$$

$$x_1 = \frac{(420)(0.8)(0.4) + \frac{(53.76)(0.8)}{2} \cdot \frac{0.8}{3}}{(420)(0.8) + \frac{(53.76)(0.8)}{2}} = 0.392\ m$$

$x_1 = 12.5 - 0.8 + 0.392 = 12.092$

$$x_2 = \frac{(414.24)(11.7)(5.85) + \frac{(336.96)(11.7)}{2} \cdot \frac{11.7}{3}}{(414.24)(11.7) + \frac{(336.96)(11.7)}{2}} = 5.286 \text{ m}$$

M_a = 117015.04 Kg-m

A = 3130 cm^2

I = 7833525.99 cm^4

y_i = 75.69 cm

y_s = 74.31 cm

e_r = 60.39

$$f_i = \frac{104025.6}{3130} + \frac{(104025.6)(60.39)}{7833525.99}(75.69) - \frac{11701504}{7833525.99}(75.69)$$

f_i = 19.13 Kg/cm^2 (tensión)

19.13 < 37.42

∴ está correcto.

$$f_s = \frac{104025.6}{3130} - \frac{(104025.6)(60.39)}{7833525.99}(74.31) + \frac{11701504}{}(74.31)$$

f_s = 84.64 Kg/cm^2

84.64 < 157.5

∴ está correcto

+ Sección M (a 11 metros del extremo de la trabe)

$$M_a = (18355.33)(11) - (1471)(11) - (2619)(8.34) - (2836)(5.06) - (2836)(1.78)$$

$$- (357.5)(10.592) - \underbrace{(5723.42)}_{F}\underbrace{(4.65)}_{\bar{x}}$$

$$F = \left(\frac{708 + 414.24}{2} \right) 10.2 = 5723.42 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(10.2)(5.1) + (\frac{1}{2})(293.76)(10.2)(\frac{1}{3})(10.2)}{(414.24)(10.2) + (\frac{1}{2})(293.76)(10.2)}$$

$$\bar{x} = 4.65$$

M_a = 114086.39 Kg-m

M_a = 11408638.7 Kg-cm

P = 104025.6 Kg

A = 2950 cm^2

I = 6258622.73 cm^4

y_i = 69.95 cm

y_s = 68.35 cm

e_r = 54.35 cm

$$f_i = \frac{104025.6}{3950} + \frac{(104025.6)(54.35)}{6258622.73}(69.65) - \frac{11408638.7}{6258622.73}(69.65)$$

f_i = 28.78 (tensión)

28.78 < 37.42

.·. es correcto

$$f_s = \frac{104025.6}{2950} - \frac{(104025.6)(54,35)}{6258622.73}(68.35) + \frac{11408638.7}{6558622.73}(68.35)$$

f_s = 98.11 Kg/cm^2 (compresión)

98.11 < 157.5

.·. está correcto.

+ Sección L. (a 10 metros del extremo de la trabe).

$$M_a = (18355.33)(10)-(1471)(10)-(2619)(7.34)-(2836)(4.06)-(2836)(0.78)$$

$$- (357.5)(9.592)-\underbrace{(5029.82)}_{F}\underbrace{(4.23)}_{\bar{x}}$$

$$F = \left(\frac{679.2 + 414.24}{2} \right) 9.2 = 5029.82 \text{ Kg}$$

$$\bar{x} = \frac{(414.29)(9.2)(4.6) + (\frac{1}{2})(264.96)(9.2)(\frac{1}{3})(9.2)}{(414.24)(9.2) + (\frac{1}{2})(264.96)(9.2)}$$

$\bar{x} = 4.23$ m

M_a = 111188.32 Kg-m

M_a = 11118832.14 Kg-cm

P = 104025.6 Kg

A = 2830 cm^2

I = 5327481.62 cm^4

y_i = 65.62 cm

y_s = 64.38 cm

e_r = 50.32 cm

$$f_i = \frac{104025.6}{2830} + \frac{(104025.6)(50.32)}{5327481.62}(65.62) - \frac{11118832.14}{5327481.62}(65.62)$$

f_i = 35.72 Kg/cm^2 (tensión)

35.72 < 37.42

∴ está correcto

+ Sección K (a 9 metros del extremo de la trabe)

$$M_a = (18355.33)(9)-(1471)(9)-(2619)(6.34)-(2836)(3.06)$$

$$- (357.5)\underbrace{(8.592)}_{x_1} - \underbrace{(4365.02)}_{F}\underbrace{(3.797)}_{\bar{x}}$$

$$x_1 = 9 - 0.8 + 0.392 = 8.592$$

$$\bar{x} = \frac{(414.24)(8.2)(4.1) + (\frac{1}{2})(236.16)(8.2)(\frac{1}{3})(.82)}{(414.24)(8.2) + (\frac{1}{2})(236.16)(8.2)}$$

$$\bar{x} = 3.797$$

$$F = \left(\frac{650.4 + 414.24}{2}\right) 8.2 = 4365.02 \text{ kg}$$

M_a = 107030.73 Kg-m

m_a = 10703072.91 Kg-cm

P = 104025.6 Kg

A = 2710 cm^2

I = 4486895.42 cm^4

y_i = 61.59 cm

y_s = 60.41 cm

e_r = 46.24 cm

$$f_i = \frac{104025.6}{2710} + \frac{(104025.6)(46.24)}{4486895.42}(61.59) - \frac{10703972.91}{4486895.42}(61.59)$$

f_i = 42.5 Kg/cm^2 (tensión)

$42.5 > 37.42$

∴ se debe colocar acero de refuerzo ordinario.

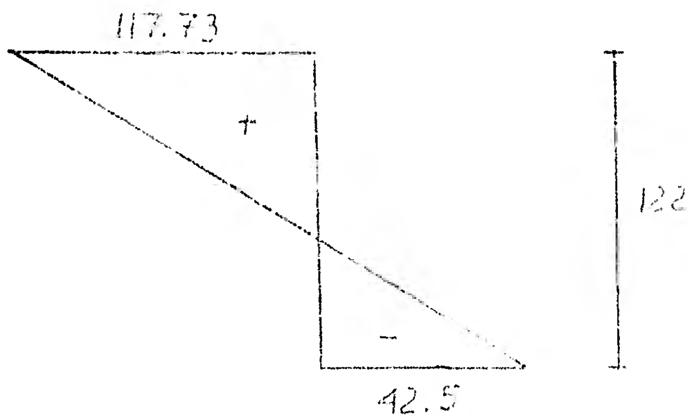
$$f_s = \frac{104025.6}{2710} - \frac{(104025.6)(46.24)}{4486895.42}(60.41) + \frac{10703072.91}{4486895.42}(60.41)$$

f_s = **117.73 Kg/cm²** (compresión)

117.73 < 157.5

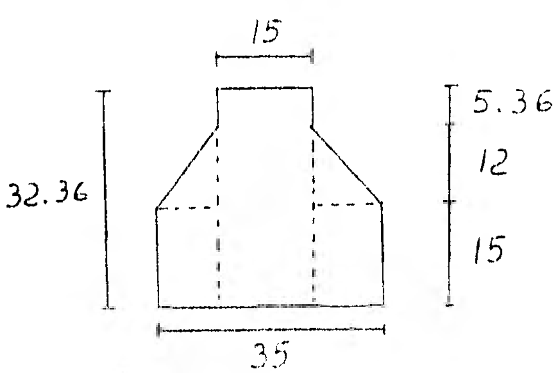
.˙. está correcto.

. Cálculo de la fuerza de tensión.



$$\frac{42.5}{x} + \frac{42.5 + 117.73}{122}$$

x = 32.36 cm



. Cálculo del centroide.

Elemento	Area (A)	$\bar{y}$	Ay
1	485.4	16.18	7853.77
2	120	19	2280
3	300	7.5	2250
Σ	905.4		12383.77

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{12383.77}{905.4}$$

$$\bar{y} = 13.68 \text{ cm}$$

$$\frac{42.5}{32.36} = \frac{f_t}{18.68}$$

$$f_t = 24.53 \text{ Kg/cm}^2$$

$$T_q = f_t(\Sigma A) = (24.53)(905.4)$$

$$T_q = 22212.5 \text{ Kg.}$$

+ Sección J (a 8 metros del extremo de la trabe)

$$M_a = (18355.33)(8)-(1471)(8)-(2619)(5.34)-(2836)(2.06)$$

$$- (357.5)\underbrace{(7.592)}_{x_1} - \underbrace{(3729.02)}_{F}\underbrace{(3.36)}_{\bar{x}}$$

$$x_1 = 8 - 0.8 + 0.392 = 7.592$$

F = (62[illegible].6 + 413.2[illegible]) (7.2) = 3729.02 [illegible]

$$\bar{x} = \frac{(414.24)(7.2)(3.6)+(\frac{1}{2})(207.36)(7.2)(\frac{1}{3})(7.2)}{(414.24)(7.2)+(207.36)(\frac{1}{2})(7.2)}$$

$\bar{x} = 3.36$ m

$M_a = 100003.37$ Kg-m

$M_a = 10000337.28$ Kg-cm

$P = 104025.6$

$A = 2590\ cm^2$

$y_i = 57.55$ cm

$y_s = 56.45$ cm

$e_r = 42.25$ cm

$$f_i = \frac{104025.6}{2590} + \frac{(104025.6)(42.25)}{3733023.22}(57.55) - \frac{10000337.28}{3733023.22}(57.55)$$

$f_i = 46.25\ Kg/cm^2$ (tensión)

$46.25 > 37.25$

.'. se debe colocar acero de refuerzo ordinario.

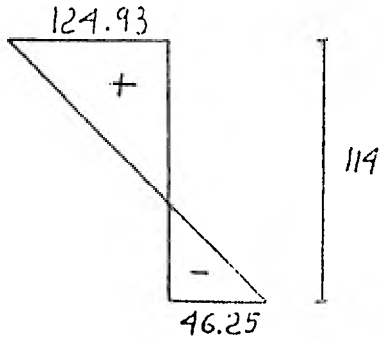
$$f_s = \frac{104025.6}{2590} - \frac{(104025.6)(42.25)}{3733023.22}(56.45) + \frac{10000337.28}{3733023.22}(56.45)$$

$f_s = 124.93\ Kg/cm^2$ (compresión)

$124.93 < 157.5$

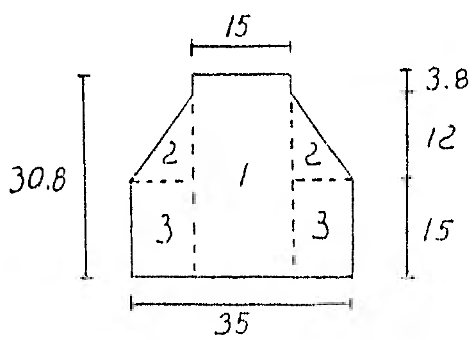
.'. está correcto.

. Cálculo de la fuerza de tensión.



$$\frac{46.25}{x} = \frac{124.93 + 46.25}{114}$$

$$x = 30.8 \text{ cm}$$



.. Cálculo del centroide

Elemento	Area	$\bar{y}$	Ay
1	462	15.4	7114.8
2	120	19	2280
3	300	7.5	2250
Σ	882		11644.8

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{11644.8}{882}$$

$$\bar{y} = 13.2 \text{ cm}$$

$$\frac{46.25}{30.8} = \frac{f_t}{17.6}$$

$$f_t = 26.43 \text{ Kg/cm}^2$$

$$T_J = f_t(\Sigma A) = (26.43)(882)$$

$$T_J = 23310 \text{ Kg}$$

+ Sección I (a 7 metros del extremo de la trabe)

$$M_a = (18355.33)(7)-(1471)(7)-(2619)(4.34)-(2836)(1.06) - (357.5)(6.952) - (3121.82)(2.92)$$

$$F = \left(\frac{592.8 + 414.24}{2}\right)(6.2) = 3121.82 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(6.2)(3.1) + (\frac{1}{2})(178.56)(6.2)(\frac{1}{3})(6.2)}{(414.24)(6.2) + (\frac{1}{2})(178.56)(6.2)}$$

$$\bar{x} = 2.92 \text{ m}$$

$$M_a = 92345.34 \text{ Kg-m}$$

$$M_a = 9234533.56 \text{ Kg-cm}$$

$$P = 104025.6 \text{ Kg}$$

$$A = 2470 \text{ cm}^2$$

$$I = 3062034.26 \text{ cm}^4$$

$$y_i = 53.52 \text{ cm}$$

$$y_s = 52.48 \text{ cm}$$

e_r = 38.22 cm

$$f_i = \frac{104025.6}{2470} + \frac{(104025.6)(38.22)}{3062024.26}(53.52) - \frac{9234533.56}{3062024.26}(53.52)$$

f_i = 49.8 Kg/cm^2

49.8 > 37.42

.˙. se debe colocar acero ordinario.

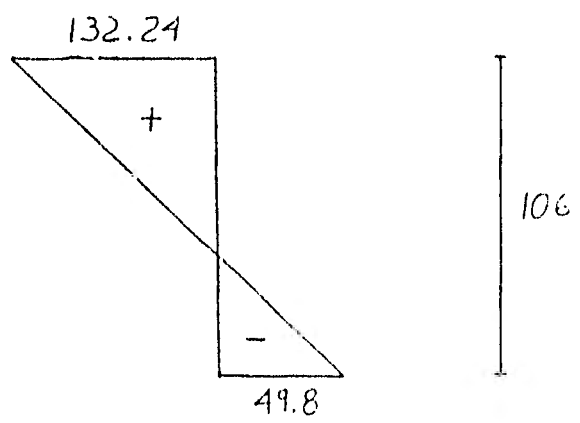
$$f_s = \frac{104025.6}{2470} - \frac{(104025.6)(38.22)}{3062024.26}(52.48) + \frac{9234533.56}{3062024.26}(52.48)$$

f_s = 132.24 Kg/cm^2

132.24 < 157.5

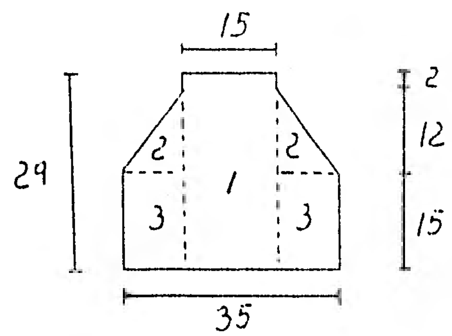
.˙. está correcto

Cálculo de la fuerza de tensión.



$$\frac{49.8}{x} = \frac{49.8 + 132.24}{106}$$

x = 29 cm



.. Cálculo del centroide

Elemento	Area	$\bar{y}$	Ay
1	435	14.5	630.5
2	120	19	2280
3	300	7.5	2250
Σ	855		10837.5

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{10837.5}{855}$$

$$\bar{y} = 12.68 \text{ cm}$$

$$\frac{49,8}{29} = \frac{f_t}{16.32}$$

$f_t = 28.03 \text{ Kg/cm}^2$ 28.03

$$T_I = f_t \ (\Sigma A)$$

$$T_I = (28.03)(855)$$

$$T_I = 23961.7 \text{ Kg}$$

+ Sección H (a 6 metros del extremo de la trabe)

$$M_a = (18355.33)(6) - (1471)(6) - (2619)(3.34) - (2836)(0.06) - (357.5)(5.592) - \underset{F}{(2543.42)}\ \underset{\bar{x}}{(2.47)}$$

$$F = \left(\frac{564 + 414.24}{2}\right)(5.2) = 2543.42 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(5.2)(2.6) + (\frac{1}{2})(149.76)(5.2)(\frac{1}{3})(5.2)}{(414.24)(5.2) + (\frac{1}{2})(149.76)(5.2)}$$

$$\bar{x} = 2.47 \text{ m}$$

M_a = 84106.97 Kg-m

M_a = 8410697.26 Kg-cm

P = 104025.6 Kg

A = 2350 cm^2

I = 2470057.57 cm^4

y_i = 49.48 cm

y_s = 48.52 cm

e_r = 34.18 cm

$$f_i = \frac{104025.6}{2350} + \frac{(104025.6)(34.18)}{2470057.57}(49.48) - \frac{8410697.26}{2470057.57}(49.48)$$

f_i = 52.99 Kg/cm^2

52.99 > 37.42

∴ se debe colocar acero ordinario

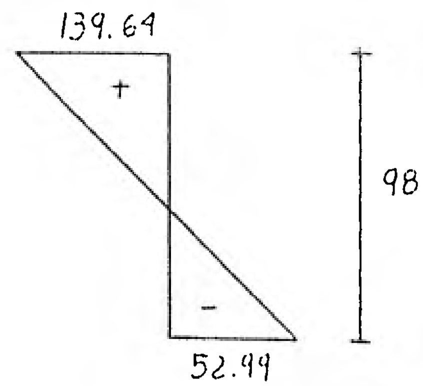
$$f_s = \frac{104025.6}{2350} - \frac{(104025.6)(34.18)}{2470057.57}(48.52) + \frac{8410697.26}{2470057.57}(48.52)$$

$f_s = 139.64\ Kg/cm^2$

$139.64 < 157.5$

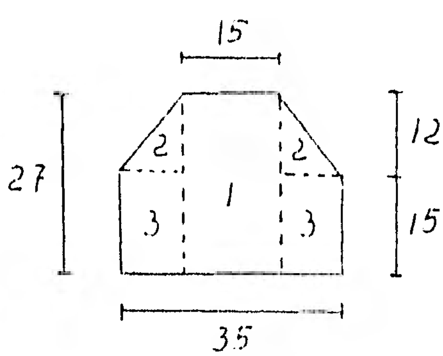
.'. está correcto.

. Cálculo de la fuerza de tensión.



$$\frac{52.99}{x} = \frac{139.64 + 52.99}{98}$$

$x = 26.96\ cm \doteq 27\ cm$



.. Cálculo del centroide

Elemento	Area	$\bar{y}$	Ay
1	405	13.5	5467.5
2	120	19	2280
3	300	7.5	2250
Σ	825		9997.5

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{9997.5}{825}$$

$$\bar{y} = 12.12 \text{ cm}$$

$$\frac{52.99}{27} = \frac{f_t}{14.88}$$

$$f_t = 29.2 \text{ Kg/cm}^2$$

$$T_H = f_t\,(\Sigma A)$$

$$T_H = (29.2)(825)$$

$$T_H = 24092.79 \text{ Kg.}$$

+ Sección G (a 5 metros del extremo de la trabe)

$$M_a = (18355.33)(5)-(1471)(5)-(2619)(2.34)-(357.5)(4.592) - (1993.82)(2.01)$$

$$F = \left(\frac{535.2 + 414.24}{2} \right)(4.2) = 1993.82 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(4.2)(2.1) + (\frac{1}{2})(120.96)(4.2)(\frac{1}{3})(4.2)}{(414.24)(4.2) + (\frac{1}{2})(120.96)(4.2)}$$

$$\bar{x} = 2.01 \text{ cm}$$

M_a = 72643.97 Kg-m

M_a = 7264397.18 Kg-cm

P = 104025.6 Kg

A = 2230 cm^2

I = 1953281.76 cm^4

y_i = 45.43 cm

y_s = 44.57 cm

e_r = 30.13 cm

$$f_i = \frac{104025.6}{2230} + \frac{(104025.6)(30.13)}{1953281.76}(45.43) - \frac{7264397.18}{1953281.76}(45.43)$$

f_i = 49.41 Kg/cm^2 (tensión)

49.41 > 37.42

.·. se debe colocar refuerzo ordinario.

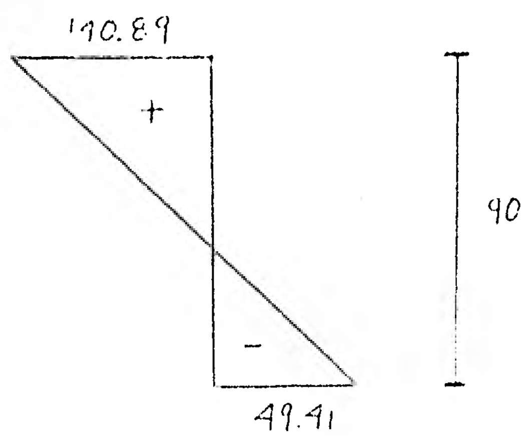
$$f_s = \frac{104025.6}{2230} - \frac{(104025.6)(30.13)}{1953281.76}(44.57) + \frac{7264397.18}{1953281.76}(44.57)$$

f_s = 140.89 Kg/cm^2 (compresión)

$140.89 < 157.5$

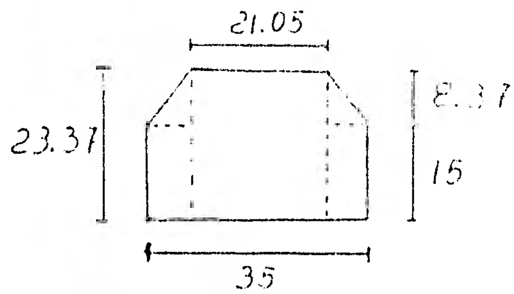
$\therefore$ está correcto

. Cálculo de la fuerza de tensión.



$$\frac{49.41}{x} = \frac{49.41 + 140.89}{90}$$

$x = 23.37$ cm.



$$\frac{12}{10} = \frac{8.37}{x}$$

$x = 6.975$ cm

.. Cálculo del centroide

Elemento	Area	$\bar{y}$	Ay
1	491.94	11.68	5748.3
2	58.38	17.79	1038.59
3	309.25	7.5	1569.38
Σ	759.57		8356.27

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{8356.27}{759.57}$$

$$\bar{y} = 11 \text{ cm}$$

$$\frac{49.41}{23.37} = \frac{f_t}{12.37}$$

$$f_t = 26.15 \text{ Kg/cm}^2$$

$$T_F = f_t(\Sigma A)$$

$$T_F = (26.15)(759.57)$$

$$T_F = 19863.12 \text{ Kg.}$$

+ Sección F (a 4 metros del extremo de la trabe)

$$M_a = (18355.33)(4) - (1471)(4) - (2619)(1.34) - (357.5)(3.592) - (1473.02)(1.55)$$

$$F = \left(\frac{506.4 + 414.24}{2}\right)(3.2) = 1473.02$$

$$\bar{x} = \frac{(414.24)(3.2)(1.6) + (\frac{1}{2})(92.16)(3.2)(\frac{1}{3})(3.2)}{(414.24)(3.2) + (\frac{1}{2})(92.16)(3.2)}$$

$\bar{x} = 1.55$

$M_a = 60460.54$ Kg-m

$M_a = 604653.9$ Kg-cm

$P = 104025.6$ Kg

$A = 2110\ cm^2$

$I = 1507855.41\ cm^4$

$y_i = 41.38$ cm

$y_s = 40.62$ cm

$e_r = 26.08$ cm

$$f_i = \frac{104025.6}{2110} + \frac{(104025.6)(26.08)}{1507855.41}(41.38) - \frac{6046053.9}{1507855.41}(41.38)$$

$f_i = -42.17\ Kg/cm^2$ (tensión)

$42.17 > 37.42$

.˙. se debe colocar refuerzo ordinario.

$$f_s = \frac{104025.6}{2110} - \frac{(104025.6)(26.08)}{1507855.41}(40.62) + \frac{6046053.9}{1507855.41}(40.62)$$

$f_s = 139.09\ Kg/cm^2$

$139.09 < 157.5$

.˙. está correcto.

.. Cálculo del centroide

Elemento	Area	$\bar{y}$	Ay
1	538.06	9.54	5133.05
2	13.87	16.36	226.95
3	102	7.5	765
Σ	653.93		6125.00

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

$$\bar{y} = \frac{6125}{653.93}$$

$$\bar{y} = 9.37 \text{ cm}$$

$$\frac{41.17}{19.08} = \frac{f_t}{9.71}$$

$$f_t = 21.46 \text{ Kg/cm}^2$$

$$T_E = f_t\ (\Sigma A)$$

$$T_E = (21.46)(563.93)$$

$$T_E = 14033.81 \text{ Kg.}$$

+ Sección E (a 3 metros del extremo de la trabe)

$$M_a = (18355.33)(3)-(1471)(3)-(2619)(0.34)(-(357.5)(2.592) - (981.02)(1.074)$$

$$F = \left(\frac{477.6 + 414.24}{2}\right)(2.2) = 981.02 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(2.2)(1.1) + (\frac{1}{2})(63.36)(2.2)(\frac{1}{3})(2.2)}{(414.24)(2.2) + (\frac{1}{2})(63.36)(2.2)}$$

$\bar{x} = 1.074$ m

$M_a = 47782.28$ Kg-m

$M_a = 4778227.45$ Kg-cm

$P = 104025.6$ Kg

$A = 1990 \text{ cm}^2$

$I = 1129936.55 \text{ cm}^4$

$y_i = 37.32$ cm

$y_s = 36.68$ cm

$e_r = 22.02$ cm

$$f_i = \frac{104025.6}{1990} + \frac{(104026.6)(22.02)}{1129936.55}(37.32) - \frac{4778227.45}{1129936.55}(37.32)$$

$f_i = -29.89 \text{ Kg/cm}^2$ (tensión)

$29.89 < 37.42$

$\therefore$ está correcta

$$f_s = \frac{104025.6}{1990} - \frac{(104025.6)(22.02)}{1129936.55}(36.68) + \frac{4778227.45}{1129936.55}(36.68)$$

$f_s = 133.03 \text{ Kg/cm}^2$ (compresión)

$133.03 < 157.5$

$\therefore$ está correcto

+ Sección D (a 2 metros del extremo de la trabe)

$$M_a = (18355.33)(2) - (1471)(2) - (357.5)(1.592) - (517.82)(0.592)$$

$$F = \left(\frac{448.8 + 414.24}{2} \right) (1.2) = 517.82 \text{ Kg}$$

$$\bar{x} = \frac{(414.24)(1.2)(0.6) + (\frac{1}{2})(34.56)(1.2)(\frac{1}{3})(1.2)}{(414.24)(1.2) + (\frac{1}{2})(34.56)(1.2)}$$

$$\bar{x} = 0.592$$

M_a = 32892.97 Kg-m

M_a = 3289297.06 Kg-cm

P = 104025.6 Kg

A = 1870 cm^2

I = 815682.83 cm^4

y_i = 33.25 cm

y_s = 32.75 cm

e_r = 17.95 cm

$$f_i = \frac{104025.6}{1870} + \frac{(104025.6)(17.95)}{815682.83} (33.25) - \frac{3289297.06}{815682.83} (33.25)$$

f_i = 2.37 Kg/cm^2

2.34 < 37.42

∴ está correcto

$$f_s = \frac{104025.6}{1870} - \frac{(104025.6)(17.95)}{815682.83} (32.75) + \frac{3289297.06}{815682.83} (32.75)$$

f_s = 112.72 Kg/cm^2 (compresión)

112.72 < 157.5

.'. está correcto

+ Sección C derecha (a 80 cm del apoyo)

M_a = (18355.33)(80) - (357.5)(39.2) - 1471(80)

M_a = 1336732.4 Kg-cm

P = 104025.6 Kg

A = 1726 cm^2

I = 517205.11 cm^4

y_i = 28.37 cm

y_s = 28.03 cm

e_r = 13.07

$$f_i = \frac{104025.6}{1726} + \frac{(104026.6)(13.07)}{517205.11}(28.37) - \frac{1336732.4}{517205.11}(28.37)$$

f_i = 61.52 Kg/cm^2 (compresión)

55.07 < 157.5

.'. está correcto

$$f_s = \frac{104025.6}{1726} - \frac{(104026.6)(13.07)}{517205.11}(28.03) + \frac{1336732.4}{517205.11}(38.03)$$

f_s = 59.03 Kg/cm^2 (compresión)

65.41 < 157.5

.'. está correcto

III.6.4. Cálculo de la cantidad de acero de refuerzo ordinario necesario para tomar las tensiones; correspondientes a la etapa después de las pérdidas. La -- fuerza de tensión crítica T, es:

$$T = 24092.79 \text{ Kg}$$

Datos del acero de refuerzo ordinario:

$$f_y = 24092.79 \text{ Kg}$$

$f_p = 0.6\ f_y$

$f_p = (0.6)(4200)$

$f_p = 2520 \text{ Kg/cm}^2$

El área de acero necesario será:

$$A_s = \frac{T}{f_p} = \frac{24092.79}{2520} = 9.56 \text{ cm}^2$$

Por lo que serán necesarias 2 barras de ϕ 1". Estas 2 barras deberán colocarse a partir de 3.30 metros del extremo de la trabe hasta 9.70 metros, es decir en 2 segmentos.

La longitud de desarrollo es de 69 cm.

III.7. Revisión por resistencia

+ Sección N. (al centro del claro)

$M_a = 11701504$ Kg-cm

$M_{ua} = (1.4)(11701504)$

$M_{ua} = 16382105.6$ Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr}\left(1 - 0.5\, P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{(20)(0.516)}{(35)(134.7)}$$

$$P_p = 0.0022$$

$$f_{sp} = 18000\left[\,1 - (0.5)(0.0022)\,\frac{18000}{350}\,\right]$$

$$f_{sp} = 16986.81 \text{ Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp}\, f_{sp}}{b\, f''_c}$$

$$f^*_c = 0.8 f'_c = (0.8)(350) = 280 \text{ Kg/cm}^2$$

$$f''_c = \left(1.05 - \frac{f^*_c}{1250}\right) 280$$

$$f''_c = 231.28 \text{ Kg/cm}^2$$

$$a = \frac{(10.32)(16986.81)}{(35)(231.28)}$$

$a = 21.66$ cm $>$ $t = 18$ cm

.'. la sección trabaja como T.

$$C = T$$

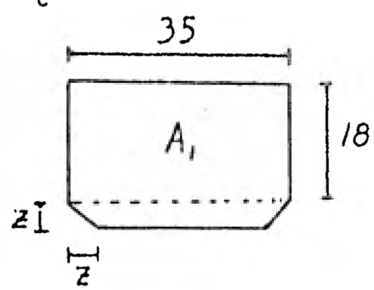
$$A_c f''_c = A_{sp}\ f_{sp}$$

A_c = Area de concreto hipotética que trabaja con 231.28 Kg/cm^2

$$A_c = \frac{A_{sp}\ f_{sp}}{f''_c}$$

$$A_c = \frac{(10.32)(16986.81)}{231.28}$$

$$A_c = 757.97\ cm^2$$



$$A_c - A_1 = 757.97 - 630 = 127.97\ cm^2$$

$$35z - z^2 = 127.97$$

$$z^2 - 35z + 127.97 = 0$$

$$z = \frac{36 \pm\ (35)^2 - (4)(127.97)}{2}$$

$$z = \frac{35 \pm 26.7}{2}$$

z = 4.15 cm (la otra raíz se descarta)

$$a = 18 + 4.15$$

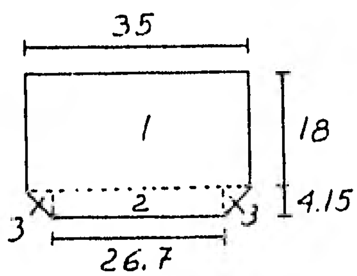
$$a = 22.15\ cm$$

$c = \frac{a}{0.8}$

$c = \frac{22.15}{0.8}$

$c = 27.69$ cm

- Cálculo del momento último resistente



Elemento	Area	$\bar{y}$	$A\bar{y}$
1	630	9	5670
2	110.8	20.07	2223.70
3	17.22	19.38	333.72
	758.02		8227.48

$y_{CG} = \frac{8227.48}{758.02}$

$y_{CG} = 10.85$ cm

$M_{uR} = F.R.\ f''_c\ A_c\ (d-10.85)$

$M_{uR} = (0.9)(231.28)(757.97)\ [\ 134.7 - 10.85\ ]$

$M_{uR} = 19540182.51$ Kg-cm $> M_{uR} = 16382105.6$ Kg-cm

$\therefore$ está correcto.

- Verificación del tipo de falla.

$$E_{sp} + E_i > E_{yp}$$

$$\frac{0.003}{c} = \frac{E_{sp}}{d-c}$$

$$E_{sp} = \frac{(134.7 - 27.68)(0.003)}{27.68}$$

$$E_{sp} = 0.0116$$

$$E_i = \frac{f_i}{E_s}$$

$$E_i = \frac{12600}{1.9 \times 10^6}$$

$$E_i = 0.0066$$

$$E_{sp} + E_i \; 0.0182 > E_{yp} = 0.01$$

.·. se presentará falla ductil.

- Revisión del acero mínimo

$$M_{uR} \geq 1.2 \; M_{agriet}$$

$$M_{agriet} = \frac{I}{y_i} \left[\frac{P}{A} + \frac{P_e}{I} y_i + 2 \quad f'_c \right]$$

$$M_{agriet} = \frac{7833525.99}{75.69} \left[\frac{104026.5}{3130} + \frac{(104025.6)(60.39)}{7833525.99}(75.69) + 2 \quad 350 \right]$$

$$M_{agriet} = 13594182.42 \text{ Kg-cm}$$

$$1.2 \; M_{agriet} = 16313018.9 \text{ Kg-cm}$$

M_{uR} = 19540182.51 Kg-cm > 1.2 M_{agriet} = 16313018.9 Kg-cm

.˙. está correcto.

+ Sección M. (A 11 metros del extremo de la trabe)

M_a = 11408638.7 Kg-cm

M_{ua} = (1.4)(11408638.7)

M_{ua} = 15972094.18 Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr}(1 - 0.5\, P_p \frac{f_{sr}}{f'_c})$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(122.7}$$

P_p = 0.0024

$$f_{sp} = 18000\ [\ 1-(0.5)(0.0024)\ \frac{18000}{350}\ ]$$

f_{sp} = 16887.72 Kg/cm^2

- Cálculo de a

$$a = \frac{A_{sp}\ f_{sp}}{b\ f''_c}$$

f''_c = 231.28 Kg/cm^2

$$a = \frac{(10.32)(16887.72)}{(35)(231.28)}$$

$a = 21.53$ cm $> t = 18$ cm

$\therefore$ la sección trabaja como T.

$$C = T$$

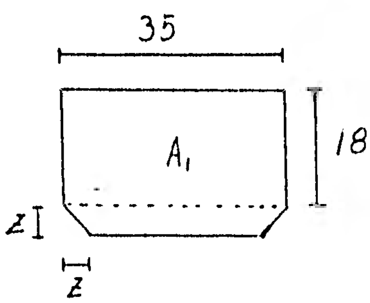
$$A_c f''_c = A_{sp} f_{sp}$$

A_c = Area de concreto hipotética que trabaja con 231.28 Kg/cm^2

$$A_c = \frac{A_{sp} f_{sp}}{f''_c}$$

$$A_c = \frac{(10.32)(16887.72)}{231.28}$$

$$A_c = 753.55 \text{ cm}^2$$



$A_c - A_1 = 753.55 - 630 = 132.55$ cm^2

$35z - z^2 = 123.55$

$z^2 - 35z + 123.55 = 0$

$$z = \frac{35 \pm (35)^2 - (4)(123.55)}{2}$$

$$z = \frac{35 \pm 27.03}{2}$$

$z = 3.98$ (la otra raíz se descarta)

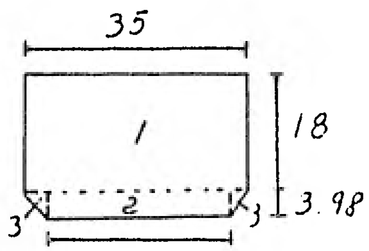
$a = 18 + 3.98$

$a = 21.98$ cm

$$c = \frac{a}{0.8}$$

$$c = \frac{21.98}{0.8} \qquad c = 27.475 \text{ cm}$$

- Cálculo del momento último resistente



Elemento	Area	$\bar{y}$	$A\bar{y}$
1	630	9	5670
2	107.62	19.99	2151.32
3	15.84	19.33	306.13
	753.46		8127.46

$$y_{CG} = \frac{8127.46}{753.46}$$

$$y_{CG} = 10.79 \text{ cm}$$

$$M_{uR} = FRf''_c \, A_c \, (d - 10.79)$$

$M_{uR} = (0.9)(231.28)(753.46)\ [\ 122.7 - 10.79\ ]$

$M_{uR} = 17551315.99$ Kg-cm $> M_{ua} = 15972094.18$ Kg-cm

.˙. está correcto

- Verificación del tipo de falla.

$$E_{sp} + E_i > E_{yp}$$

$$\frac{0.003}{c} = \frac{E_{sp}}{d-c}$$

$$E_{sp} = \frac{(0.003)(122.7 - 27.475)}{27.475}$$

$$E_{sp} = 0.0104$$

$$E_i = 0.0066$$

$$E_{sp} + E_i = 0.0104 + 0.0066$$

$$E_{sp} + E_i = 0.017 > E_{yp} = 0.01$$

.˙. se presentará falla ductil

- Revisión del acero mínimo

$$M_{uR} \geq 1.2\ M_{agriet.}$$

$$M_{agriet.} = \frac{I}{y_i}\ [\ \frac{P}{A} + \frac{Pe}{I}\ y_i + 2\ \ f'_c\ \ ]$$

$$M_{agriet.} = \frac{6258622.73}{69.65}\ [\ \frac{104025.6}{2950} + \frac{(104025.6)(54.35)}{6258622.73}\ (69.65) + 2\ \ 350\ ]$$

$M_{agriet.} = 12184638.49$ Kg-cm

$1.2\ M_{agriet.} = 14621566.19$ Kg-cm

$M_{uR} = 17551315.99$ Kg-cm $> 1.2\ M_{agriet.} = 14621566.19$

$\therefore$ está correcto

+ Sección L. (A 10 metros del extremo de la trabe)

$M_a = 11118832.14$ Kg-cm

$M_{ua} = (1.4)(11118832.14)$

$M_{ua} = 15566365$ Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr}\ (1 - 0.5\ P_p \frac{f_{sr}}{f'_c})$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(114.7)}$$

$$P_p = 0.0026$$

$$f_{sp} = 18000\ [1 - (0.5)(0.0026)\ \frac{18000}{350}\ ]$$

$$f_{sp} = 16810\ \text{Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp}\ f_{sp}}{b\ f''_c}$$

$$f''_c = 231.28\ \text{Kg/cm}^2$$

$$a = \frac{(10.32)(16810)}{(35)(231.28)}$$

$a = 21.43$ cm $> t = 18$ cm

.˙. la sección trabaja como T.

$$C = T$$

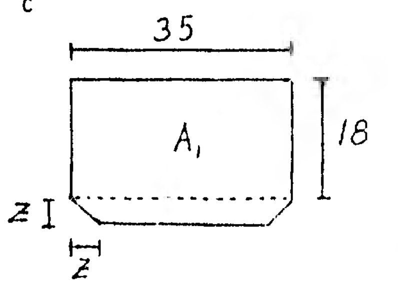
$$A_c f''_c = A_{sp} f_{sp}$$

A_c = Area de concreto hipotética que trabaja con 231.28 Kg/cm^2

$$A_c = \frac{A_{sp} f_{sp}}{f''_c}$$

$$A_c = \frac{(10.32)(16810)}{231.28}$$

$$A_c = 750.08 \text{ cm}^2$$



$A_c - A_1 = 750.08 - 630 = 120.08$ cm^2

$35z - z^2 = 120.08$

$z^2 - 35z + 120.08 = 0$

$$z = \frac{35 \pm 35^2 - (4)(120.08)}{2}$$

$z = 3.855$ cm

$a = 3.855 + 18$

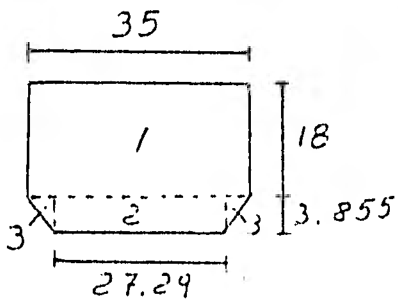
$a = 21.855$ cm

$$c = \frac{a}{0.8}$$

$$c = \frac{21.855}{0.8}$$

$$c = 27.318 \text{ cm}$$

- Cálculo del momento último resistente.



Elemento	Area	$\bar{y}$	$A\bar{y}$
1	630	9	5670
2	105.2	19.93	2096.37
3	14.86	19.28	286.57
Σ	750.06		8052.94

$$y_{CG} = \frac{8052.94}{750.06}$$

$$y_{CG} = 10.74 \text{ cm}$$

$$M_{uR} = F.R. f''_c\ A_c\ A_c\ (d-10.74)$$

$$M_uR = (0.9)(231.28)(750.06)\ [114.7 - 10.74]$$

$$M_{uR} = 16230909.81 \text{ Kg-cm} > M_{ua} = 15566365 \text{ Kg-cm}$$

∴ está correcto.

- Verificación del tipo de falla

$$E_{sp} + E_i > E_{yp}$$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.03)(114.7-27.318)}{27.318}$$

$$E_{sp} = 0.0096$$

$$E_i = 0.0066$$

$$E_{sp} + E_i = 0.0066$$

$$E_{sp} + E_i = 0.0162 > E_{yp} = 0.01$$

.'. se representará falla dúctil.

+ Sección K (a 9 metros del extremo de la trabe)

M_a = 10703072.91 Kg-cm

M_{ua} = (1.4)(10703072.91)

M_{ua} = 14984302.07 Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\, P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(106.7)}$$

$$P_p = 18000 \left[1 - (0.5)(0.0028) \frac{18000}{350}\right]$$

f_{sp} = 16720.93 Kg/cm^2

- Cálculo de a

$$a = \frac{A_{sp} f_{sp} + A_s f_y}{b\, f''_c}$$

f''_c = 231.28 Kg/cm^2

$$a = \frac{(10.32)(16720.93) + (10.14)(4200)}{(35)(231.28)}$$

a = 26.58 cm > t = 18 cm

.'. la sección trabaja como T.

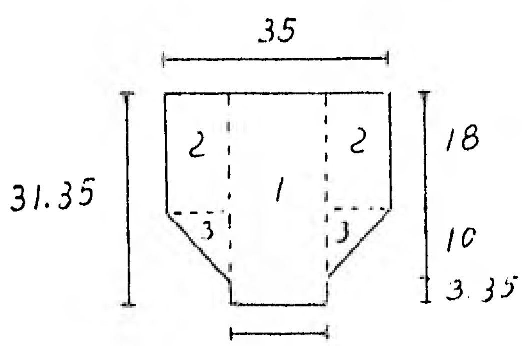
$$C = T$$

$$A_c f''_c = A_{sp} f_{sp} + A_s f_y$$

$$A_c = \frac{A_{sp} f_{sp} + A_s f_y}{f''_c}$$

$$A_c = \frac{(10.32)(16720.93) + (10.14)(4200)}{231.28}$$

$$A_c = 930.25 \text{ cm}^2$$



$A_2 + A_3 = 460\ cm^2$

$930.25 - 460 = 470.25\ cm^2$

$15x = 470.25$

$x = 31.35\ cm$

$a = \underline{31.35}\ cm$

$c = \frac{31.32}{0.8}$

$c = 39.19\ cm$

.˙. todo el presfuerzo trabaja a tensión.

- Cálculo del momento último resistente.

  Cálculo del centroide de A_c

Elemento	A	y	Ay
1	470.25	15.67	7371.77
2	360	9	3140
3	100	21.33	2133.33
Σ	930.25		12744.5

$y_{CG} = \frac{12744.5}{930.25}$

$y_{CG} = 13.7\ cm$

$M_{uR} = F.R.f''_c\ A_c\ (d - 13.7)$

. Cálculo de d

$d = h - r$

$$r = \frac{(T_{sp})(r_{rs}) + (T)(r')}{T_{sp} + T}$$

$T_{sp} = A_{sp} f_{sp} = (10.32)(16720.93)$

$T_{sp} = 172560$ Kg

$T = A_s f_y = (10.14)(4200)$

$T = 42588$ Kg

$r_{rs} = 15.3$ cm

$r' = 7.5$ cm

$$r = \frac{(172560)(15.3) + (42588)(7.5)}{172560 + 42588}$$

$r = 13.76$ cm

$d = 122 - 13.76$

$d = 108.24$ cm

$M_{uR} = (0.9)(231.28)(930.25)(108.24 - 13.7)$

$M_{uR} = 18306101.45$ Kg-cm $> M_{ua} = 14984302.07$ Kg-cm

$\therefore$ está correcto

- Verificación del tipo de falla.

$E_{sp} + E_i > E_{yp}$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.003)(108.24 - 39.19)}{39.19}$$

$E_{sp} = 0.0053$

$E_i = 0.0066$

$E_{sp} + E_i = 0.0053 + 0.0066$

$E_{sp} + E_i = 0.0119 > E_{yp} = 0.01$

$\therefore$ se presenta falla ductil

- Revisión del acero mínimo

$M_{uR} \geq 1.2\ M_{agriet.}$

$$M_{agriet.} = \frac{I}{y_i} \left[\frac{P}{A} + \frac{P_e}{I} y_i + 2\ f'_c \right]$$

$$M_{agriet.} = \frac{4486895.42}{61.59} \left[\frac{104025.6}{2710} + \frac{(104025.6)(46.29)}{4486894.42} (61.59) + 2\ 350 \right]$$

$M_{agriet.} = 10337628.84$ Kg-cm

$M_uR = 18306101.45$ Kg-cm $>$ $1.2\ M_{agriet.} = 12405154.61$ Kg-cm

$\therefore$ está correcto

+ Sección J (a 8 metros del extremo de la trabe)

$M_a = 10000337.28$ Kg-cm

$M_{ua} = (1.4)(10000337.28)$

$M_{ua} = 14000472.19$ Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\ P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(98.7)}$$

$P_p = 0.003$

$$f_{sp} = 18000 \left[1 - (0.5)(0.003) \frac{18000}{350} \right]$$

$$f_{sp} = 16617.26 \text{ Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp} f_{sp} + A_s f_y}{b f''_c}$$

$$f''_c = 231.28 \text{ Kg/cm}^2$$

$$a = \frac{(10.32)(16617.26) + (10.14)(4200)}{(35)(231.28)}$$

$$a = 26.45 \text{ cm} > t = 18 \text{ cm}$$

∴ la sección trabaja como T.

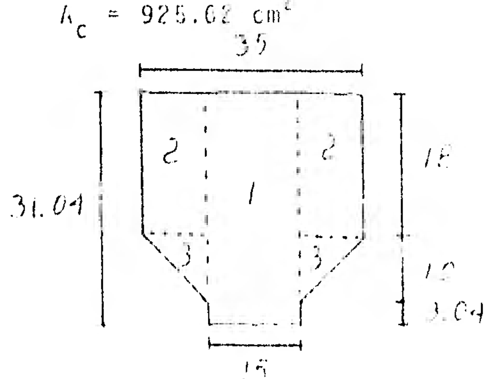
$$C = T$$

$$A_c f''_c = A_{sp} f_{sp} + A_s f_y$$

$$A_c = \frac{A_{sp} f_{sp} + A_s f_y}{f''_c}$$

$$A_c = \frac{(10.32)(16617.26) + (10.14)(4200)}{231.28}$$

$$A_c = 925.62 \text{ cm}^2$$



$A_2 + A_3 = 460\ cm^2$

$925.62 - 460 = 465.62\ cm^2$

$15x = 465.62$

$x = 31.04\ cm$

$a = 31.04\ cm$

$c = \frac{31.04}{0.8}$

$c = 38.8\ cm$

$47.5 < 75.2 = 114 - 38.8$

$\therefore$ todo el presfuerzo trabaja a tensión.

- **Cálculo del momento último resistente.**

Cálculo del centroide de A_c

Elemento	A	y	Ay
1	465.6	15.52	7226.11
2	360	9	3240
3	100	21.33	2133.33
Σ	925.6		12599.44

$y_{CG} = \frac{12599.44}{925.6}$

$y_{CG} = 13.61\ cm$

$M_{uR} = F.R.f''_c\ A_c\ (d-13.61)$

. Cálculo de d

$$d = h - r$$

$$r = \frac{(T_{sp})(r_{rs}) + (T)(r')}{T_{sp} + T}$$

$$T_{sp} = A_{sp}f_{sp} = (10.32)(16617.36)$$

$$T_{sp} = 171490.12 \text{ Kg}$$

$$r_{rs} = 15.3 \text{ cm}$$

$$T = A_s f_y = (10.14)(4200)$$

$$T = 42588 \text{ Kg}$$

$$r' = 7.5 \text{ cm}$$

$$r = \frac{(171490.12)(15.3) + (42588)(7.5)}{171490.12 + 42588}$$

$$r = 13.75 \text{ cm}$$

$$d = 114 - 13.75$$

$$M_{uR} = (0.9)(231.28)(930.25)(100.25 - 13.61)$$

$$M_{uR} = 16776397.6 \text{ Kg-cm} > M_{ua} = 14000472.19 \text{ Kg-cm}$$

+ Sección I (a 7 metros del extremo de la trabe)

$$M_a = 9234533.56 \text{ Kg-cm}$$

$$M_{ua} = (1.4)(9234533.56)$$

$$M_{ua} = 12928346.98 \text{ Kg-cm}$$

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\, P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(90.7)}$$

$$P_p = 0.0033$$

$$f_{sp} = 18000 \left[1 - (0.5)(0.0033) \frac{18000}{350} \right]$$

$$f_{sp} = 16495.29 \text{ Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp}\, f_{sp} + A_s\, f_y}{b f''_c}$$

$$f''_c = 231.28 \text{ Kg/cm}^2$$

$$a = \frac{(10.32)(16495.29) + (10.14)(4200)}{(35)(231.28)}$$

$$a = 26.29 \text{ cm} > t = 18 \text{ cm}$$

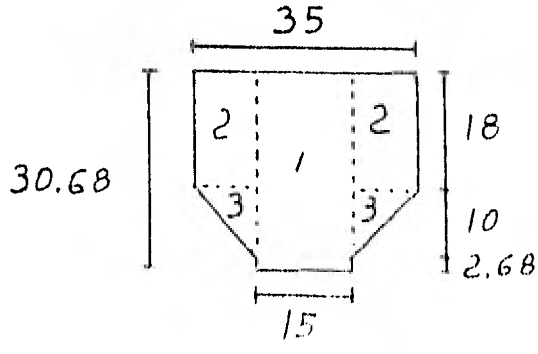
.·. la sección trabaja como T.

$$C = T$$

$$A_c f''_c = A_{sp} f_{sp} + A_s f_y$$

$$A_c = \frac{(10.32)(16495.29) + (10.14)(4200)}{231.28}$$

$$A_c = 920.18 \text{ cm}^2$$



$A_2 + A_3 = 460\ cm^2$

$920.18 - 460 = 460.18\ cm^2$

$15x = 460.18$

$x = 30.68\ cm$

$a = 30.68\ cm$

$c = \frac{30.68}{0.8}$

$c = 38.35\ cm$

$47.5 < 67.5$

.˙. todo el presfuerzo trabaja a tensión.

- Cálculo del momento último resistente.

Cálculo del centroide A_c

Elemento	A	$\bar{y}$	Ay
1	460.2	15.34	7059.47
2	360	9	3240
3	100	21.33	2133.33
Σ	920.2		12432.80

$y_{CG} = \frac{12432.80}{920.2}$

$y_{CG} = 13.51\ cm$

$M_{uR} = F.R.f''_c A_c\ (d-13.51)$

. Cálculo de d

$$d = h - r$$

$$r = \frac{(T_{sp})(r_{rs}) + (T)(r')}{T_{sp} + T}$$

$$T_{sp} = A_{sp} f_{sp} = (10.32)(16495.29)$$

$$T_{sp} = 170231.39 \text{ Kg}$$

$$r_{rs} = 15.3 \text{ cm}$$

$$T = A_s f_y = (10.14)(4200)$$

$$T = 42588 \text{ Kg}$$

$$r' = 7.5 \text{ cm}$$

$$r = \frac{(170231.39)(15.3) + (42588)(7.5)}{170231.39 + 42588}$$

$$r = 13.74 \text{ cm}$$

$$d = 106 - 13.74$$

$$d = 92.26 \text{ cm}$$

$$M_{uR} = (0.9)(231.28)(920.2)(92.26 - 13.51)$$

$$M_{uR} = 15083890.79 \text{ Kg-cm} > M_{ua} = 12928346.98 \text{ Kg-cm}$$

+ Sección H (a 6 metros del extremo de la trabe)

$$M_a = 8410697.26 \text{ Kg-cm}$$

$$M_{ua} = (1.4)(8410697.26)$$

$$M_{ua} = 11774976.16 \text{ Kg-cm}$$

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\, P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(82.7)}$$

$$P_p = 0.0036$$

$$f_{sp} = 18000 \left[1 - (0.5)(0.0036) \frac{18000}{350} \right]$$

$$f_{sp} = 16349.74 \text{ Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp} f_{sp} + A_s f_y}{b\, f''_c}$$

$$f''_c = 231.28 \text{ Kg/cm}^2$$

$$a = \frac{(10.32)(16349.74) + (10.14)(4200)}{(35)\ (231.28)}$$

$a = 26.11$ cm $>$ $t = 19$ cm

.˙. la sección no trabaja como rectangular.

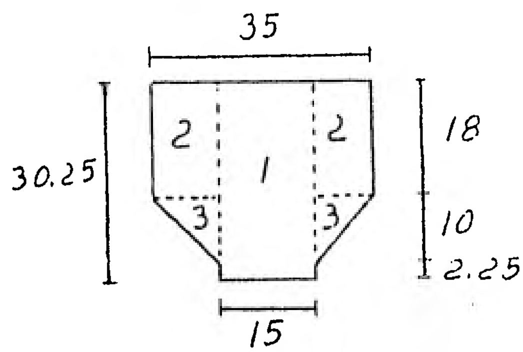
$$C = T$$

$$A_c f''_c = A_{sp} f_{sp} + A_s f_y$$

$$A_c = \frac{A_{sp} f_{sp} + A_s f_y}{f''_c}$$

$$A_c = \frac{(10.32)(16349.74) + (10.14)(4200)}{231.28}$$

$$A_c = 913.69 \text{ cm}^2$$



$A_2 + A_3 = 460 \text{ cm}^2$

$913.69 - 460 = 453.69 \text{ cm}^2$

$15x = 453.69$

$x = 30.25$

$a = 30.25 \text{ cm}$

$c = \dfrac{30.25}{0.8}$

$c = 37.81 \text{ cm}$

$47.5 < 60.19$

.·. todo el presfuerzo trabaja a tensión

- Cálculo del momento último resistente.

Cálculo del centroide de A_c

Elemento	A	y	Ay
1	453.75	15.125	6862.97
2	360	9	3240
3	100	21.33	2133.33
Σ	913.75		12236.3

$$y_{CG} = \frac{12236.3}{913.75}$$

$$y_{CG} = 13.39 \text{ cm}$$

$$M_{uR} = F.R.f''_c A_c \ (d - 13.39)$$

. Cálculo de d

$$d = h - r$$

$$r = \frac{(T_{sp})(r_{rs}) + (T)(r')}{T_{sp} + Y}$$

$$T_{sp} = A_{sp} f_{sp} = (10.32)(16349.74)$$

$$T_{sp} = 168729.32 \text{ Kg}$$

$$r_{rs} = 15.3 \text{ cm}$$

$$T = A_s f_y$$

$$T = (10.14)(4200)$$

$$T = 42588 \text{ Kg}$$

$$r' = 7.5 \text{ cm}$$

$$r = \frac{(168729.32)(15.3) + (42588)(7.5)}{168729.32 + 42588}$$

$$r = 13.73 \text{ cm}$$

$$d = 98 - 13.73$$

$$d = 84.27 \text{ cm}$$

$$M_{uR} = F.R.f''_c \ A_c \ (84.27 - 13.39)$$

$$M_{uR} = (0.9)(231.28)(913.75)(84.27 - 13.39)$$

$$M_{uR} = 134812.97.33 \text{ Kg-cm} \quad > \quad M_{ua} = 11774976.16 \text{ Kg-cm}$$

+ Sección G (a 5 metros del extremo de la trabe)

$M_a = 7264397.18$ Kg-cm

$M_{ua} = (1.4)(7264397.18)$

$M_{ua} = 10170156.05$ Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\, P_p \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{10.32}{(35)(74.7)}$$

$$P_p = 0.0039$$

$$f_{sp} = 18000 \left[1 - (0.5)(0.0039) \frac{18000}{350} \right]$$

$$f_{sp} = 16173 \text{ Kg/cm}^2$$

- Cálculo de a

$$a = \frac{A_{sp} f_{sp} \quad A_s f_y}{b f''_c}$$

$$a = \frac{(10.32)(16173) + (10.14)(4200)}{(35)\ (231.28)}$$

$a = 25.88$ cm $>$ $t = 18$ cm

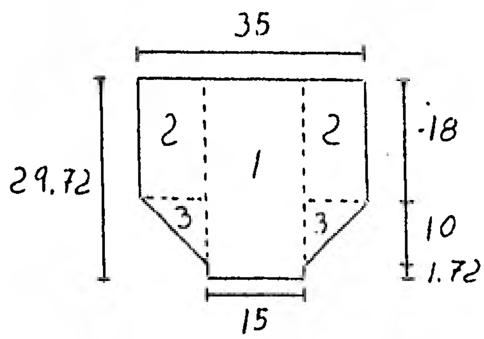
$\therefore$ la sección no trabaja como rectangular

$$C = T$$

$$A_c f''_c = A_{sp} f_{sp} + A_s f_y$$

$$A_c = \frac{(10.32)(16173) + (10.14)(4200)}{231.28}$$

$$A_c = 905.8 \text{ cm}^2$$



$$A_2 + A_3 = 460 \text{ cm}^2$$

$$905.8 - 460 = 445.8 \text{ cm}^2$$

$$15x = 445.8$$

$$x = 29.72 \text{ cm}$$

$$a = 29.72 \text{ cm}$$

$$c = \frac{29.72}{0.8}$$

$$c = 37.15 \text{ cm}$$

$$47.5 < 52.85$$

$\therefore$ todo el presfuerzo trabaja a tensión.

- Cálculo del momento último resistente

  Cálculo del centroide de A_c

Elemento	A	y	Ay
1	445.8	14.86	6624.59
2	360	9	3240
3	100	21.33	2133.33
Σ	905.8		11997.92

$$y_{CG} = \frac{11997.92}{905.8}$$

$$y_{CG} = 13.25 \text{ cm}$$

$$M_{uR} = F.R.f''_c\ A_c\ (d - 13.25)$$

. Cálculo de d

$$d = h - r$$

$$r = \frac{(T_{sp})(r_{rs}) + (T)(r')}{T_{sp} + T}$$

$$T_{sp} = A_s f_{sp} = (10.32)(16173)$$

$$T_{sp} = 166905.36 \text{ Kg}$$

$$r_{rs} = 15.3 \text{ cm}$$

$$T = A_s f_y = (10.14)(4200)$$

$$T = 42588 \text{ Kg}$$

$$r' = 7.5 \text{ cm}$$

$$r = \frac{(166905.36)(15.3) + (42588)(7.5)}{166905.36 + 42588}$$

$$r = 13.71 \text{ cm}$$

$$d = 90 - 13.71$$

$$d = 76.29 \text{ cm}$$

$$M_{uR} = (0.9)(231.28)(905.8)(76.29 - 13.25)$$

$$M_{uR} = 11885818.91 \text{ Kg-cm} \quad > \quad M_{ua} = 10170156.05 \text{ Kg-cm}$$

- Verificación del tipo de falla

$$E_{sp} + E_i > E_{yp}$$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.003)(76.29) - 37.15)}{37.15}$$

$$E_{sp} = 0.0032$$

$$E_i = 0.0066$$

$$E_{sp} + E_i = 0.0032 + 0.0066$$

$$E_{sp} + E_i = 0.0098 \doteq E_{yp} = 0.01$$

∴ se puede considerar falla dúctil.

+ Sección F (a 4 metros del extremo de la trabe)

$M_a = 6046053.9$

$M_{ua} = (1.4)(6046053.9)$

$M_{ua} = 8464475.46$ Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} (1 - 0.5\, p_p \frac{f_{sr}}{f'_c})$$

$$p_p = \frac{A_{sp}}{bd}$$

$$p_p = \frac{(16)(0.516)}{(35)(74.25)} = \frac{8.256}{2334.5} = 0.0032$$

$$f_{sp} = 18000 [1 - (0.5)(0.0032) \frac{18000}{350}]$$

- Cálculo de a

$$a = \frac{A_{sp}f_{sp} + A_s f_y}{b\ f''_c}$$

$$a = \frac{(8.256)(16529.54) + (10.14)(4200)}{(35)(231.28)}$$

$a = 22.12$ cm $>$ $t = 18$ cm

$\therefore$ la sección no trabaja como rectangular

$$C = T$$

$$A_c f''_c = A_{sp}f_{sp} + A_s f_y$$

$$A_c = \frac{(8.256)(16529.54) + (10.14)(4200)}{231.28}$$

$$A_c = 774.2\ cm^2$$

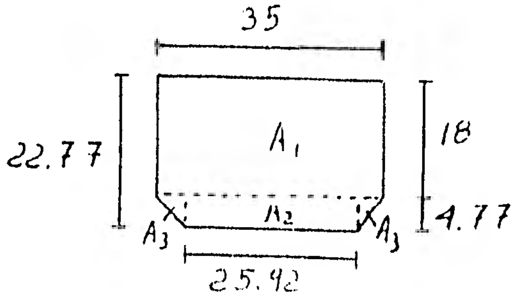
$$774.2 - A_1 = 774.2 - 630 = 144.2\ cm^2$$

$$35x - x^2 = 144.2$$

$$x^2 - 35x + 144.2 = 0$$

$$x = \frac{35 \pm \sqrt{1225 - (4)(144.2)}}{2}$$

$x = 4.77$ cm (la otra raíz se desecha)



$a = 22.77$ cm

$$c = \frac{22.77}{0.8}$$

$c = 28.46$ cm

- Cálculo del momento último resistente.

Cálculo del centroide de A_c

Elemento	A	y	Ay
1	630	9	5670
2	123.64	20.38	2519.78
3	22.75	19.59	445.73
Σ	776.39		8635.51

$$y_{CG} = \frac{6410.61}{776.39}$$

$y_{CG} = 11.12$ cm

$$M_{uR} = F.R.f''_c\ A_c\ (d' - 11.12)$$

$d' = h - r$

$h = 82$ cm

$$r = \frac{(T_{sp})\ (r_{rs}) + (T)\ (r')}{T_{sp} + T}$$

$$T_{sp} = A_{sp}\ f_{sp}$$

$$T_{sp} = (8.256)(16529.54)$$

$$r_{rs} = \frac{2.5 + 13}{2} = 7.75 \text{ cm}$$

$$T = A_s f_y = (10.14)(42000)$$

$$T = 42588 \text{ Kg}$$

$$r' = 7.5 \text{ cm}$$

$$r = \frac{(136467.88)(7.75) + (42588)(7.5)}{136467.88 + 42588}$$

$$r = 7.69 \text{ cm}$$

$$d' = h - r$$

$$d' = 82 - 7.69$$

$$c' = 74.31 \text{ cm}$$

$$M_{uR} = (0.9)(231.28)(774.2)(74.31-11.12)$$

$$M_{uR} = 10183149.28 \text{ Kg-cm} > 8464475.46 \text{ Kg-cm}$$

∴ está correcto.

- Verificación del tipo de falla.

$$E_{sp} + E_i > E_{yp}$$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.003)(74.31 - 28.46)}{28.46}$$

$$E_{sp} = 0.0048$$

$$E_i = 0.0066$$

$E_{sp} + E_i = 0.0114$ [illegible] E_{yp} = [illegible]

∴ se presenta falla dúctil.

- Revisión del acero mínimo

$$M_{uR} \geq 1.2\ M_{agriet.}$$

$$M_{agriet.} = \frac{I}{y_i} \left[\frac{P}{A} + \frac{Pe}{I} y_i + 2 \quad f'_c \right]$$

$$M_{agriet.} = \frac{1507855.41}{41.38} \left[\frac{104025.6}{2110} + \frac{(104025.6)(26.08)}{1507855.41}(41.38) + 2 \quad 350 \right]$$

$$M_{agriet.} = 5872917.89 \text{ Kg-cm}$$

$$M_{uR} = 10183149.28 \text{ Kg-cm} > 1.2\ M_{agriet.} = 7047501.46 \text{ Kg-cm}$$

∴ está correcto

+ Sección E (a 3 metros del extremo de la trabe)

M_a = 4778227.45 Kg-cm

M_{ua} = (1.4)(4778227.45)

M_{ua} = 6689518.43 Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr}(1 - 0.5\ p_p \frac{f_{sr}}{f'_c})$$

$$p_p = \frac{A_{sp}}{bd} = \frac{(16)(0.516)}{(35)(66.25)} = \frac{8.256}{2318.75} = 0.0036$$

$$f_{sp} = 18000 \left[1 - (0.5)(0.0036) \frac{18000}{350} \right]$$

f_{sp} = 16350 Kg/cm^2

- Cálculo de a

$$a = \frac{A_{sp} f_{sp}}{b f''_c}$$

$f''_c = 231.28 \text{ Kg/cm}^2$

$$a = \frac{(8.256)(16352)}{(35)(231.28)}$$

$a = 16.68 \text{ cm} < t = 18 \text{ cm}$

$c = 20.85 \text{ cm}$

.˙. la sección trabaja como rectangular

- Cálculo del momento último resistente

$$M_{uR} = FR \left[a b f''_c \left(d - \frac{a}{2}\right) \right]$$

$$M_{uR} = 0.9 \left[(16.68)(35)(231.28)(66.25) - \frac{16.68}{2} \right]$$

$M_{uR} = 7037173.26 \text{ Kg-cm} > M_{ua} = 6689518.43 \text{ Kg-cm}$

- Verificación del tipo de falla.

$$E_{sp} + E_i > E_{yp}$$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.003)(66.25 - 20.85)}{20.85}$$

$E_{sp} = 0.0065$

$E_i = 0.0066$

$E_{sp} + E_i = 0.0131 > E_{yp} = 0.01$

.˙. se observa falla ductil

- Revisión del acero mínimo

$$M_{uR} \geq 1.2\ M_{agriet.}$$

$$M_{agriet.} = \frac{I}{y_i}\ [\frac{P}{A} + \frac{Pe}{I}\ y_i + 2\ \ f'_c\ \ ]$$

$$M_{agriet.} = \frac{1129936.55}{37.32}\ [\ \frac{104026.6}{1990} + \frac{(104025.6)(22.02)}{1129936.55}\ (37.32) + 2\ \ 350\ ]$$

$$M_{agriet.} = 5006207.77\ Kg\text{-}cm$$

M_{uR} = 7037173.26 Kg-cm > 1.2 $M_{agriet.}$ = 6007449.32 Kg-cm

.·. está correcto.

+ Sección D (a 2 metros del extremo de la trabe)

M_a = 3289297.06 Kg-cm

M_{ua} = (1.4)(3289297.06)

M_{ua} = 4605015.89 Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr}\ (1 - 0.5\ p_p\ \frac{f_{sr}}{f'_c}\ )$$

$$f_{sp} = 18000\ [\ 1 - (0.5)(0.004)\ \frac{18000}{350}\ ]$$

$$f_{sp} = 16125.64\ Kg/cm^2$$

- Cálculo de a

$$a = \frac{A_{sp}\ f_{sp}}{bf''_c}$$

$$f''_c = 231.28\ Kg/cm^2$$

$$a = \frac{(8.256)(16125.64)}{(35)(231.28)}$$

$$a = 16.46\ cm \quad < \quad t = 18\ cm$$

.˙. la sección trabaja como rectangular

$$c = \frac{a}{0.8}$$

$$c = \frac{16.45}{0.8}$$

$$c = 20.56\ cm \quad > \quad 13\ cm$$

.˙. los 16 torones trabajan a tensión.

- Cálculo del momento último resistente.

$$M_{uR} = F\ R\ \left[\ abf''_c\ \ (d - \frac{a}{2})\ \right]$$

$$M_uR = 0.9\ [(16.45)(35)(231.28)(58.25 - \frac{16.45}{2}\ ]$$

$$M_{uR}\ 5995171.79\ Kg\text{-}cm \quad > M_{ua} = 4605015.89\ Kg\text{-}cm$$

.˙. está correcto.

+ Sección C derecha (a 80 centímetros del extremo de la --- trabe).

$$M_a = 1454412.4\ Kg\text{-}cm$$

$$M_{ua} = (1.4)(1454412.4)$$

M_{ua} = 203677.36 Kg-cm

- Cálculo de f_{sp}

$$f_{sp} = f_{sr} \left(1 - 0.5\ P_p\ \frac{f_{sr}}{f'_c}\right)$$

$$P_p = \frac{A_{sp}}{bd} = \frac{8.256}{(35)(48.65)} = 0.0048$$

$$f_{sp} = 18000\ \left[\ 1 - (0.5)\ (0.0048)\ \frac{18000}{350}\ \right]$$

$$f_{sp} = 15755.78\ Kg/cm^2$$

- Cálculo de a

$$a = \frac{A_{sp}\ \ f_{sp}}{b\ f''_c}$$

$$a = \frac{(8.256)(15755.78)}{(35)(231.28)}$$

a = 16.07 cm < t = 18 cm

.·. la sección trabaja como rectangular.

$$c = \frac{a}{0.8}$$

$$c = \frac{16.07}{0.8}$$

c = 20.09 cm < 13 cm

.·. los 16 torones trabajan a tensión.

- Cálculo del momento último resistente.

$M_{uR} = FR \; [\; abf''_c \; (d - \frac{a}{2}) \;]$

$M_{uR} = 0.9 \; [\; (16.07)(35)(231.28)(48.65 - \frac{16.07}{2}) \;]$

$M_{uR} = 4755004.88$ Kg-cm $< M_{ua} = 2036177.36$ Kg-cm

$\therefore$ = está correcto.

- Verificación del tipo de falla.

$E_{sp} + E_i > E_{yp}$

$$E_{sp} = \frac{(0.003)(d-c)}{c}$$

$$E_{sp} = \frac{(0.003)(48.65 - 20.09)}{20.09}$$

$E_{sp} = 0.0043$

$E_i = 0.0066$

$E_{sp} + E_i = 0.0109 > E_{yp} = 0.01$

$\therefore$ se presenta falla ductil.

III.9. Revisión por cortante

- Las secciones críticas que se deben revisar y sus respectivos cortantes y momentos actuantes son:

Sección	Va (Kg)	Ma (Kg-cm)	Distancia al extremo (m)	Vua (Kg)
A	16777.23	420770	0.25	23488.12
B	16526.83	1336732.4	0.8	23137.56
C	16009.01	3289297.06	2.0	22412.61
D	12926.81	4778227.45	3.0	18097.53
E	12434.81	6046053.9	4.0	17408.73
F	11914.01	7264397.18	5.0	16679.61
G	8528.41	8410697.26	6.0	11939.77
H	7950.01	9234533.56	7.0	11130.01
I	7342.81	10000337.28	8.0	10279.93
J	6706.81	10703072.91	9.0	9389.53
K	3206.01	11118832.14	10.0	4488.41
L	2512.41	11408638.7	11.0	3517.37
M	1418.01	11701504	12.5	1985.21

- Se emplearan estribos del número 3, es decir de $\phi \frac{3"}{8}$

+ Sección A

La sección es presforzada.

- Obtención de V_c

$$V_{c\ mín} = F.R.\ 0.5\ bd\ \ f_c^*$$

$V_{c\ mín} = (0.8)(0.5)(36)(44.25)\ \ 280$

$V_c\ mín = 10366.22$ Kg

$V_{c\ máx} = F\ R\ 1.3\ bd\ \ f_c^*$

$V_c\ máx = (0.8)(1.3)(35)(44.25)\ \ 280$

$V_{c\ máx} = 26952.17$ Kg

$$V_c = F\ R\ bd\ \ (0.15\ \ f_c^*\ \ + 50\ \frac{V_a\ d_t}{M_a}$$

$$V_c = (0.8)(35)(44.25)\ [0.15\ \ 280 + (50(44.25)\ \frac{16777.23}{420770}\ ]$$

$$V_c = 26952.17 \text{ Kg}$$

Como:

$V_{ua} = 23488.12 < V_c = 26952.17$

se requieren estribos por especificación.

Por área mínima:

$$S \leq \frac{FR\ A_v\ f_y}{3.5\ b}$$

$$S \leq \frac{(0.8)(1.42)(4200)}{(3.5)(35)}$$

$S \leq 38.95$ cm

Por separación máxima:

$S \leq 0.75\ h$

$S \leq (0.75)(52)$

$S \leq 39$ cm

∴ la separación definitiva será:

$S = 35$ cm

+ Sección B (sección I)

La sección es presforzada.

- Obtención de V_c

$V_{c\ mín.} = F.R.\ 0.5\ (b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(48.65) + (18)^2]\ \ 280$

$V_{c\ mín.} = 7053.04$ Kg

$V_{c\ máx.} = F.R.\ 1.3\ (b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(48.65) + (18)^2]\ \ 280$

$V_{c\ máx.} - 18337.91$ Kg.

$V_c = FR\ (b'd + t^2)(0.15\ \ f_c^* \ + 50\ \frac{V_a}{M_a}\ dr)$

$V_c = (0.8)\ [(15)\ (48.65)+(18)^2]\ [0.15\ \ 280 + (50)\frac{1626.83}{1336732.4}(48.65)]$

$V_c = 27468.69$ Kg.

$V_{c\ def.} = 18337.91$ Kg.

Como: $V_{ua} = 23137.56$ Kg $>$ $V_c = 18337.91$ Kg, se colocarán estribos por especificación.

$S_{req.} = \frac{F.R.Avfyd}{V_{ua} - V_c}$

$S_{req.} = \frac{(0.8)(1.42)(4200)(48.65)}{23137.56 - 18337.91}$

$S_{req.} = 48.36$ cm

$S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$$S_{am} = \frac{(3.8)(1.42)(4200)}{(3.5)(15)}$$

$$S_{am} = 90.88 \text{ cm}$$

$$S_{máx.} = 0.75 \text{ h}$$

$$S_{máx.} = (0.75)(56.4)$$

$$S_{máx.} = 42.3 \text{ cm}$$

$$S = 42.3 \text{ cm}$$

$$S_{def.} = 40 \text{ cm}$$

+ Sección C

La sección es presforzada

- Obtención de V_c

$$V_{c\ mín.} = F.R.\ 0.5(b'd + t^2)\ \ f_c^*$$

$$V_{c\ mín.} = (0.8)(0.5)\ [(15)(58.25) + (18)^2]\ \ 280$$

$$V_{c\ mín.} = 8016.88 \text{ Kg}$$

$$V_{c\ máx.} = F.R.\ 1.3\ (b'd + t^2\ \ f_c^*$$

$$V_{c\ máx.} = (0.8)(1.3)\ [(15)(58.25) + (18)^2]\ \ 280$$

$$V_{c\ máx.} = 20843.88 \text{ Kg}$$

$$V_{c\ máx.} = FR\ (b'd + t^2)(015\ \ f_c^*\ \ + (18)^2]\ \ 280$$

$$V_c = F\ R\ (b'd + t^2)\ (0.15\ \ f_c^*\ \ + 50\ \frac{V_a}{M_a}\ dt)$$

$$V_c = (0.8)\ [(15)(58.25) + (18)^2]\ [0.15\ \ 280\ \ + 50\ \frac{16009.01}{3289297.06}\ 58.25]$$

V_c = [illegible]

$h < 1m$

$h = \frac{h}{b'} = \frac{66}{15} = 4.4 < 6$

.'. está correcto.

$V_{c\ def.} = 15987.68$ Kg.

$V_{ua} - F_{c\ def.} = 22412.61 - 15987.68$

$V' = 6424.93$ Kg

Se requieren estribos por especificación.

- $S_{req.} = \frac{FR\ Av\ fy\ d}{V'}$

$S_{req.} = \frac{(0.8)(1.42)(4200)(58.25)}{6424.93}$

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $1.5\ FR\ bd\ \ f_c^* =)1.5)(0.8)(15)(58.25)\ \ 280 = 17544.76$

$V_{ua} = 22412.61$ Kg > 17544.76 Kg

$S_{máx} = 0.37\ h$

$S_{máx} = (0.37)(66)$

$S_{máx} = 24.42$ cm

$S = 24.42$ cm

$S_{def.} = 25$ cm

+ Sección D

La sección es presforzada

- Obtención de V_c

$$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f_c^*$$

$$V_{c\ mín.} = (0.8)(0.5)\ [(15)(66.25) + (18)^2]\ \ 280$$

$$V_{c\ mín.} = 8820\ Kg$$

$$V_{c\ máx.} = FR\ 1.3\ (b'd + t^2)\ \ f_c^*$$

$$V_{c\ máx.} = (0.8)(1.3)\ [(15)(66.25) + (18)^2]\ \ 280$$

$$V_{c\ máx.} = 22932.18\ Kg$$

$$V_c = FR\ (b'd + t^2)\ (0.15\ \ f_c^*\ + 50\ \frac{V_a}{M_a}]\ \ 280$$

$$V_c = (0.8)\ [(15)(66.25)+(18)^2][0.15\ \ 280\ + 50\ \frac{12926.81}{4778227.45}\ 66.25]$$

$$V_c = 12093.23\ Kg$$

h = 74 cm < 6

.·. está correcto.

$$V_{c\ def.} = 12093.23\ Kg.$$

- Obtención de V'

$$V' = V_{ua} - V_{c\ def.}$$

$$V' = 18097.53 - 12093.23$$

$$V' = 6004.3\ Kg.$$

Se requieren estribos por especificación.

- $S_{req.} = \frac{FR\ Av\ fyd}{V'}$

$S_{req.} = \frac{(0.8)(1.42)(4200)(66.25)}{6004.3}$

$S_{req.} = 52.64$ cm

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $1.5\ FR\ v'd\ \ f_c^* = (1.5)(0.8)(15)(66.25)\ \ 280 = 19954.34$ Kg

$V_{ua} = 18097.53 < 19954.37$ Kg

$S_{máx.} = 0.75\ h$

$S_{máx.} = (0.75)(74)$

$S_{máx.} = 55.5$ cm

$S = 52.64$ cm

$S_{def.} = 50$ cm

+ Sección E

$T_t = T_{pref.} + T_{ref.}$

$T_{ref.} = A_{sp} f_{sp} = (8.256)(16529.54)$

$T_{pref.}$ = 136476.88 Kg

$T_{ref.}$ = $A_s f_y$ = (10.14)(4200)

$T_{ref.}$ = 42588 Kg.

T_t = 179055.88 Kg.

$T_{pref.}$ = 136476.88 > 0.40 T_t = 71622.35

.'. se considera la sección presforzada.

$V_{c\ mín.} = FR\ 0.5\ (b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(74.25) + (18)^2\ \ 280$

$V_{c\ mín.}$ = 9623.26 Kg

$V_{c\ máx.} = FR\ 1.3\ (b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(74.25) + (18)^2]\ \ 280$

$V_{c\ máx.}$ = 25020.48 Kg.

$$V_c = FR(b'd + t^2)(0.15)\ \ f_c^* + 50\frac{V_a}{M_a}\ dt)$$

$$V_c = (0.8)\ [(15)(74.25) + (18)^2]\ [0.15\ \ 280 + 50\ \frac{12434.81}{6046053.9}\ 74.31]$$

V_c = 11676.35 Kg.

h = 82 cm < 1m

$\frac{h}{b'} = \frac{82}{15} = 5.47 < 6$

.'. V_c está correcto

$V_{c\ def.}$ = 11676.35 Kg.

- Obtención de V'

$V' = V_{ua} - V_{c\ def.}$

$V' = 17408.73 - 11676.35$

$V' = 5732.38$ Kg

.˙. se requieren estribos por especificación.

- $S_{req.} = \frac{FR\ Av\ fy\ d}{V'}$

$S_{req.} = \frac{(0.8)(1.42)(4200)(74.25)}{5732.38}$

$S_{req.} = 61.8$ cm.

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $1.5\ FR\ b'd\ \ f_c^* = (1.5)(0.8)(15)(74.25)\ \ 280 = 22363.92$ Kg.

$V_{ua} = 17408.73$ Kg < 22363.92 Kg

$S_{máx.} = 0.75\ h$

$S_{máx.} = (0.75)(82)$

$S_{máx.} = 61.5$ cm

$S = 61.5$ cm.

+ Sección F

$T_t = T_{presf.} + T_{ref.}$

$T_{presf.} = A_{sp}\ f_{sp} = (10.32)(16173)$

$T_{presf.} = 166905.36$ Kg

$T_{ref.} = (10.14)(4200)$

$T_{ref.} = 42588$ Kg

$T_t = 209493.36$ Kg

$T_{presf.} = 166905.36 \text{ Kg} > 0.40T_t = 83797.34$ Kg.

.˙. se considera la sección presforzada.

$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(74.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 9668.44$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(74.7) + (18)^2]\ \ 280$

$V_{c\ máx.} = 25137.95$ Kg.

$$V_c = FR(b'd + t^2)(0.15\ \ f_c^* + 50\ \frac{V_a}{M_a}\ dt)$$

$$V_c = (0.8)\ [(15)(74.25) + (18)^2]\ [0.15\ \ 280\ + 50\ \frac{11914.01}{7264397.18}\ 76.29]$$

$V_c = 10082.62$ Kg.

$h = 90 \text{ cm} < 1\text{m}$

$$\frac{h}{b'} = \frac{90}{15} = 6$$

$$\therefore \; V_c = 0.8 \; V_c$$

$V_c = (0.8)(10082.62)$

$V_c = 8066.1$ Kg.

$V_{c\ def.} = 9668.44$ Kg.

- Obtención de V.

$V' = V_{ua} - V_{c\ def.}$

$V' = 16679.61 - 9668.44$

$V' = 7011.17$ Kg.

$\therefore$ se requieren estribos por especificación.

- $S_{req.} = \dfrac{FR\ Av\ fy\ d}{V'}$

$S_{req.} = \dfrac{(0.8)(1.42)(4200)(74.7)}{7011.17\ Kg.}$

$S_{req.} = 50.83$ cm

- $S_{am} = \dfrac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \dfrac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $1.5\ FRb'd\ f^*_c = (1.5)(0.8)(15)(74.7)\ 280 = 22499.46$ Kg.

$V_{ua} = 16679.61\ Kg. < 22499.46\ Kg.$

$S_{máx.} = 0.75$

$S_{máx.} = (0.75)(90)$

$S_{máx.} = 67.5$ cm

S = 50.83 cm.

+ Sección G

$T_t = T_{presf.} + T_{ref.}$

$T_{presf.} = A_{sp}\ f_{sp} = (10.32)(16349.74)$

$T_{presf.} = 168729132$ Kg.

$T_{ref.} = A_s f_y = (10.14)(4200)$

$T_{ref.} = 42588$ Kg.

$T_t = 211317.32$ Kg.

$T_{presf.} = 168729.32$ Kg $>$ $0.40T_t = 84526.93$ Kg.

.˙. se considera la sección presforzada.

$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8(0.5)\ [(15)(82.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 10471.64$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3\ [(15)(82.7) + (18)^2]\ \ 280$

$V_{c\ máx.} = 27226.26$ Kg.

$$V_c = FR\ (b'd + t^2)\ (0.15)\ \ f_c^* \ + 50\ \frac{V_a}{M_a}\ d_t)$$

$$V_c = (0.8)\ [(15)(82.7) + (18)^2]\ [0.15\ \ 280\ \ + 50\ \frac{8528.41}{8410697.26}\ 84.27]$$

$$V_c = 8488.92\ Kg.$$

$$h = 98\ cm \quad < \quad 1\ m$$

$$\frac{h}{b'} = \frac{98}{15} = 6.53 \quad > \quad 6$$

$\therefore$ se toma 0.8 V_c

$$V_c = (0.8)(8488.92)$$

$$V_c = 6791.14\ Kg.$$

$$V_{c\ def.} = 10471.64\ Kg.$$

- Obtención de V'

$$V' = V_{ua} - V_{c\ def.}$$

$$V' = 11939.77 - 10471.64$$

$$V' = 1468.13\ Kg.$$

$\therefore$ se requieren estribos por especificación.

- $S_{req.} = \frac{FR\ Av\ fy\ d}{V'}$

$$S_{req.} = \frac{(0.8)(1.42)(4200)(82.7)}{1468.13}$$

$$S_{req.} = 268.76\ cm.$$

$- \; S_{am} = \frac{F_R \; A_v \; f_y}{3.5b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

$- \; 1.5 \; FR \; b'd \quad f_o^* = (1.5)(0.8)(15)(82.7) \quad 280 \quad = 24909.04$ Kg.

$V_{ua} = 1193.977$ Kg $< \; 24909.04$ Kg.

$S_{máx} = 0.75 \; h$

$S_{máx} = (0.75)(98)$

$S_{máx} = 73.5$ cm

$S = 73.5$ cm

+ Sección H

$T_t = T_{pref.} + T_{ref.}$

$T_{pref.} = A_{sp} \; f_{sp} = (10.32)(16495.29)$

$T_{pref.} = 170231.39$ Kg.

$T_{ref.} = A_s f_y = (10.14)(4200)$

$T_{ref.} = 42588$

$T_t = 212819.39$ Kg.

$T_{pref.} = 170231.39$ Kg $> \; 0.40 \; T_t = 85127.76$ Kg.

.˙. se considera la sección presforzada.

$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(90.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 11274.83$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (08.)(1.3)\ \ [(15)(90.7) + (18)^2]\ \ 280$

$V_{c\ máx.} = 29314.56$ Kg.

$V_c = FR(b'd + t^2)(0.15\ \ f_c^*\ + 50\ \frac{V_a}{M_a}\ dt)$

$V_c = (0.8)\ [(15)(90.7) + (18)^2]\ \ [0.15\ \ 280\ + 50\ \frac{5950.01}{9234533.56}\ 92.26]$

$V_c = 8734.22$ Kg.

$h > 1m$

$\frac{h}{b'} = \frac{106}{15} = 7.1 > 6$

.'. no trasciende.

$V_{c\ def.} = 11274.83$ Kg.

Como: $V_{c\ def.} = 11274.83$ Kg $> V_{ua} = 11130.01$ Kg.

se requieren estribos por especificación.

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $S_{mas.}$

$1.5\ FRb'd\ \ f_c^* = (1.5)(0.8)(15)(90.7)\ \ 280 = 27318.62$

$V_{ua} = 11130.01$ Kg $<$ 27318.62 Kg.

$S_{máx.} = 0.75\ h$

$S_{máx.} = (0.75)(106)$

$S_{máx.} = 79.5$ cm

S = 79.5 cm.

+ Sección I

$T_t = T_{presf.} + T_{ref.}$

$T_{presf.} = A_{sp} f_{sp} = (10.32)(16617.26)$

$T_{presf.} = 171490.12$ Kg.

$T_{ref.} = A_s f_y = (10.14)(4200)$

$T_{ref.} = 42588$ Kg.

$T_t = 214078.12$ Kg.

$T_{pref.} = 171490.12$ Kg $>$ $0.40 T_t = 85631.25$ Kg.

.'. se considera la sección presforzada.

$V_{c\ mín.} = FR\ 0.5\ (b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(98.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 12078.02$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(98.7) + (18)^2]\ \ 280$

$V_{c\ máx.} = 31402.86$ Kg.

$V_{c\ máx.} = 31402.86$ Kg.

$V_c = FR\ (b'd + t^2)(0.15\ \ f_c^* + 50\ \frac{V_a}{M_a}\ dt)$

$V_c = (0.8)\ [(15)(98.7) + (18)^2]\ \ [0.15\ \ 280\ \ + 50\ \frac{7342.81}{10000337.28}\ 100.25]$

$V_c = 8936.52$ Kg; h>m y $\frac{h}{b'} > 6$ son intrascendentes.

$V_{c\ def.} = 12078.02$ Kg.

Como: $V_{c\ def.} = 12078.02$ Kg $> V_{ua} = 10279.93$ Kg.

se requieren estribos por especificación.

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_{am} = 90.88$ cm

- $S_{máx.}$

$1.5\ FRb'd\ \ f_c^* = (1.5)(0.8)(15)(98.7)\ \ 280\ \ = 39728.2$ Kg.

$V_{ua} = 10279.93$ Kg $<$ 29728.2 Kg.

$S_{máx.} = 0.75$ h.

$S_{máx.} = (0.75)(114)$

$S_{máx.} = 85.5$ cm

$S = 85.5$ cm

+ Sección J

$T_t = T_{presf.} + T_{ref.}$

$T_{presf.} = A_{sp} f_{sp} = (10.32)(16720.93)$

$T_{presf.} = 172560$ Kg

$T_{ref.} = A_s f_y = (10.14)(4200)$

$T_{ref.} = 42588$ Kg.

$T_t = 215148$ Kg.

$T_{presf.} = 172560$ Kg $> 0.40 T_t = 86059.2$ Kg.

.'. se considera la sección preforzada.

$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f_c^*$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(106.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 12881.22$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ 280$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(106.7) + (18)^2]\ 280$

$V_{c\ máx.} = 33491.17$ Kg.

$$V_c = FR(b'd + t^2)\ (0.15\ \ f_c^* + 50 \frac{V_a}{M_a} dt)$$

$$V_c = (0.8)\ [(15)(106.7) + (18)^2]\ [0.15\ \ 280 + 50 \frac{6706.81}{10703072.91}\ 108.24]$$

V_c = 9085.6 Kg; h>1m, y $\frac{h}{b'}$ > 6 son intrascendentes.

$V_{c\ def.}$ = 12881.22 Kg.

Como: $V_{c\ def.}$ = 12881.22 Kg > V_{ua} = 9389.53 Kg.

se requieren estribos por especificación.

- $S_{am} = \frac{FR\ Av\ fy}{3.5\ b'}$

  $S_{am} = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

  S_{am} = 90.88 cm

- $S_{máx.}$

1.5 FRb'd f^*_c = (1.5)(0.8)(15)(98.7) 280 = 29728.2 Kg.

V_{ua} = 9389.53 Kg < 29728.2 Kg.

$S_{máx.}$ = 0.75 h

$S_{máx.}$ = (0.75)(122)

$S_{máx.}$ = 91.5 cm.

S = 90.88 cm.

+ Sección K

  La sección es presforzada

$V_{c\ mín.}$ = FR 0.5(b'd + t^2) f^*_c

$V_{c\ mín.}$ = (0.8)(0.5) [(15)(114.7) + $(18)^2$ 280

$V_{c\ mín.}$ = 13684.41 Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f_c^*$

$V_{c\ máx.} = (0.8)(1.3)\ [(15)(114.7) + (18)^2\ \ 280$

$V_{c\ máx.} = 35579.47$ Kg.

$V_c = FR\ (b'd + t^2)\ (0.15\ \ f_c^*\ + 50\ \frac{V_a}{M_a}\ dt)$

$V_c = (0.8)\ [(15)(114.7) + (18)^2]\ [0.15\ \ 280\ + 50\ \frac{3206.01}{11118832.14}\ 114.7]$

$V_c = 6810$ Kg; h>1 y $\frac{h}{b'}$ > 6 son intrascendentes

$V_{c\ def.} = 13684.41$ Kg.

Como:

$V_{ua} = 4488.41$ Kg < $V_{c\ def.} = 13684.41$ Kg.

se requieren estribos por especificación.

Los área mínima

$S_m = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_m = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

$S_m = 90.88$ cm

Por separación máxima:

$V_{lim} = 1.5\ FR\ bd\ \ f_c^*\ = (1.5)(0.8)(15)(114.7)\ \ 280\ = 34547.37$ Kg.

$V_{ua} = 4488.41$ Kg < 34547.37 Kg.

S = 0.76 h

S = (0.75)(130)

S = 97.5 cm.

S = 90.88 cm.

+ Sección L

La sección es presforzada

$V_{c\ mín.} = FR\ 0.5(b'd + t^2)\ \ f^*_c$

$V_{c\ mín.} = (0.8)(0.5)\ [(15)(122.7) + (18)^2]\ \ 280$

$V_{c\ mín.} = 14487.6$ Kg.

$V_{c\ máx.} = FR\ 1.3(b'd + t^2)\ \ f^*_c$

$V_{c\ máx.} = (0.8)1.3)\ [(15)(122.7) + (18)^2\ \ 280$

$V_{c\ máx.} = 377667.77$ Kg.

$V_{c\ máx.} = 37667.77$ Kg.

$V_c = FR\ (b'd + t^2)\ (0.15\ \ f^*_c\ \ + 50\ \frac{V_a}{M_a}\ dt)$

$V_c = (0.8)\ [(15)(122.7) + (18)^2]\ [0.15\ \ 280\ \ + 50\ \frac{2512.41}{11408638.7}\ 122.7]$

$V_c = 6685.76$; $h > 1$ y $\frac{h}{b'} > 6$ son intrascendentes.

$V_{c\ def.} = 14487.6$ Kg.

Como:

$V_{ua} = 3517.37$ Kg $< V_{c\ def.} = 14487.6$ Kg.

se requieren estribos por especificación.

Por área mínima:

$S_m = \frac{FR\ Av\ fy}{3.5\ b'}$

$S_m = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$

S_m = 90.88 cm.

Por separación mínima:

V_{lim} = 1.5 FR bd f_c^* = (1.5)(0.8)(15)(122.7) 280 = 36956.95 Kg.

V_{ua} = 3517.37 Kg < 36956.95 Kg.

S = 0.75 h

S = (0.75)(138)

S = 103.5 cm

S = 90.88 cm.

+ Sección M

La sección es presforzada

$V_{c\ mín.}$ = FR 0.5(b'd + t^2) f_c^*

$V_{c\ mín.}$ = (0.8)(0.5) [(15)(134.7) + $(18)^2$] 280

$V_{c\ mín.}$ = 15692.4 Kg.

$V_{c\ máx.}$ = FR 1.3(b'd + t^2) f_c^*

$V_{c\ máx.}$ = (0.8)(1.3) [(15)(134.7) + $(18)^2$] 280

$V_{c\ máx.}$ = 40800.23 Kg.

V_c = FR (b'd + t^2)(0.15 f_c^* + 50 $\frac{V_a}{M_a}$ dt)

V_c = 0.8 [(15)(134.7) + $(18)^2$] [0.15 280 + 50 $\frac{1418.01}{11701504}$ 134.7]

V_c = 6238.5 Kg; h > 1 y $\frac{h}{b'}$ > 6 son intrascendentes.

$V_{c\ def.}$ = 15692.4 Kg.

Como:

V_{ua} = 1985.21 Kg < $V_{c\ def.}$ = 15692.4 Kg.

se requieren estribos por especificación.

Por área mínima.

$$S_m = \frac{FR\ Av\ fy}{3.5\ b'}$$

$$S_m = \frac{(0.8)(1.42)(4200)}{(3.5)(15)}$$

$$S_m = 90.88\ cm.$$

Por separación máxima:

$V_{lim.}$ = 1.5 FR bd f_c^* = (1.5)(0.8)(15)(134.7) 280 = 40571.32 Kg.

V_{ua} = 1º85.21 Kg < 40571.32 Kg.

$$S = 0.75\ h$$

$$S = (0.75)(150)$$

$$S = 112.5\ cm$$

S = 90.88 cm.

- Se colocarán estribos del número 3 a cada 25 cm, en toda la extensión de la trabe portante.

IV. DISEÑO DE COLUMNAS

IV.I. Cálculo de la fuerza sísmica.

Se considera a la columna empotrada en su base y libre en el extremo superior.

El peso concentrado en el extremo superior es:

$$W = (2)(11)(18355.33) + (0.35)(0.5)(2400)(2.26)$$

$$W = 404762.26 \text{ Kg.}$$

$$K = (22)\ \frac{12\ EI}{h^3}$$

$$h = 450 \text{ cm}$$

$$E = 10000\ \ f'_c\ = 10000\ \ 200$$

$$E = 141421 \text{ Kg/cm}^2$$

$$I = \frac{bh^3}{12}$$

$$I = \frac{(35)(50)^3}{12}$$

$$I = 364583.33 \text{ cm}^4$$

$$K = (22)\ \left[\ \frac{(12)(141421)(364583.33)}{(450)^3}\ \right]$$

$$K = 149374.72 \text{ Kg/cm}$$

Se supone que la nave se localiza en la zona III - (terreno compresible); según su uso se clasifica en el grupo B, y el factor de ductilidad es de 2.

$$m = \frac{W}{g} = \frac{404762.26}{981}$$

$$m = 412.6 \quad \frac{kg\ seg^2}{cm}$$

$$w = \frac{K}{m} = \frac{149374.72}{412.6}$$

$$w = 19.03 \text{ rad/seg.}$$

$$T = \frac{2\pi}{w} \quad \text{(período}$$

$$T = \frac{2\pi}{19.03}$$

Como: $T = 0.33 < T_1 = 0.8$, se tiene

$$a^* = [a_o + (c - a_o) \frac{T}{T'}]\ g$$

$$a_o = 0.06$$

$$a = [0.06 + (0.24 - 0.06) \frac{0.33}{0.8}]\ g$$

$$a^* = 0.1343g$$

$$Q' = 1 + (Q - 1) \frac{T}{T'}$$

$$Q' = 1 + (2 - 1) \frac{0.33}{0.8}$$

$$Q' = 1.4125$$

$$\therefore a = \frac{0.1343g}{1.4125}$$

$$a = 0.0951\ g$$

La fuerza que produce esa aceleración es:

$$F = ma$$

$$F = \frac{W}{g}\, 0.0951\ g$$

$$F = (404762.26)(0.0951)$$

$$F = 38484.65\ \text{Kg}$$

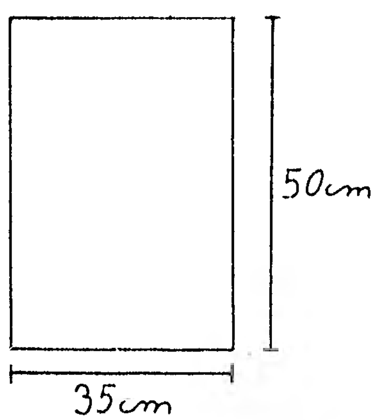
es decir, en cada columna se tendrá una fuerza de:

$$F_s = \frac{F}{22}$$

$$F_s = 1749.3\ \text{Kg.}$$

IV.2. Diseño de la columna.

IV.2.1. Datos:



$$F_y = 4200\ \text{Kg/cm}^2$$

$$F'_c = 200\ \text{Kg/cm}^2$$

$$E_c = 141421\ \text{Kg/cm}^2$$

$$M_a = 787185\ \text{Kg-cm}$$

$$P_a = 18355.33\ \text{Kg.}$$

IV.2.2. Determinación del factor de amplificación del momento "δ".

$$r = \frac{I}{A}$$

$$r = \frac{364583.33}{1750}$$

$$r = 14.43 \text{ cm}$$

$$\frac{kl}{r} = \frac{(2)(450)}{14.43}$$

De manera que la relación de esbeltez es:

$$\frac{kl}{r} = 62.37$$

En esta columna se tiene que:

$$34-12\frac{M_1}{M_2} = 34 \quad < \quad \frac{kl}{r} = 62.37 < 100$$

por lo que se trata de una columna esbelta.

$$\delta = \frac{C_m}{1 - \frac{P_{ua}}{F_R P}}$$

$$C_m = 1$$

$$P = \frac{\pi^2 EI}{(Kl)^2}$$

$$EI = \frac{0.4\ E_c\ I_g}{1 + \beta_d}$$

$$\beta_d = 0$$

$$EI = \frac{(0.4)(141921)(364583.33)}{1 + 0}$$

$$EI = 2.06 \times 10^{10}$$

$$P = \frac{\pi^2(2.06 \times 10^{10})}{(900)^2}$$

$$P = 251295.91 \text{ Kg.}$$

$$\delta = \frac{1}{1 - \frac{25696.46}{(85)(251295.91)}}$$

$$\delta = 1.14$$

IV.2.3. Determinación de la cantidad de acero empleando - las ayudas de diseño; para $\frac{d}{h} = 0.9$, se tiene.

$$R = \frac{M_u}{F_R b h^2 f''_c} = \frac{(1.14)(1.4)(1749.3)(450)}{(0.85)(35)(50)^2(136)}$$

$$R = 0.1242$$

$$K = \frac{P_u}{F_R b h f''_c} = \frac{(1.4)(18355.33)}{(0.85)(35)(50)(136)}$$

$$K = 0.127$$

Con R = 0.124 y K = 0.127 se tiene:

$$1 = 0.185$$

$$p = q \frac{f''_c}{f_y}$$

$$p = (0.185) \frac{136}{4200}$$

$$p = 0.006$$

$$A_s = 0 \text{ b h}$$

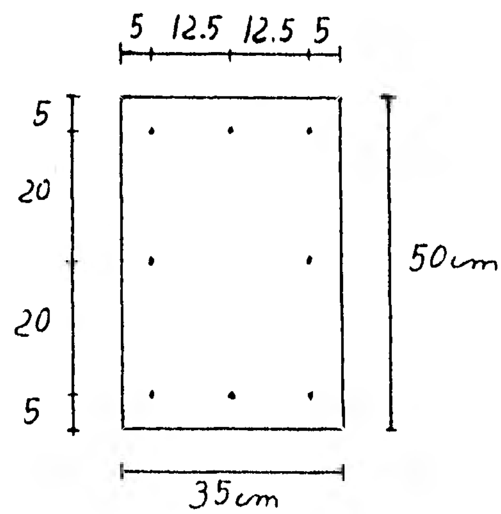
A_s = (0.006)(35)(50)

A_s = 10.5 cm.

Se emplearán 8 varillas de $\frac{1}{2}$" de diámetro

$8 \phi \frac{1}{2}" = 10.16 \text{ cm}^2$

IV.2.4. Colocación del acero



8 barras del número 4

IV.2.5. Revisión de la columna.

$$\frac{d}{h} = \frac{45}{50}$$

$$\frac{d}{h} = 0.9$$

$$p = \frac{A_s}{bh}$$

$$p = \frac{10.56}{(35)(50)}$$

$$p = 0.0058$$

$$q = p \frac{f_y}{f''_c}$$

$$q = 0.0058 \frac{4200}{136}$$

$$q = 0.1793$$

$$e = \frac{F_s \; h_c}{P}$$

$$e = \frac{(1749.3)(450)}{18355.33}$$

$$e = 42.89 \text{ cm.}$$

$$\frac{e}{h} = \frac{42.89}{50}$$

$$\frac{e}{h} = 0.86$$

De la fig. 9 de las ayudas de diseño de las normas de concreto de la publicación No. 401 del Instituto de Ingeniería, con $q = 0.1793$ y $\frac{e}{h} = 0.86$ se tiene:

$$K = 0.15$$

$$R = 0.125$$

de donde:

$$P_{UR} = K \; F_R \; bhf''_c$$

$$P_{UR} = (0.15)(0.85)(35)(50)(136)$$

$P_{uR} = 30345 Kg \quad > \quad P_{ua} = 25697.46 Kg.$

.˙. está correcto

$M_{uR} = R \; F_R \; b \; h^2 \; f''_c$

$M_{uR} = 1264375 \; Kg\text{-}cm > M_{ua} = 1256347.26 \; Kg.\text{-}cm$

.˙. está correcto.

IV.3. Diseño por cortante

IV.3.1. Obtención de V_{ua}

$V_{ua} = F \; C \; V_a$

$V_{ua} = (1.4)(1749.3)$

$V_{ua} = 2449.02 \; Kg$

IV.3.2. Obtención del cortante que resiste el concreto (V_c)

$0.7 \; f^*_c \; Ag + 2000A_s = (0.7)(160)(1750) + (2000)(10.16) = 216320 \; Kg$

$P_{ua} = F \; C \; P_a$

$P_{ua} = (1.4)(18355.33)$

$P_{ua} = 25697.46 \; Kg.$

$$p = \frac{A_{st}}{bh}$$

$$p = \frac{3.81}{(35)(50)}$$

$p = 0.0022$

Se tiene:

$P_{ua} = 25697.46 \text{ Kg} < 0.7 f_c^* A_g + 2000 \, A_s = 216320 \text{ Kg}.$

$p = 0.22 < 0.01$

$\therefore \; V_c = F_R \, b \, d \, (0.2 + 30p) \quad f_c^* \quad [1 + 0.007 \, \frac{P_{ua}}{Ag}]$

$V_c = (0.8)(35)(40) \, [0.2 + 30 \, (0.0022)] \quad 160 \quad [1 + 0.007 \, \frac{25697.46}{1750}]$

$V_c = 4155.78 \text{ Kg}.$

IV.3.3. Separación de los estribos.

Se emplearán estribos de 3/8" de diámetro.

Se tiene:

$V_{ua} = 2449.02 \text{ Kg} < V_c = 4155.78 \text{ Kg}$

.˙. se colocarán estribos por especificación.

$S \leq \frac{F_R \, A_v \, f_y}{3.5 \, b}$

$S \leq \frac{(0.8)(1.27)(4200)}{(3.5)(35)}$

$S \leq 34.83 \text{ cm}.$

La separación máxima de los estribos debe cumplir también con:

$$\frac{850}{fy}\, dv = \frac{850}{4200}\,(1.27) = 16.66 \text{ cm}$$

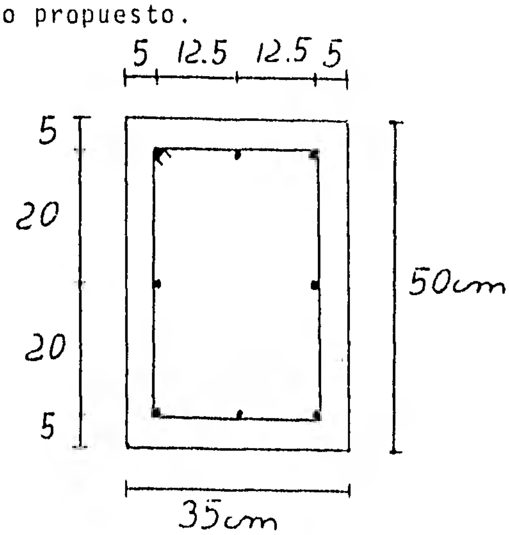
$$S \leq 48\, d_{est.} = (48)(0.95) = 45.6 \text{ cm}$$

$$t_{mín.} = 35 \text{ cm}$$

$S_{mín} = 16.66$ cm

$S_{def.} = 15$ cm.

IV.4. Armado propuesto.



Acero longitudinal: 8 barras de $\phi\ \frac{1}{2}"$

Acero transversal: $\phi\ \frac{3}{8}"$ 15 cm.

V. CONCLUSIONES

Se deja pendiente el cálculo de las conexiones columna suelo y columna trabe portante; así como los planos, porque sería extenso para los fines de la presente tesis o trabajo escrito.

Las ventajas de emplear elementos de concreto pretensado en las construcciones es la obtención de mayor rapidez de construcción y menos volumen de concreto, ya que estos elementos son prefabricados. También se obtiene economía en cimbra y obra falsa, y mayor control de calidad, puesto que se fabrican en plantas de presfuerzo.

Las desventajas de este tipo de obra es que requieren transporte y montaje, así como la ejecución de conexiones especiales y además la elaboración de planos y el cálculo estructural son más laboriosos.