

الباب الخامس

CHAPTER 5

الإطارات

Frames

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البيانات العامة

الإطارات Frames

٥-١: مقدمة:

في معظم منشآتنا يتم استخدام النظام التقليدي (البلاطة - الكمره - العمود) لتغطية المساحات المطلوبة بالأسقف الخرسانية ، أما في حالة ما إذا كانت المساحات المطلوب تغطيتها ذات بحور واسعة (Too Large Spans) ولا يسمح باستخدام أعمدة داخل المساحة نفسها فإننا نلجأ إلى استخدام نظام الإطارات (Frames) .

إذن تعتبر الإطارات أحد النظم الإنشائية المستخدمة في تغطية مساحات واسعة دون الحاجة إلى أعمدة داخلية ، ونحن عادة نبدأ في التفكير في نظام الإطارات حين يزيد البحر عن ١٢ م تقريباً .

وللإطارات أشكال هندسية كثيرة إلا أن أكثرها مثالية واقتصاداً هو ما أخذ شكل خط الضغط (Pressure Line) وهو في العادة يكون مقلوب مخطط عزوم الانحناء (B.M.D) ، ويبين شكل (١) فلسفة هذا الاعتبار في الحالات الثلاث الآتية :

- أ - حالة حمل مركز واحد .
- ب - حالة حملين مركزيين .
- ج - حالة حمل موزع .

٥ - ٢ : تصنيف الإطارات طبقاً لدرجة التحدد الإستاتيكي :

Classification of frames according to indeterminacy:

يمكن تقسيم الإطارات إلى نوعين :

١ - الإطارات المحددة إستاتيكيًا : Statically determinate frames .

يبين شكل (٢) مجموعة من الإطارات المحددة أستاتيكيًا وهي تلك التي يمكن إيجاد قيم ردود أفعالها من خلال معادلات الاتزان دون حاجة لطرق حل خاصة ، وتستخدم الإطارات المحددة أستاتيكيًا في حالة التربة الأضعف نسبياً وكلما قويت التربة كلما كان استخدام الإطارات غير المحددة إستاتيكيًا أنسب .

٢ - الإطارات غير المحددة استاتيكيًا : Statically indeterminate frames

يبين شكل (٣) بعض أشكال الإطارات غير المحددة استاتيكيًا ، ويلاحظ أنه كلما زادت درجة عدم التحدد كلما كان ذلك أنسب لأنواع التربة ذات المقاومة العالية .

٥ - ٣ : مزايا استخدام نظام الإطارات Advantages of R.C frame as a structural system

الفرق بين الإطار والنظام العادي التقليدي (الكمرة والعمود) أنه يوجد وصلة قوية بين العنصرين الكمرة والعمود rigid connection تستطيع أن تتحمل عزوم الانحناء مما يساهم في تخفيض قيمة العزوم الموجبة في منتصف بحر الكمرة ، ويتولد عزوم سالبة عند أطرافها وينعكس علي قمة الأعمدة (أرجل الإطار) لتحقيق اتزان الوصلة . وهذا السلوك يعيد توزيع العزوم ويقلل من قيمتها مما ينعكس علي كميات حديد التسليح والتكلفة .

شكل رقم (٤) يوضح كيف أن تحويل الكمرة الرئيسية من حالتها البسيطة إلي نظام الإطار يقلل من قيمة عزم الانحناء الموجب بدرجة كبيرة .

٥ - ٤ : الأبعاد الهندسية لعناصر الإطار Dimensioning of R.C frame

من المعلوم أن عزم الانحناء المتولد عند الوصلة (connection) بين الكمرة الرئيسية (Girder) والعمود (column) يعتمد علي تناسب أبعادهما ، ويبين شكل (٥) ثلاث حالات رئيسية ذات أبعاد كبيرة وصغيرة ومتوسطة بالنسبة للعمود (رجل الإطار) ومدى تأثير ذلك علي قيم عزوم الانحناء ، وعليه فإنه من الأنسب أن يكون عمق الكمرة = طول قطاع رجل الإطار عند التقائهما عند الوصلة .

- من الخبرات العملية السابقة يمكن وضع العلاقات الآتية شكل (٦) .

L : span of frame = (12 - 25 m) .

H : height of frame .

h_v : clear height of frame = $H - \frac{1}{2} l_g$.

b: breadth of frame = 30 - 50 cm .

$$t_g = \frac{\text{span}}{12-16} \cong \frac{L}{14}$$

$$t_u = (0.6 \rightarrow 1)t_g \cong t_g$$

$$t_l = 0.6t_g$$

$$t_3 \cong t_g \Rightarrow \text{for simplicity.}$$

$$t_4 = (0.5 \rightarrow 0.6)t_g$$

$$t_5 = \text{from design (OR)} = 0.6 t_g$$

$$t_6 = 0.5t_5$$

$$t_7 = t_{link} = \text{greater of } 0.4 t_g \text{ or } L / 20$$

٥ - ٥ : ترتيب أماكن الإطارات :

يبين شكل (٧) طريقة ترتيب الإطارات متتالية الواحد تلو الآخر بهدف تغطية إحدى الصالات حيث ، يمكن ملاحظة الآتي :

- ١ - المسافات البينية بين الإطارات تكون في حدود من ٤ : ٦ م .
- ٢ - يراعى عند وضع الكمرات الثانوية أن تكون بينها بلاطات ثنائية توزع الأحمال two ways slabs
- ٣ - يراعى أن يتم عمل فاصل تمدد كل مسافة (٣٠ : ٤٠ م) بعرض في حدود ٢ سم .
- ٤ - من المناسب أن يكون ارتفاع الإطار مساويا لنصف بجره حيث يساعد ذلك علي تكوين قيم عزوم موجبة وسالبة مناسبة .
- ٥ - تنتقل الأحمال من البلاطات للكمرات الثانوية ومنها لكمرات الإطار Frame girder .
- ٦ - في العادة تكون أبعاد الكمرات الثانوية في حدود ٢٥ × ٥٠ .

- Loads on frame:

٥ - ٦ : حساب الأحمال :

مثال :

الموضح بشكل (٨) إطار له الخصائص الآتية :

سمك البلاطات = ١٢ سم .

الحمل الحي = ٠,٢ طن / م^٢ .

أبعاد الكمرات الثانوية = ٢٥ × ٥٠ .

احسب قيم الأحمال علي الإطار .

الحل :

$$t_g = \frac{L}{12-16} \cong \frac{L}{14} = 114.29 \cong 120cm.$$

For cantilever $t_{bigger} = 120 \text{ cm}$, $t_{smaller} = 60 \text{ cm}$, $t_{av} = 90 \text{ cm}$.

$$W_{su} = 1.4 g_s + 1.6 p_s = 1.4 (0.12 * 2.5 + 0.15) + 1.6 * 0.2 = 0.95 \text{ t / m}^2 .$$

شكل رقم (٩) يبين شكلا مجردا statical system للإطار وعليه الأحمال بنوعيه الموزع والمركز ، ويلاحظ أن الحمل الموزع ينتج من الوزن الخاص بكمرات الإطار girder بالإضافة لأحمال المتلثات الثمانية في ناحيتي الكمرات ، أما الأحمال المركزة فهي نتيجة ارتكاز الكمرات الثانوية علي كمرات الإطار .

Distributed load:

$w_1 = o.w \text{ of frame girder} * 1.4 + \text{slab load}$

$$= \gamma_c \times t_g \times b \times 1.4 + (\sum \text{area of slabs}) \frac{W_{su}}{\text{span}}$$

$$\therefore w_1 = 2.5 \times 1.2 \times 0.35 \times 1.4 + \frac{W_{su}}{16} \times 8 [4 \times 2 \times 0.50] = 3.37 \text{ t / m}^- .$$

$w_2 = o.w. \text{ of cantilever} \times 1.4 + \text{slab load}$

$$= 2.5 \times 0.90 \times 0.35 \times 1.4 + \frac{0.95}{4} \times 2 [4 \times 2 \times 0.5] = 3 \text{ t / m}^- .$$

Concentrated loads :

$P = \text{spacing} * (\text{o.w of sec. beam} * 1.4 + \text{slab load}) .$

$$P = 5 \times (\gamma_c * 0.25 * 0.5 * 1.4 + \sum \text{area of slabs on sec beam} * \frac{W_{su}}{\text{span}})$$

$$\therefore P_1 = 5 \left[2.5 * 0.25 * 0.5 * 1.4 + \frac{0.95}{5} * 2 \left[\frac{5+1}{2} * 2 \right] \right] = 13.59 \text{ ton}$$

$$P_2 = 5 \left[2.5 * 0.25 * 0.5 * 1.4 + \frac{0.95}{5} \left[\frac{5+1}{2} * 2 \right] \right] = 7.89 \text{ ton}$$

تبسيط :

في حالة وجود عدد من الأحمال المركزة (ثلاثة فأكثر) يوصي بتوزيع هذه الأحمال باعتبارها حملا موزعا مكافئا (شكل ١٠) .

$$w_{eq.} = \frac{\sum p}{\text{span}} * 1.10$$

$$\text{الحمل المكافئ} = \frac{3 * 13.59}{16.0} * 1.1 = 2.8 \text{ t/m}^2 .$$

حساب مؤثرات القوى الداخلية :

Straining actions:

والمقصود بها قيم :

- | | |
|-------------|----------------------|
| - B . M . D | ١ - عزوم الانحناء . |
| - N . F . D | ٢ - قوى القص . |
| - S . F . D | ٣ - القوى العمودية . |

- يتم عمل جدول كالتالي :

Sec No	M_u	N_u	Sec is designed for
1		بالإشارة	M_u only
2			N_u only
3			M_u & N_u
⋮	⋮	⋮	⋮

ويجب رسم منحنيات مؤثرات القوي الداخلية بصورة صحيحة وتجنب الخطأ فيها لاعتماد شكل التسليح عليها ، كما سيتضح فيما بعد :-

- تصميم قطاعات الإطار : Design of frame sections :

يتم تصميم جميع القطاعات التي تتغير عندها (M_u , N_u) طبقاً لما سبق شرحه في الأبواب السابقة .

1 - Section subjected to M_u only:

use R - ω curve :

$$R = \frac{M_u}{f_{cu} b d^2} \rightarrow \omega$$

$$A_s = \omega b d \frac{f_{cu}}{f_y}$$

Note:

If section subjected to M_u & N_u (- ve) but $N_u \leq 0.04 f_{cu} A_c$.

\therefore neglect N_u and design for M_u only .

2 – Section subjected to M_u & N_u (-ve : comp.) , $e / t < 0.05$:

∴ Neglect M_u and design for N_u only as short column.

$$N_u \cdot 1000 = 0.35 f_{cu} A_c + 0.67 f_y A_{sc} .$$

3 – Section subjected to M_u & N_u (-ve : comp.) : But $e / t > 0.05$.

∴ Design the section for M_u & N_u as ecc . sec .

∴ use interaction diagram .

∴ use chart of : $\zeta = 0.9$ & $\alpha = 0.60$

فإذا وقع القطاع في منطقة الضغط (شكل ١١) يتم الحل باستخدام منحنيات التفاعل
 . (Interaction diagrams)

$$\text{curve} \xrightarrow{\text{get}} \rho \rightarrow \mu = \rho f_{cu} \times 10^{-5}$$

$$\therefore A_s = \mu bt$$

$$\& A_s^- = \alpha A_s .$$

أما لو وقع القطاع في منطقة الشد فلا تستخدم منحنيات التفاعل (Interaction diagrams) ،
 ولكن يمكن استخدام المخطط البياني $R - \omega$.

$$e_s = e + t/2 - \text{cover} \rightarrow Mu_s = Nu.e_s$$

$$\therefore R = \frac{Mu_s}{f_{cu}bd} \xrightarrow{\alpha=0.4} \text{get } \omega$$

$$A_s = \omega bd \frac{f_{cu}}{f_y} - \frac{Mu}{f_y \gamma_s} \& A_s^- = \alpha A_s .$$

وغالبا ما يكون هذا القطاع في الجزء العلوي من رجل الإطار .

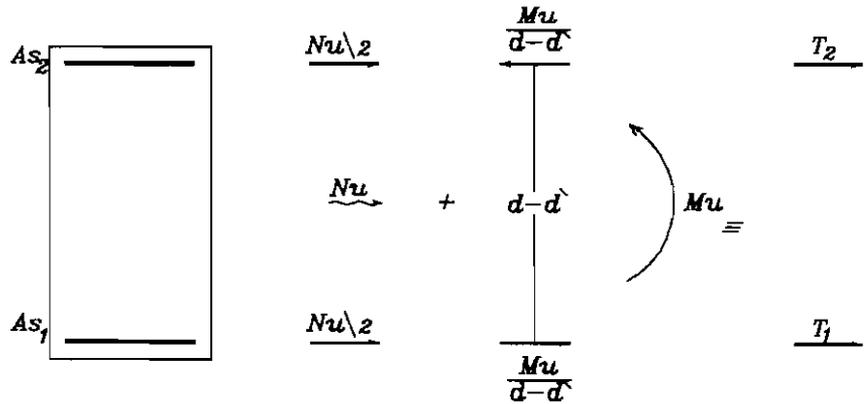
4 – Section subjected to M_u & N_u (+ve : tension) : & $e/t < 0.5$ ∴ *Small.ecc.*

$$T_1 = \frac{N_u}{2} + \frac{M_u}{d - d'}$$

$$T_2 = \frac{N_u}{2} - \frac{M_u}{d - d'}$$

$$\therefore A_{s1} = \frac{T_1}{f_y / \gamma_s}$$

$$A_{s2} = \frac{T_2}{f_y / \gamma_s}$$



شكل (١٢)

5 – Section subjected to M_u & N_u (+ve : tension) : & $e/t > 0.5$ ∴ *Larg.ecc.*

Use R ω (curve) :

$$e_s = e - t/2 + \text{cover}$$

$$\therefore M_{us} = N_u \times e_s.$$

$$R = \frac{M_{us}}{f_{cu} b d^2} \xrightarrow{\text{curve}} \omega$$

$$\therefore A_s = \omega b d \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s}.$$

٥ - ٧ : تصميم أرجل الإطار

Design of frame legs :

شكل (١٣) يبين إطاراً له رجلان إحداهما عنصر وصل link member ، كما يلاحظ أن هناك كمرات متعامدة على الإطار في منتصف الارتفاع تقريباً للمساهمة في حمل الحوائط الطوب والتي يجب أن لا تزيد المساحة المستمرة من المباني عن حد معين (من ٢٠ - ٢٥ م) .

- ولتصميم الرجل اليمنى شكل (١٤) : نصمم قطاعاً له عمق t_{av} يقع عند ثلثي ارتفاع الرجل ، وهنا يجب دراسة القطاع في كلا الاتجاهين (x , y) .

$$\therefore t_{av} = t_L + \frac{2}{3}(t_u - t_L).$$

x - direction :-

Top end condition case 1 ($t_g \geq t_u$) .

bottom end condition case 3 (hinged support) .

$$H_e = K. \text{ clear Height } (H_c)$$

$$\lambda_{av} = H_e / t_{av}$$

$$\text{If : } \lambda_{av} \leq 10(\text{braced}), \lambda_{av} \leq 15(\text{unbraced})$$

\therefore no additional M i.e. (short column) .

$$\text{, If : } \lambda_{av} > 10(\text{braced}), \lambda_{av} > 15(\text{unbraced})$$

\therefore M_{addy} exist (long column) .

$$M_{addy} = \delta \cdot N_u \cdot$$

$$\delta = \frac{\lambda_{av}^2 \cdot t_{av}}{2000}.$$

شكل (١٥) : y - direction

Top end condition :

$$t_b > b \rightarrow \therefore \text{case(1)}$$

$$t_b < b \rightarrow \therefore \text{case(2)}$$

Bottom end condition fixed at support \therefore (case 1) .

$$\therefore H_e = K * (\text{larger of } H_1 \text{ \& } H_2) .$$

$$\lambda_b = \frac{H_e}{b} .$$

$$\text{If : } \lambda_b \leq 10. \text{ braced } \text{ or : } \lambda_b \leq 15 \text{ unbraced}$$

\therefore No M_{add} (short column) .

$$\text{, If : } \lambda_b > 10 \text{ braced . } \text{ or : } \lambda_b > 15 \text{ unbraced}$$

$\therefore M_{addx}$.exists (long column) .

$$, M_{addx} = \delta . N_u \text{ \& } \delta = \frac{\lambda_b^2 * b}{2000}$$

يتم تصميم قطاع العمود (sec.1) علي أبعاد ($b * t_u$) شكل (١٦) وعلي القوى الآتية :

$$N_u = \text{Reaction}$$

$$M_{u, design} = M_{u, 1-1} + M_{addy}(\text{in.x - dir})$$

حيث $M_{u, 1-1}$ هو العزم الأصلي علي القطاع

$$M_{u, design} = M_{addx}(\text{in.y - dir})$$

لا حظ لا يوجد عزم أصلي علي القطاع في هذا الاتجاه .

- Design of link member:

٥ - ٨ : تصميم عنصر الوصل:

نفس الخطوات المتبعة سابقا عدا :

١ - لا يوجد t_{avr} لأن t_{link} ثابتة علي طول العنصر .

٢ - $M_{add} = Mu_{design}$ لأنه لا يوجد عزم أصلي علي القطاع .

$$e = M_u / N_u$$

If $e / t < 0.05$..

∴ Design as short column & neglect M_u .

$$N_u * 10^3 = 0.35 f_{cu} A_c + 0.67 f_y * A_{sc} .$$

get A_{sc} .

If $A_{sc} = -ve$.

∴ Use $A_{s_{min}} = 0.006 A_c$.

- Design of tie member:

٥ - ٩ : تصميم عنصر الربط :

شكل (١٧) حيث يتم فرض أبعاد الشداد كالتالي :-

$$b_{tie} = b_{girder} = 30 - 40 \text{ cm} .$$

$$t_{tie} = 50 - 60 \text{ cm} .$$

يتم تصميم الشداد علي قيمة N_u بالإضافة إلي $M_{u.o.w}$ (العزم الناتج عن الوزن) .

$$M_{u.o.w} = \frac{W_{uo.w} L^2}{8}$$

ملاحظة : يمكن تصميم الشداد علي N_u فقط في حالة استعمال شمعات الشد (posts) فيكون

منحني العزوم للشداد تحت تأثير وزنه قيمة صغيرة يمكن إهمالها (شكل ١٨) .

∴ Design tie for N_u only

$$A_{s_{tie}} = \frac{N_u * 1000}{f_y / \gamma_s} \text{ cm}^2 .$$

ويتم توزيع $A_{s_{tie}}$ علي القطاع بالتساوي .

Check of shear :

٥ - ١٠ : التحقق من القص :

القطاع الحرج في القص يكون علي بعد $\frac{d}{2}$ من وجه العمود (شكل ١٩) .

$$\therefore Q_{ured} = Q_u - W_u \left(\frac{\text{column.dim}}{2} + \frac{d}{2} \right)$$

$$q_u = \frac{Q_u * 10^3}{bd}$$

$$q_{cu \max} = 2.2 \sqrt{\frac{f_{cu}}{\gamma_c}}$$

$$q_{cu} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}}$$

$$q_{su} = q_u - 0.5q_{cu}$$

If $q_u > q_{cu \max}$.

\therefore concrete dimensions. are unsafe

\therefore Increase b or d .

If $q_u < q_{cu}$

\therefore use $A_{st.min}$

$$\therefore A_{st.min} = \frac{3.5b.s}{f_{y.st} / \gamma_s} \text{ area of all branches}$$

If $q_{cu} < q_u < q_{cu \max}$ \therefore we need stirrups $\therefore A_{st} = \frac{q_{su} \cdot b \cdot s}{f_{y.st} / \gamma_s}$ (area of all branches).

Design of hinged Base:

٥ - ١١ : تصميم الركيزة المفصلية شكل (٢٠) :

Bearing check:

$$f = \frac{y_A}{A_1} \leq f_b .$$

$$f_b = 0.67 f_{cu} / \gamma_c \leq 0.67 f_{cu} / \gamma_c \sqrt{\frac{A_2}{A_1}}$$

$$A_1 = b \cdot t_f / 3 .$$

$$A_2 = (2 * h + t_f / 3) \cdot (2h + b) .$$

If $f < f_b$ \therefore safe .

If $f > f_b$ increase lead plate width to $\frac{t_f}{2}$

2 - Area of dowels :

تصميم عدد وقطر (الأسيار) :

$$A_{s_{dowels}} = \frac{X}{0.8 f_y / \gamma_s}$$

$A_{s_{dowels}}$ = area of all dowels.

3 – Horizontal stirrups:

الكاتات الأفقية شكل (٢١) :

distributed through height t_c .

$$T = \frac{y_A}{4} \rightarrow \frac{y_A}{6}$$

$$A_{sh} = \frac{T}{f_y / \gamma_s}$$

$$A_{sh} = A_{req} \text{ for all stirrups both branches Number of stirrups} = \frac{A_{sh}}{2 \times 0.785}$$

Where 0.785 = A_s of $\phi 10$

4 – Inclined closed stirrups :

الكاتات الزاوية شكل (٢٢) :

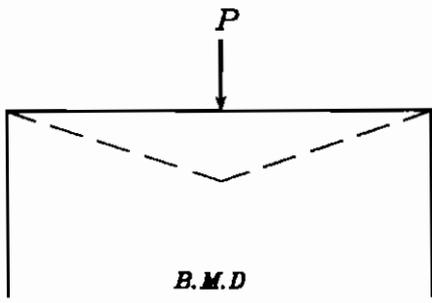
$$T = \frac{A_s f_y}{\gamma_s} \quad \text{Closed stirrups.}$$

$$A_{st} = \frac{\sqrt{2}T}{4 f_{y,st} / \gamma_s} = 0.35 \frac{f_y}{f_{y,st}} A_s = 0.53 A_s. \quad \text{where } T = \text{splitting force .}$$

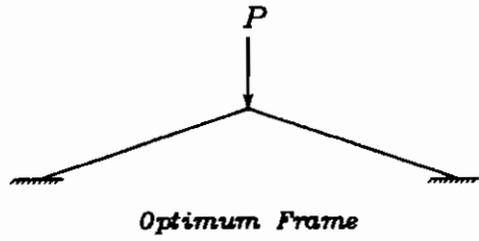
A_{st} = area of all stirrups for both branches.

Using $\phi 10$

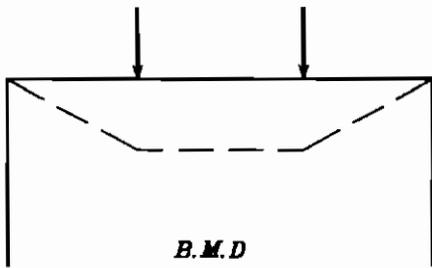
$$\therefore \text{Number of closed stirrups} = \frac{A_{st}}{2 * 0.785}$$



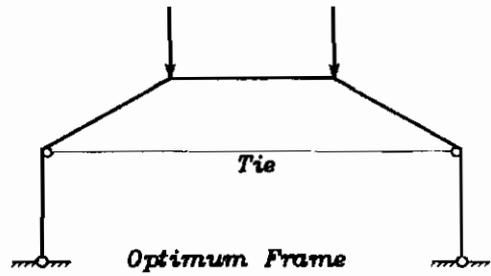
For one concentrated load



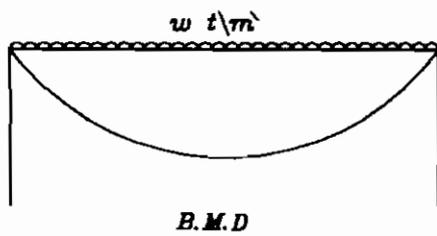
أ- في حالة حمل مركز واحد



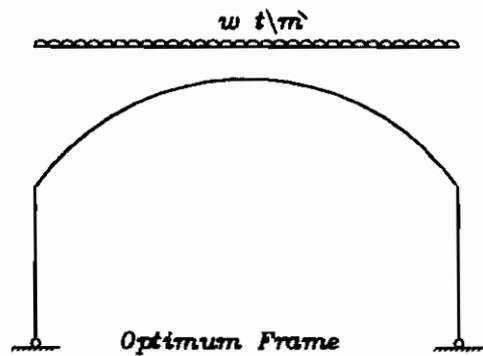
For two concen. Loads



ب- في حالة حملين مركزيين

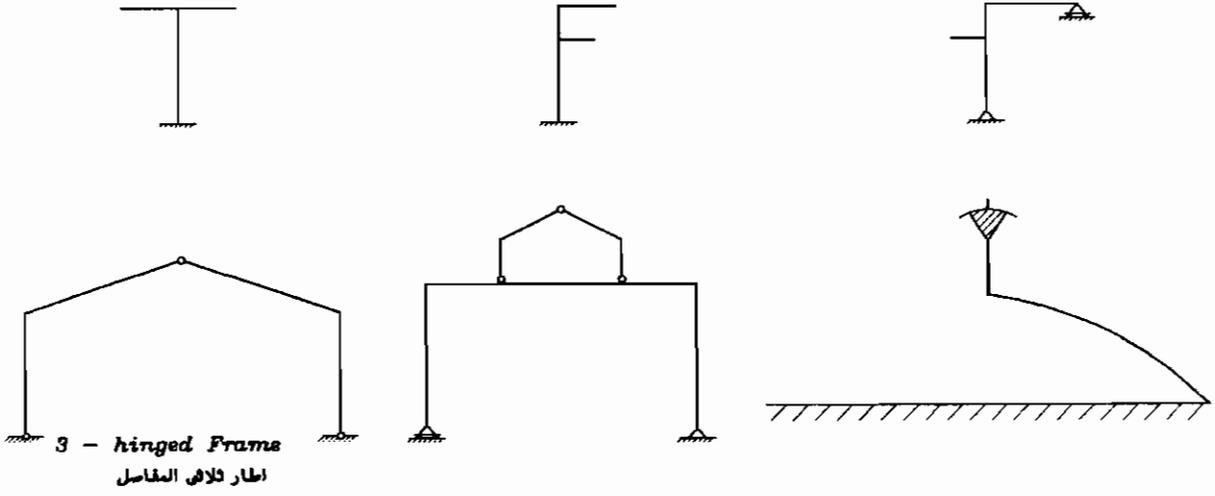


Distributed Load



ج- في حالة حمل موزع

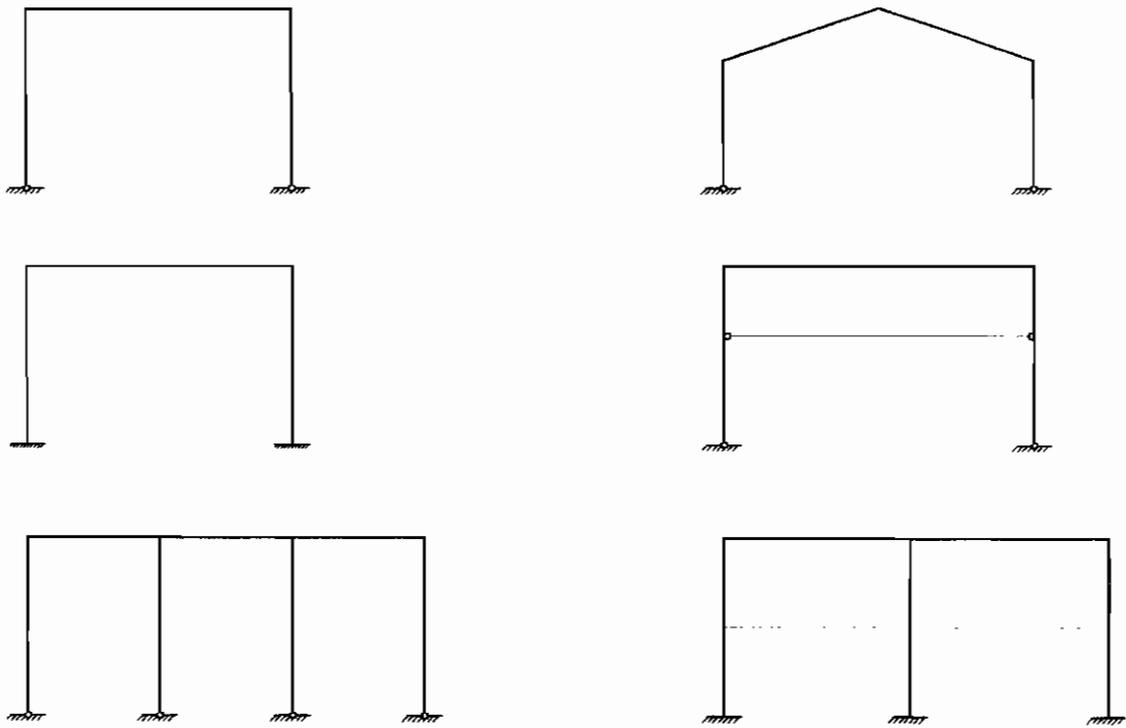
شكل (١) الشكل المثالي للاطار



Statically
Determinate
Frames .

الاطارات المحددة استاتيكية

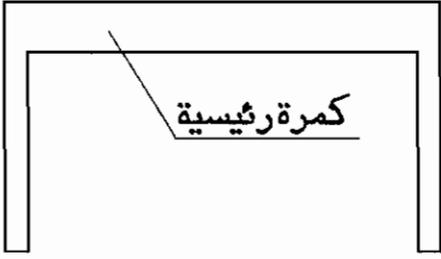
شكل (٢) أمثلة لاطارات المحددة استاتيكية



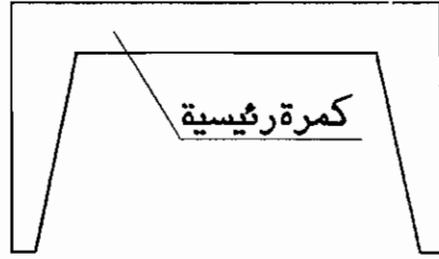
Continuous Frame

Continuous Multi-Story Frame

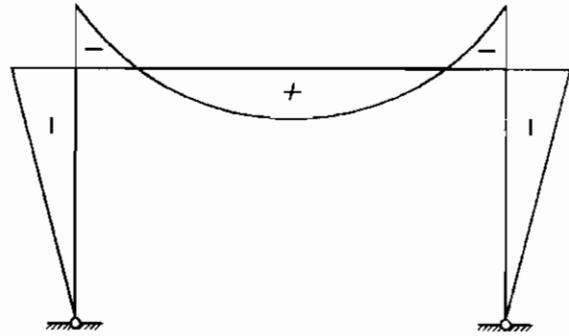
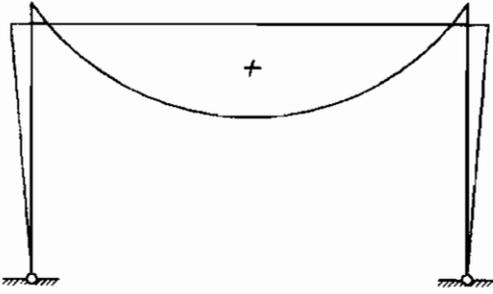
شكل (٣) أمثلة لاطارات الغير محددة استاتيكية



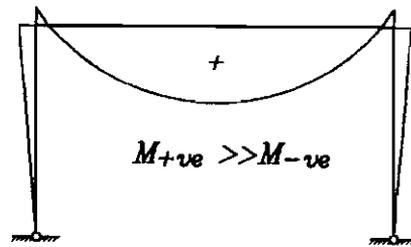
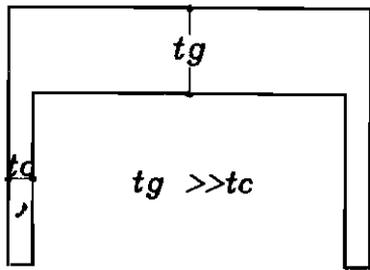
Simple beam with Columns



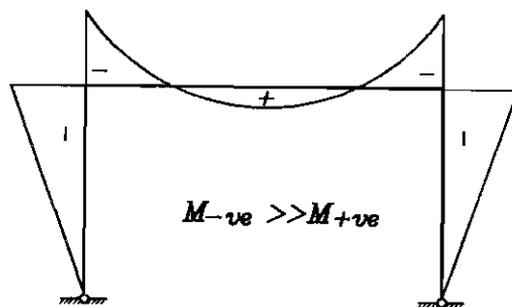
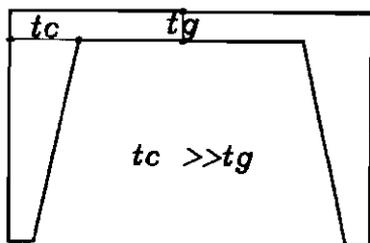
R.c Frame



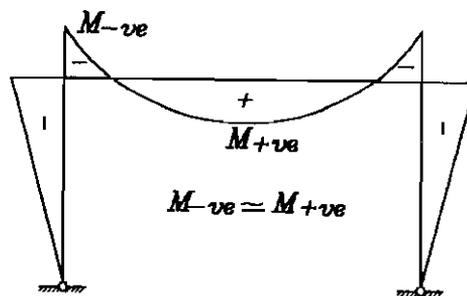
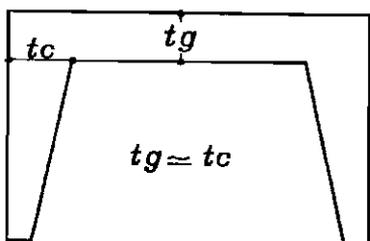
شكل (٤) الكمره الرئيسيه في حالتها البسيطه و الاطار .



Case of too large Girder

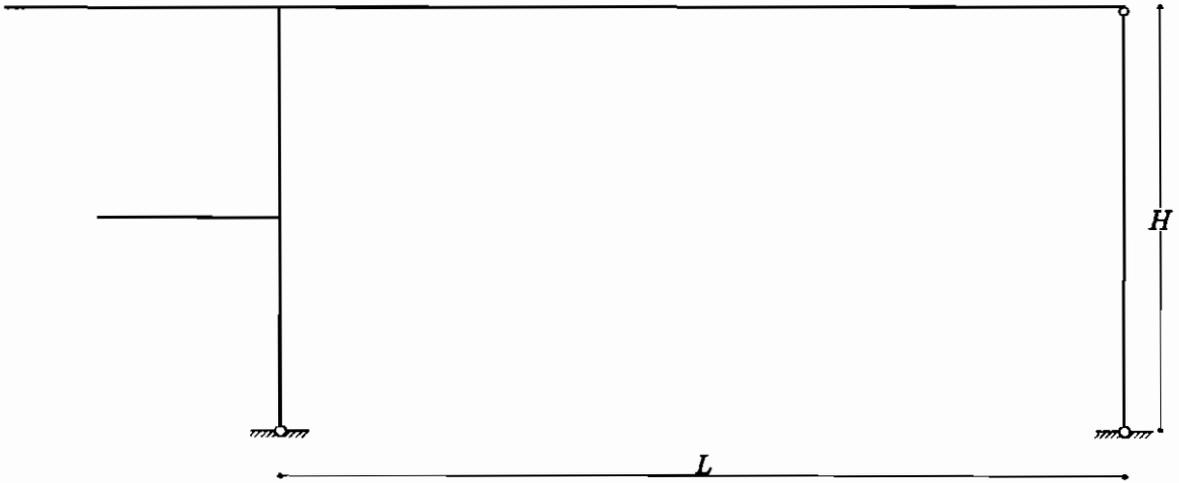
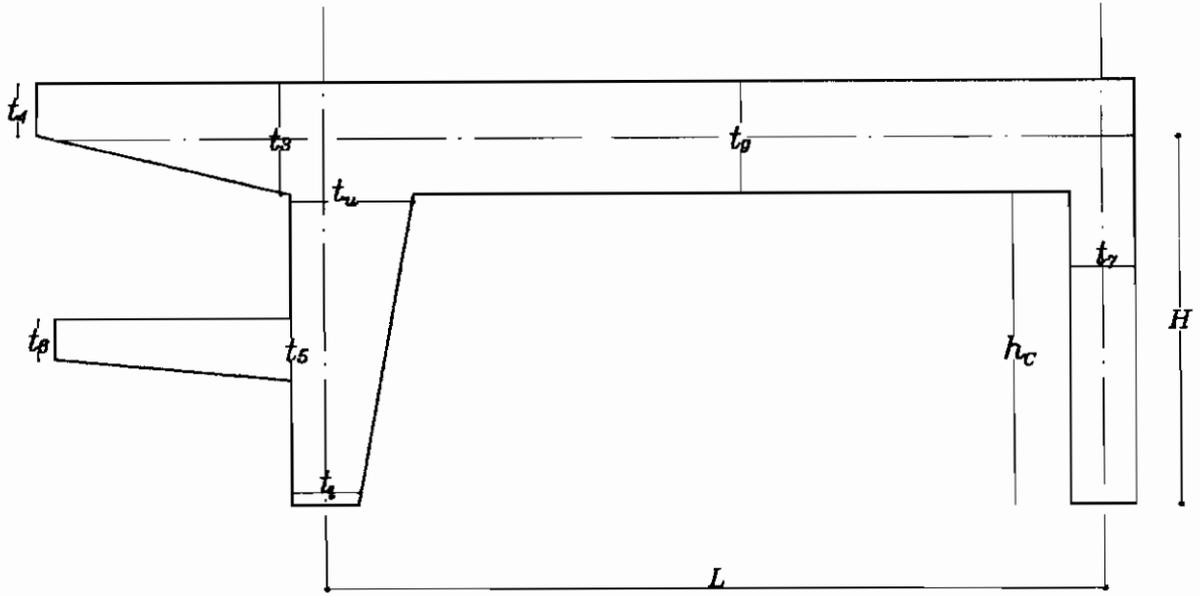


Case of too large Column

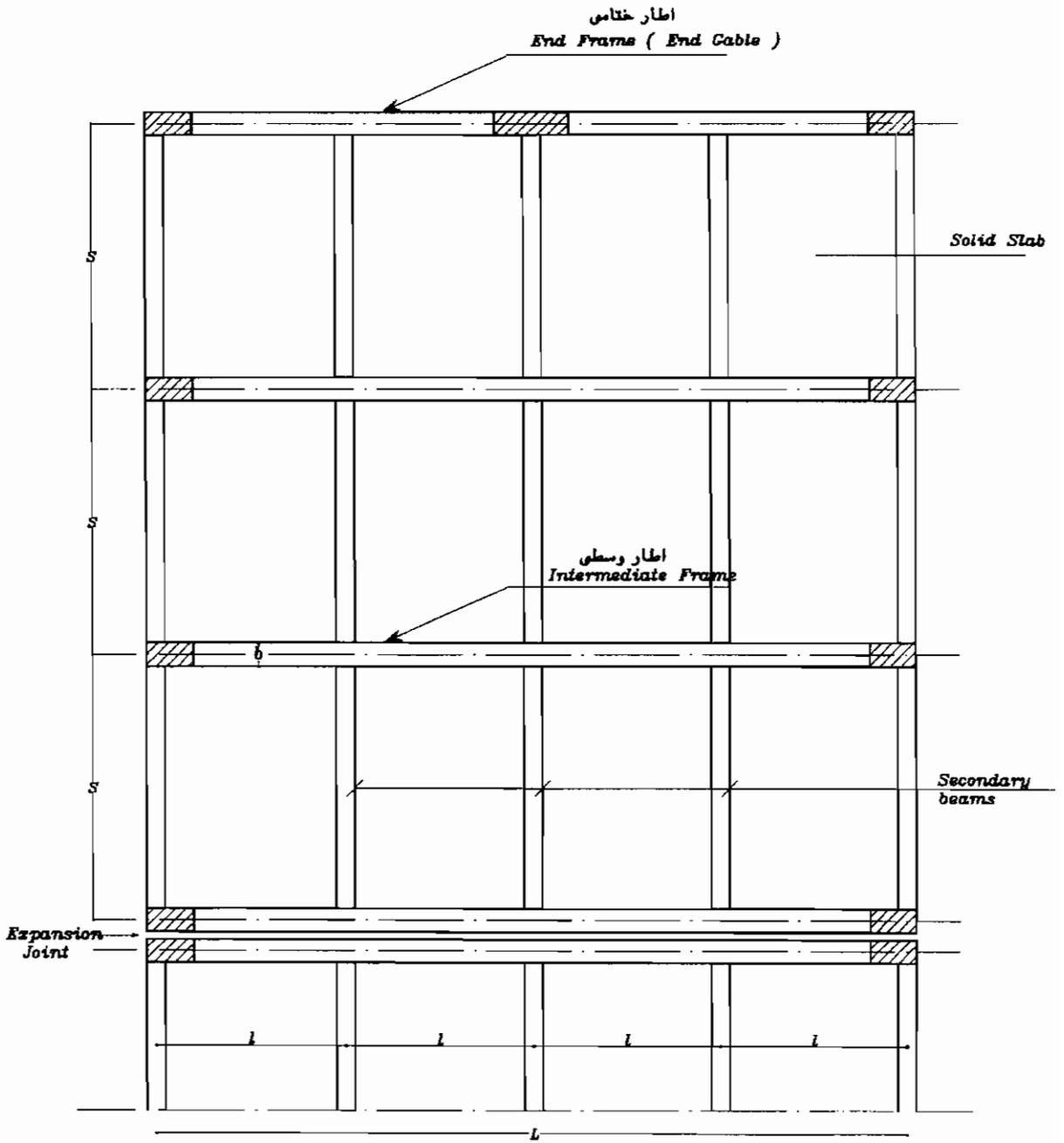


Case of relatively Equal dimensions (The best case)

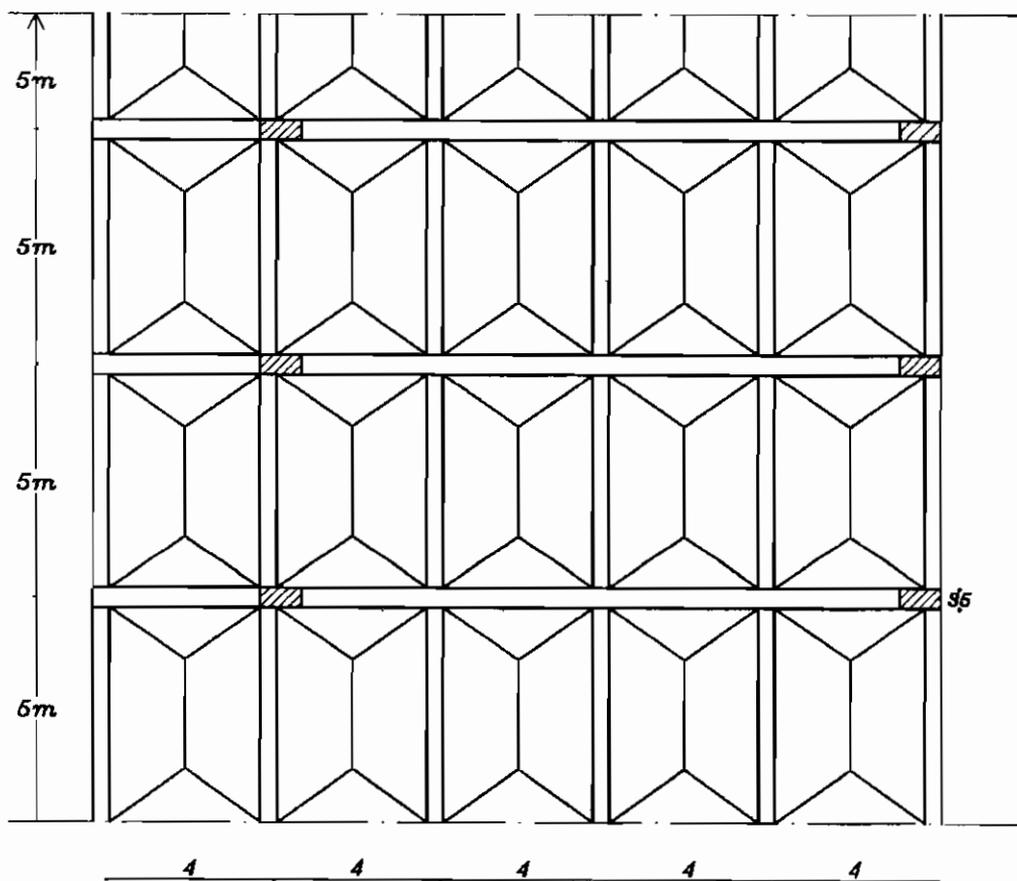
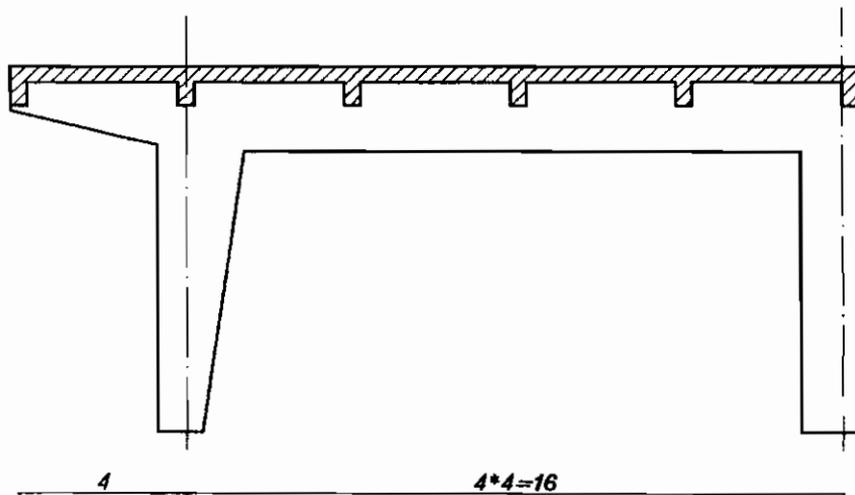
شكل (٥) علاقة أبعاد الكمرة بأبعاد رجل الاطار .



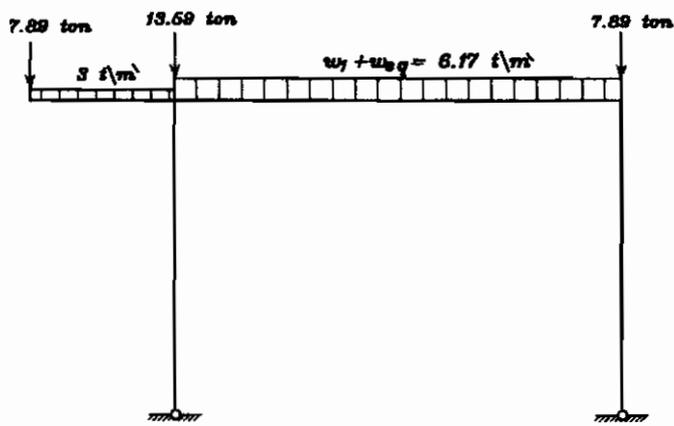
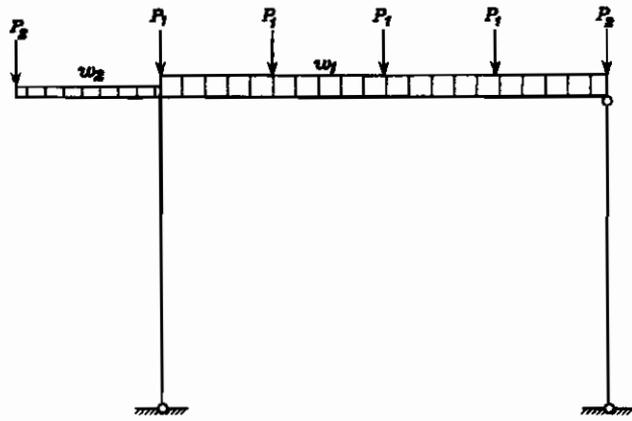
شكل (٦) علاقات الأبعاد الهندسية لعناصر الأطار



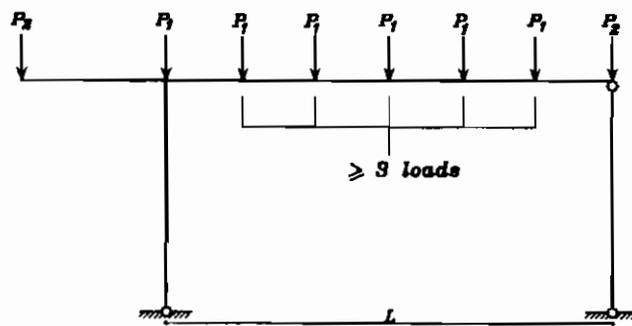
شكل (٧) طريقة ترتيب الاطارات .



شکل (۸) اطاردو کابولی



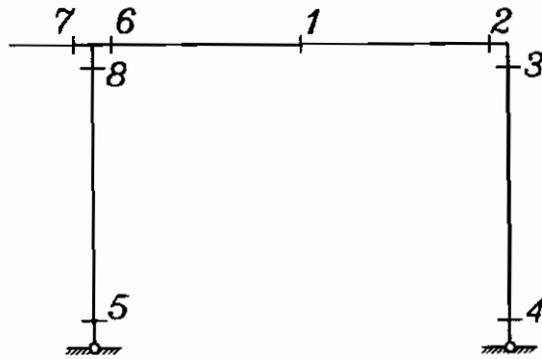
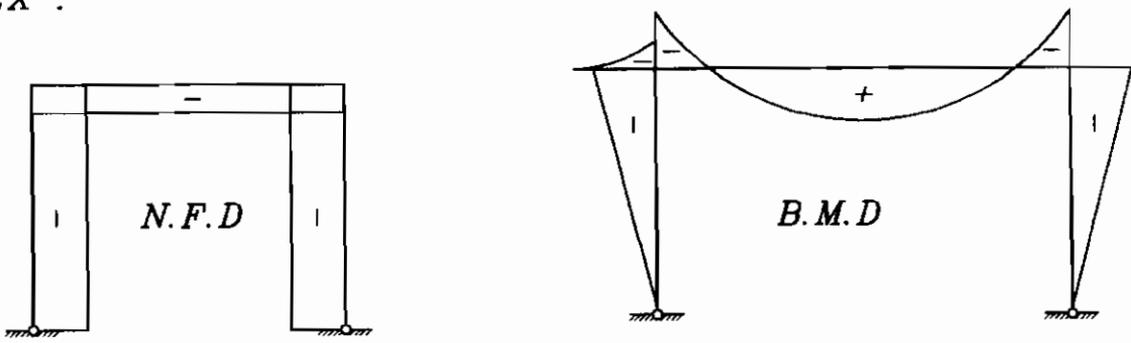
شكل (٩)



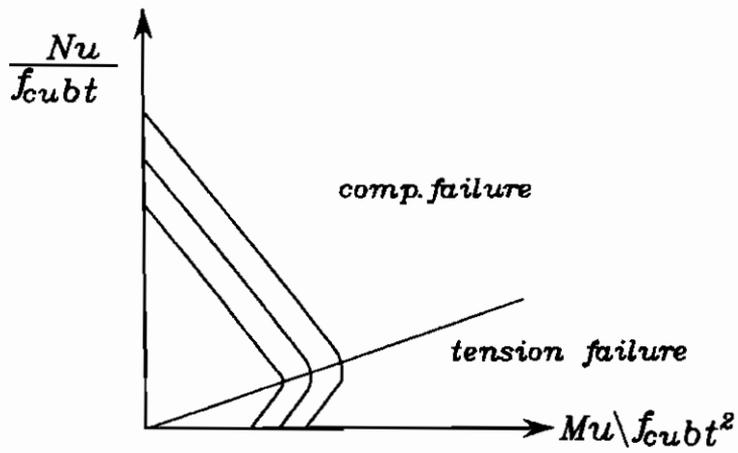
$$W_{eq} = \frac{\sum P}{\text{span}} + 1.10$$

شكل (١٠) حالة عامة

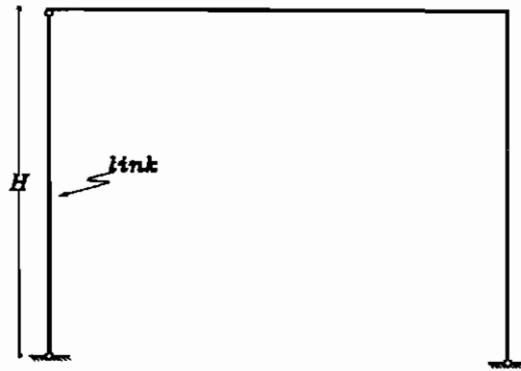
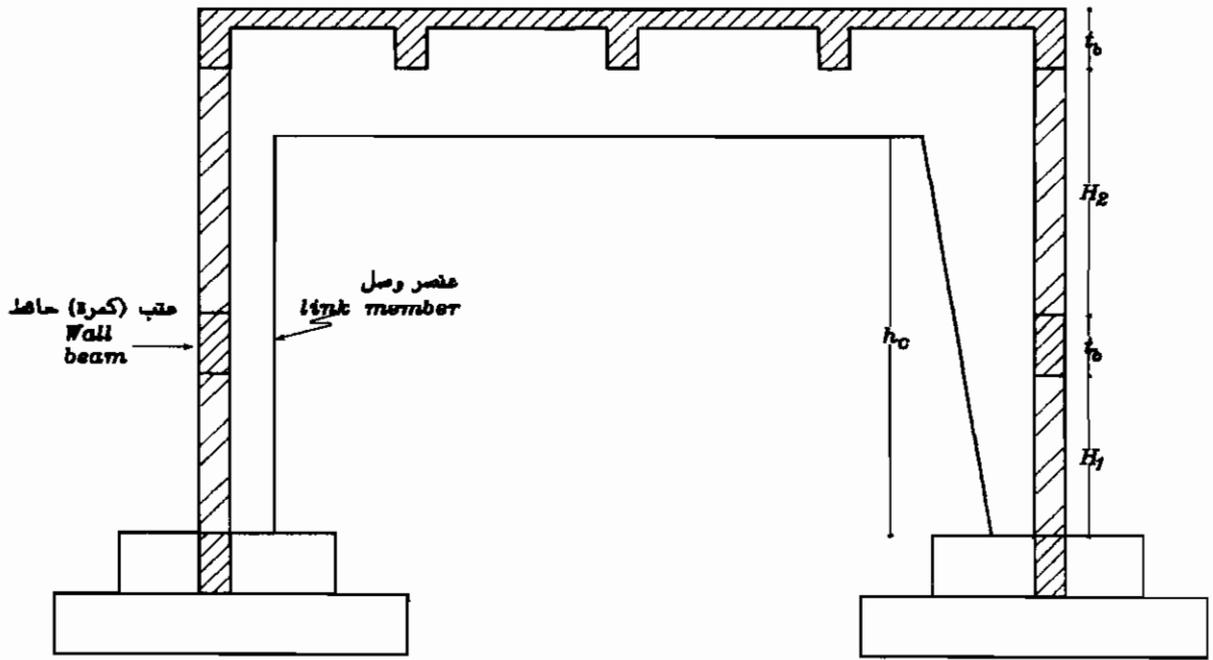
EX :



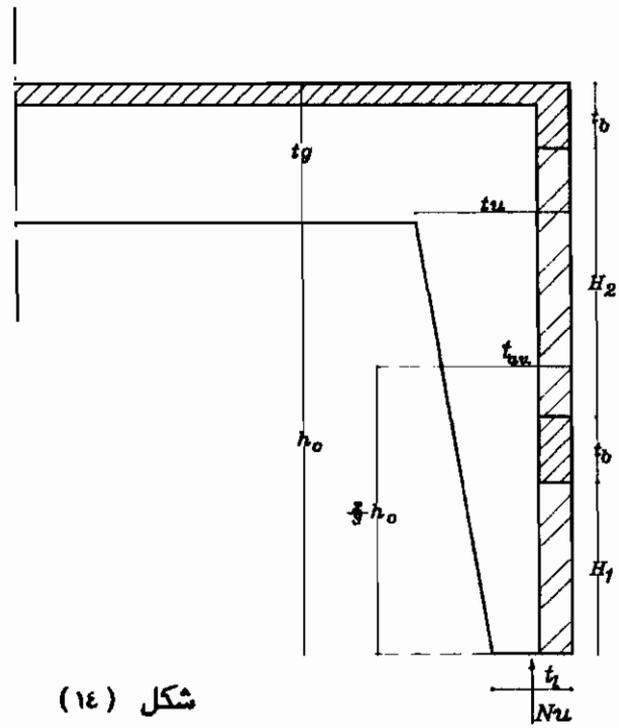
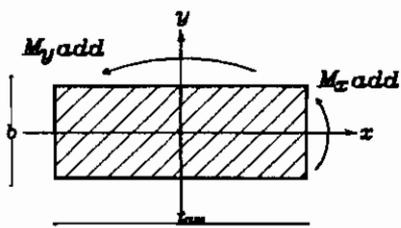
يجب تصميم الثانية مقاطعات الموضحة



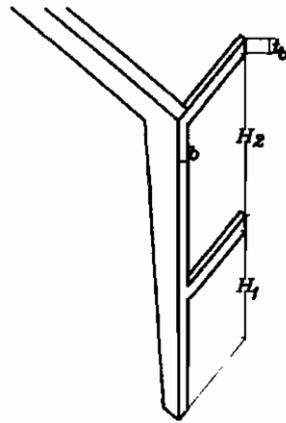
شكل (11)



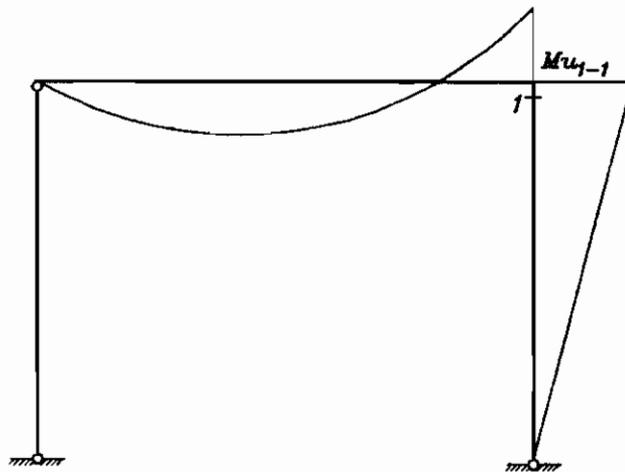
شكل (١٣)



شكل (١٤)



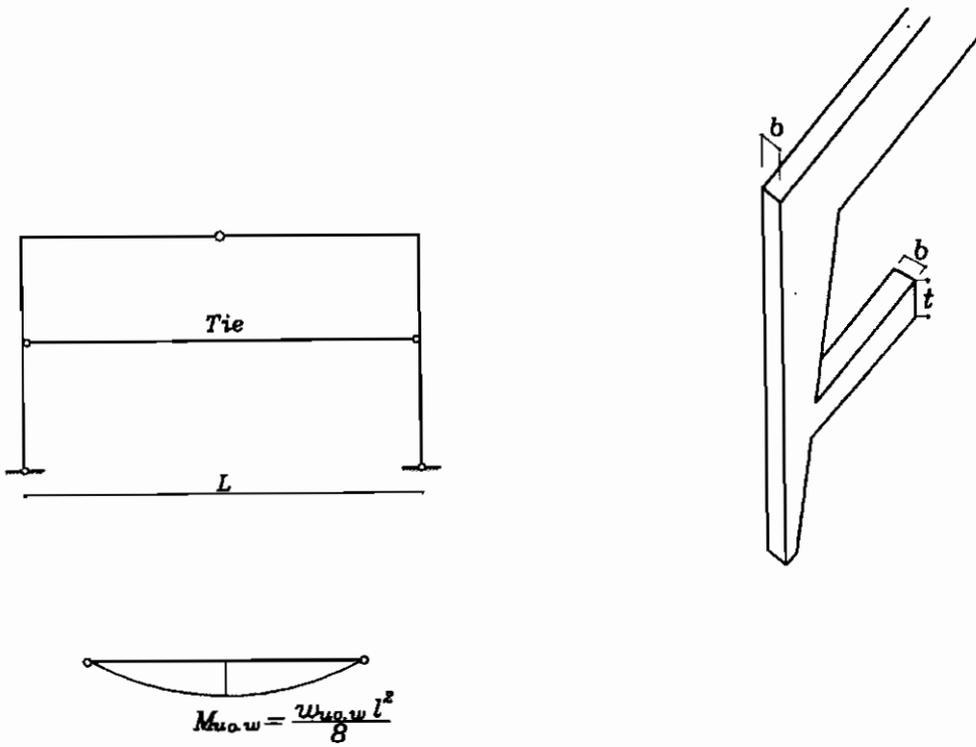
شكل (١٥)



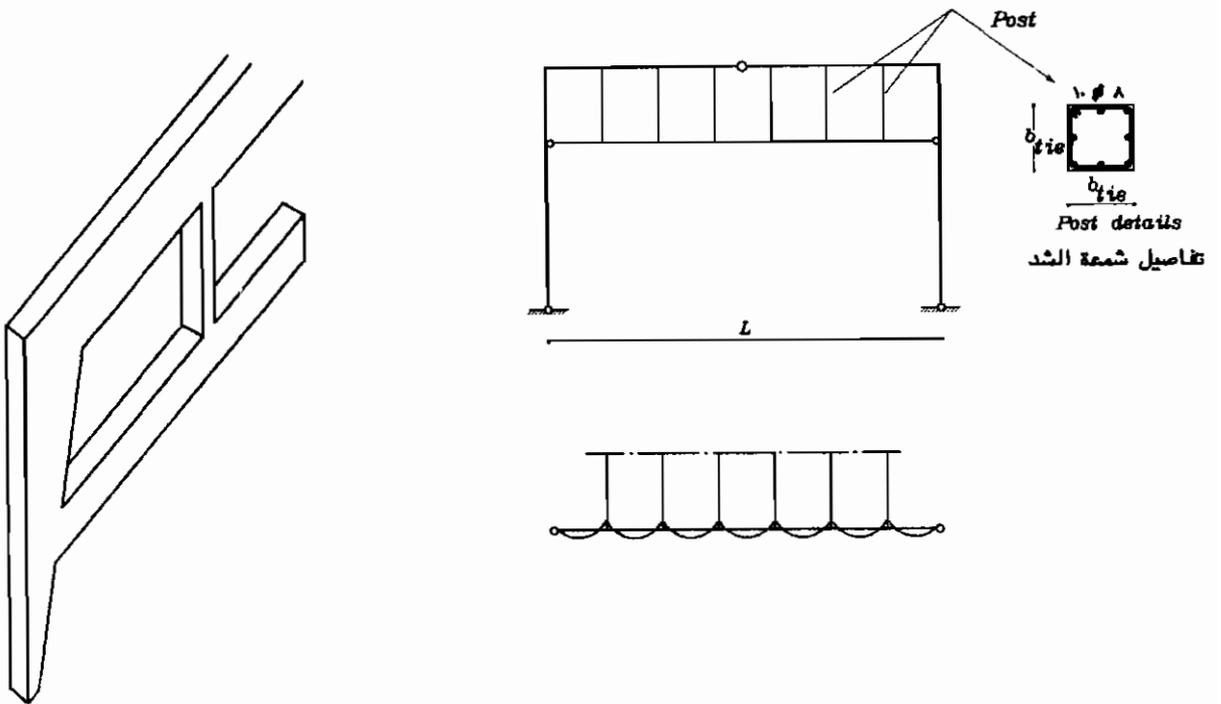
لاحظ لا يوجد عزم اصلي على القطاع

في هذا الاتجاه ←

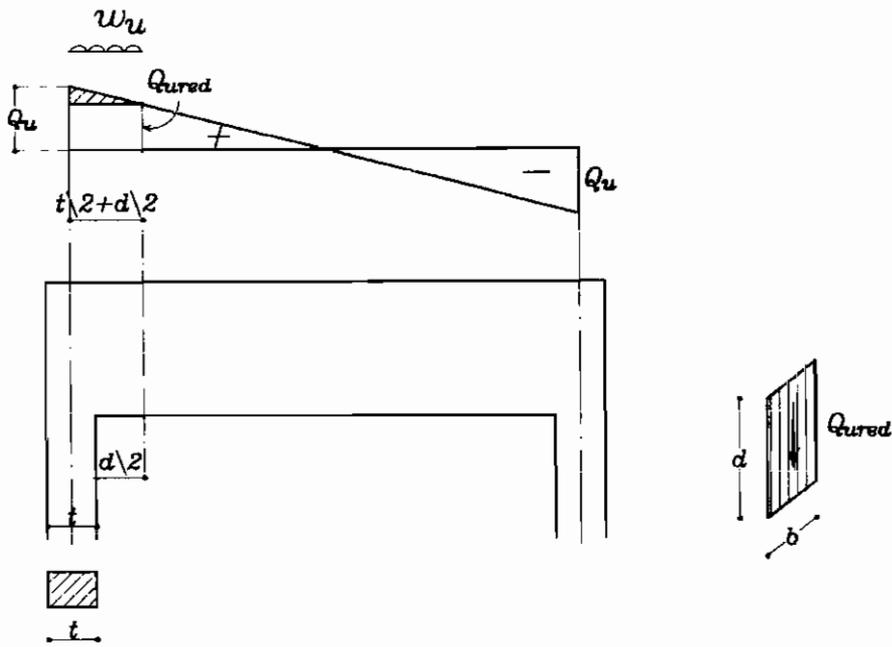
شكل (١٦)



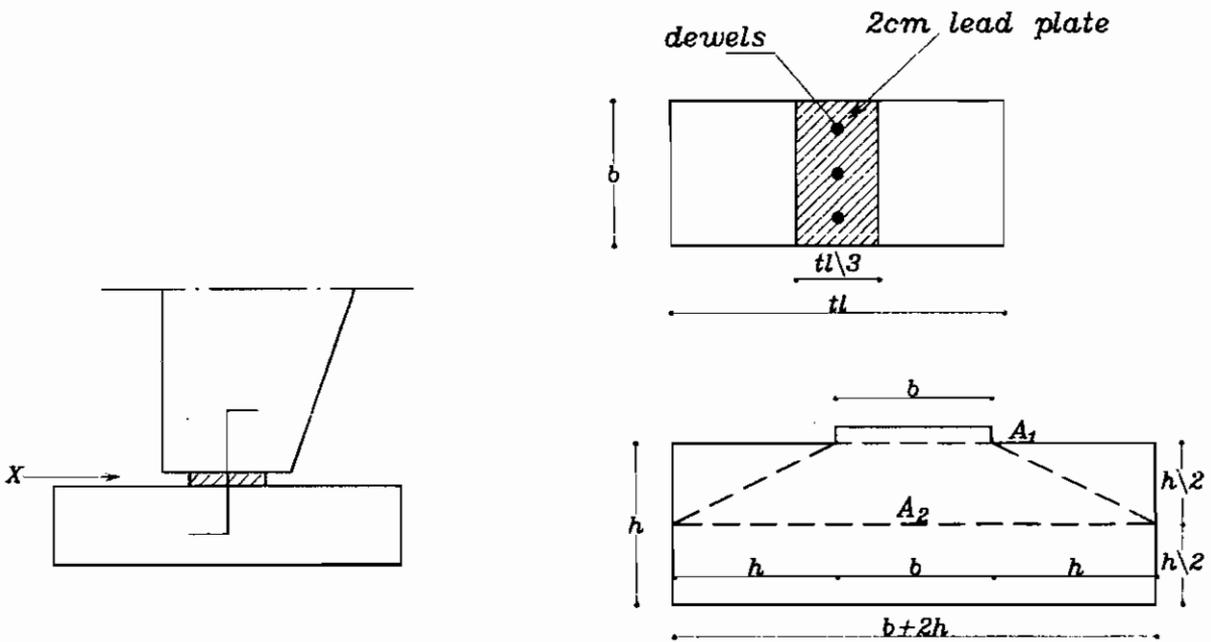
شكل (١٧)



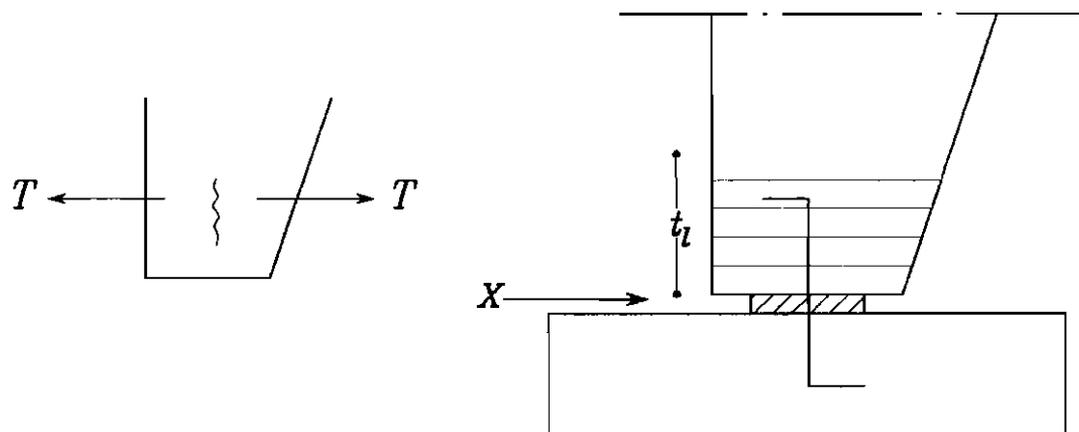
شكل (١٨)



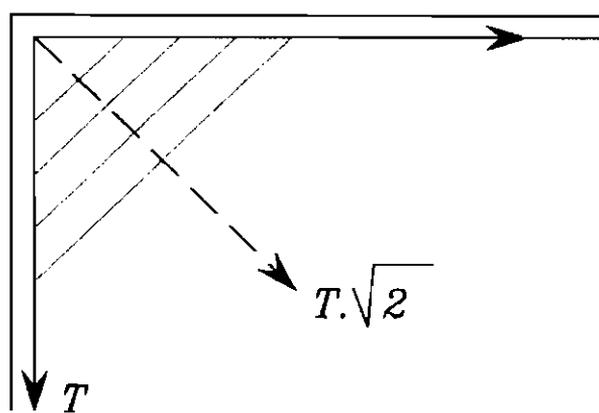
شکل (۱۹)



شکل (۲۰)



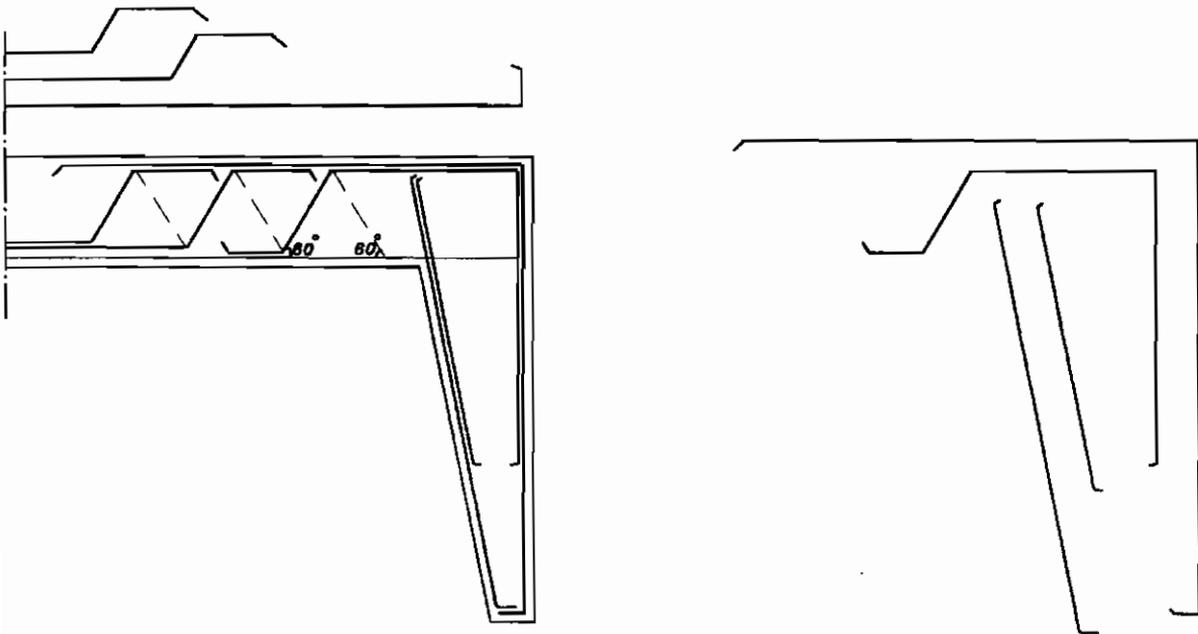
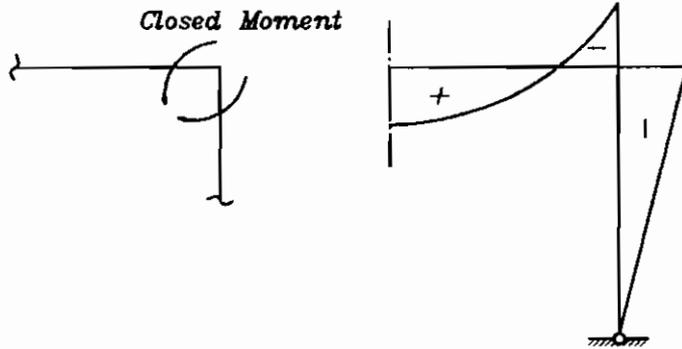
شکل (۲۱)



شکل (۲۲)

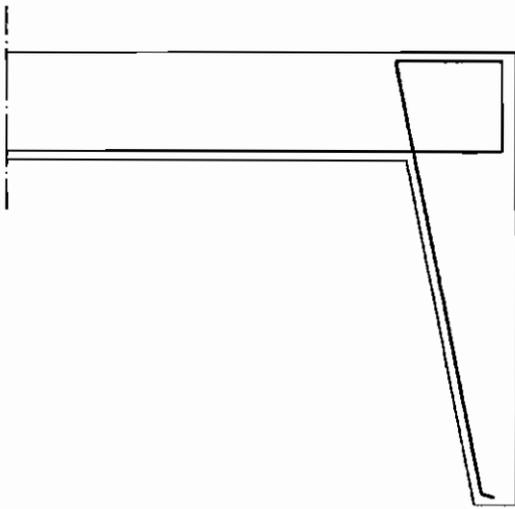
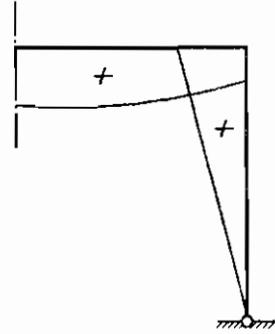
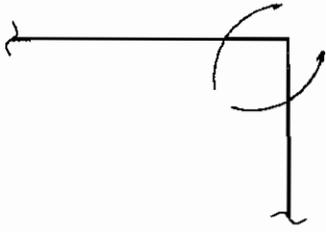
1- Connection (1)

وصلة ١

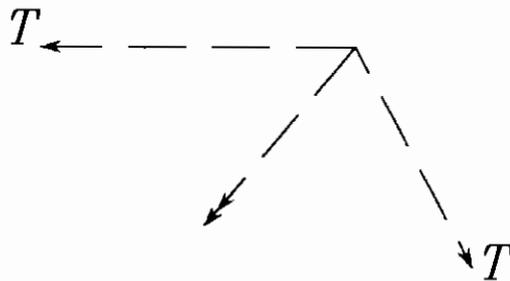
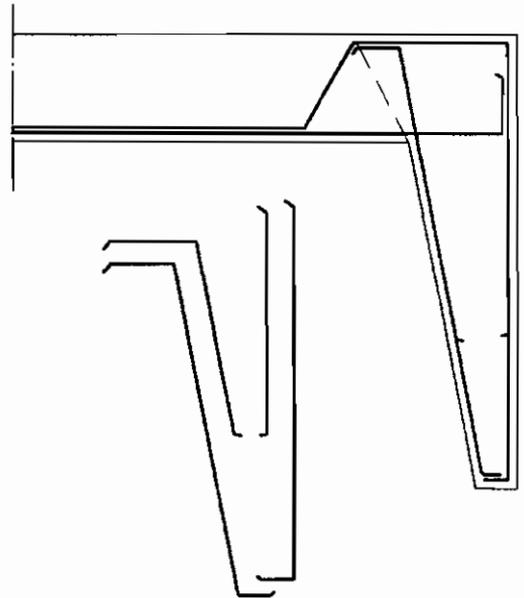


شكل (٢٣)

Opening Moment

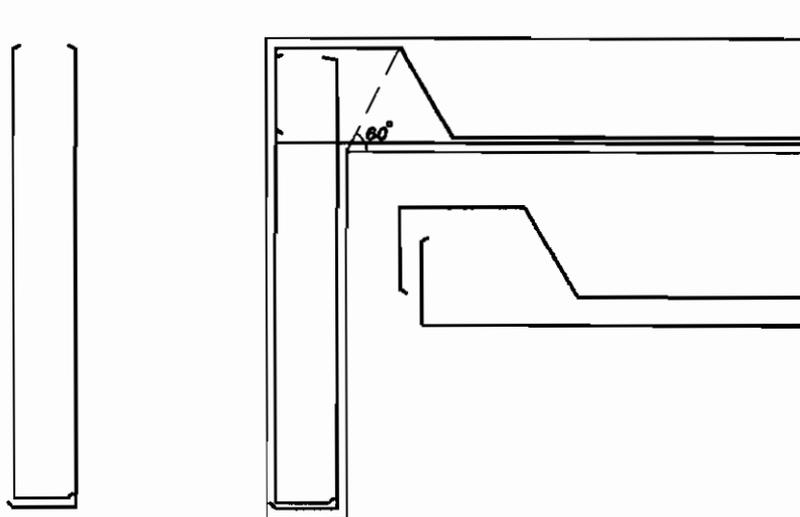
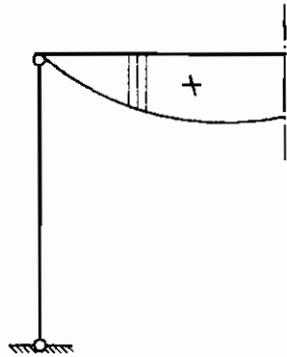


Or

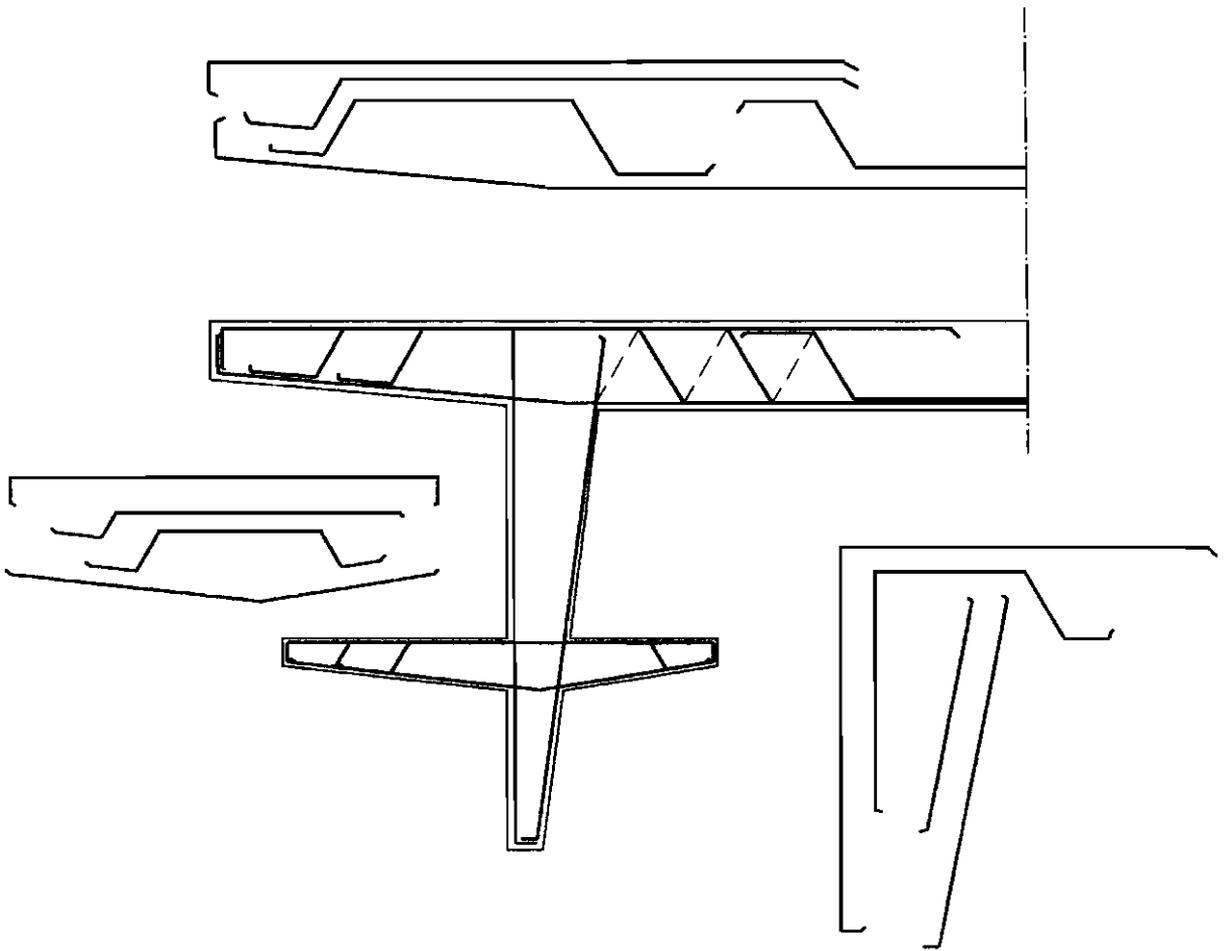
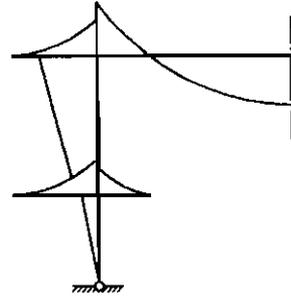
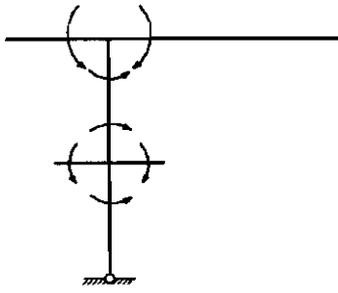


محصلة الشد يمكن أن
تسبب انهيار الغطاء
الخرساني .

شكل (٢٤)



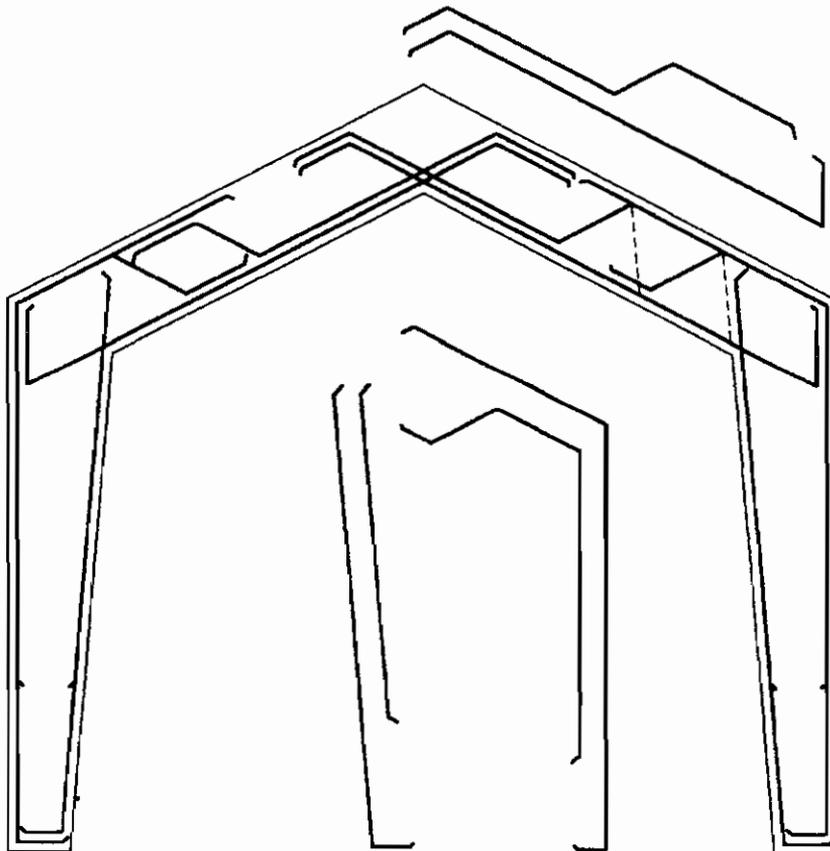
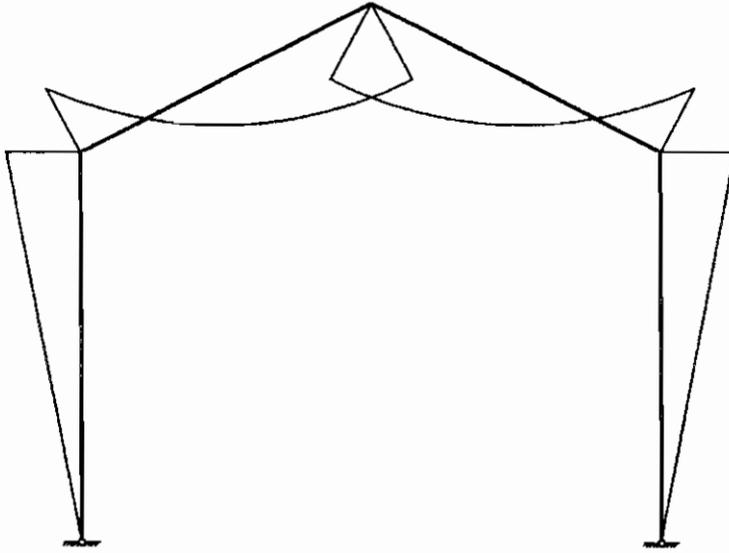
شكل (٢٥)



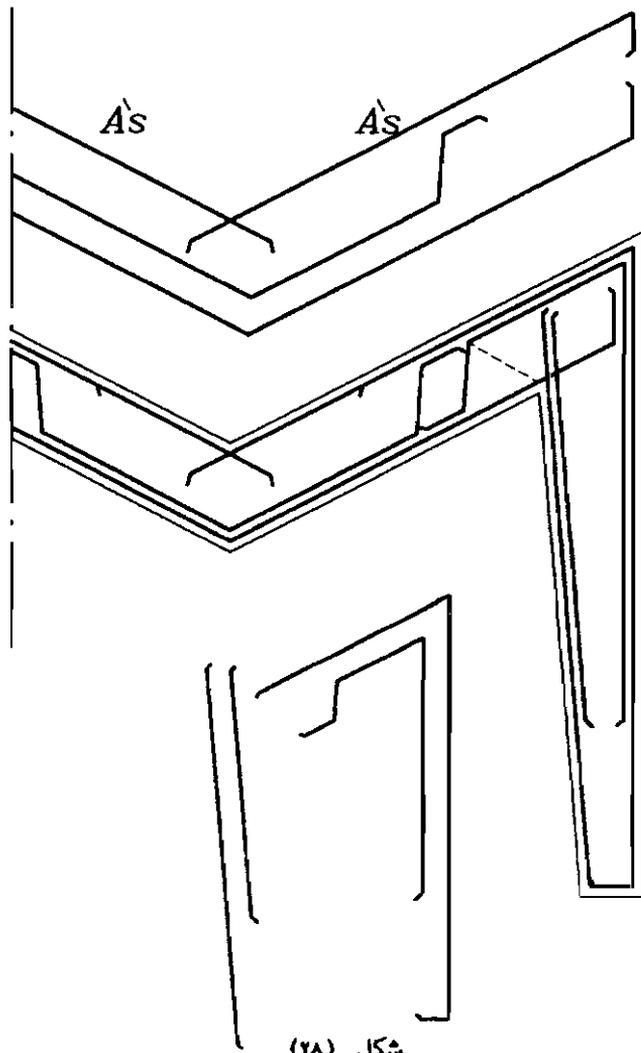
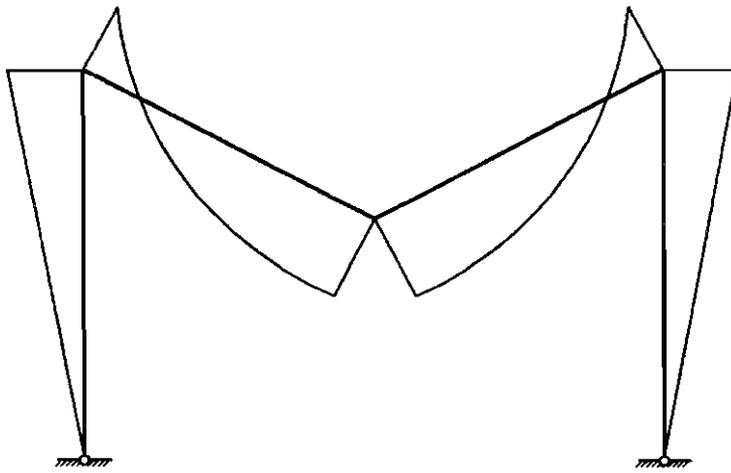
شكل (١١)

5- Connection 5 :-

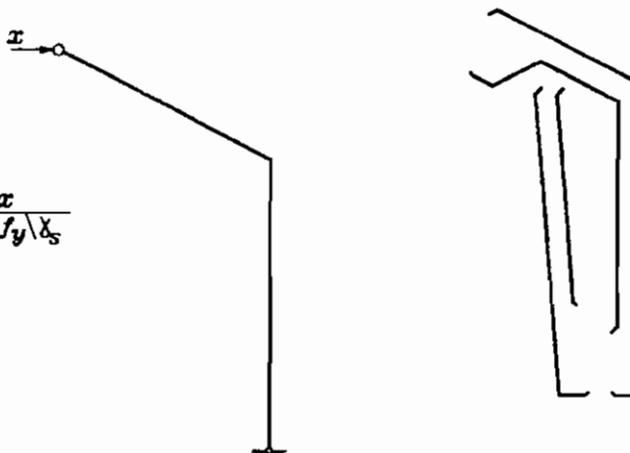
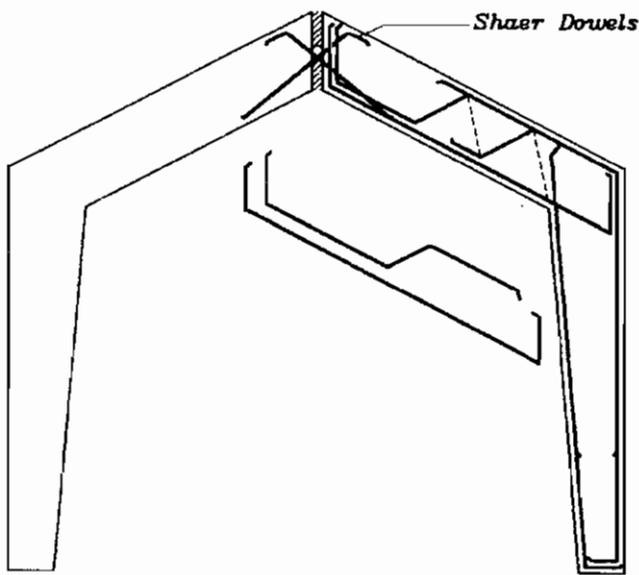
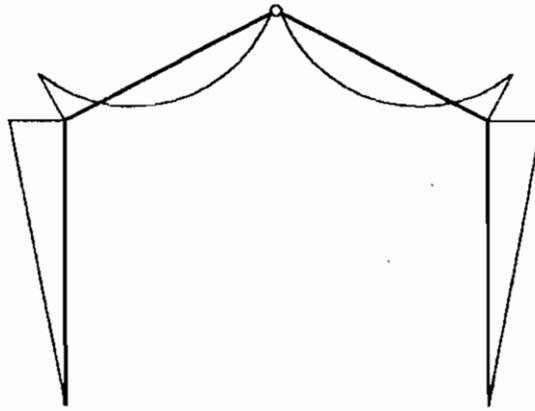
وصلة ٥



شكل (٢٧)

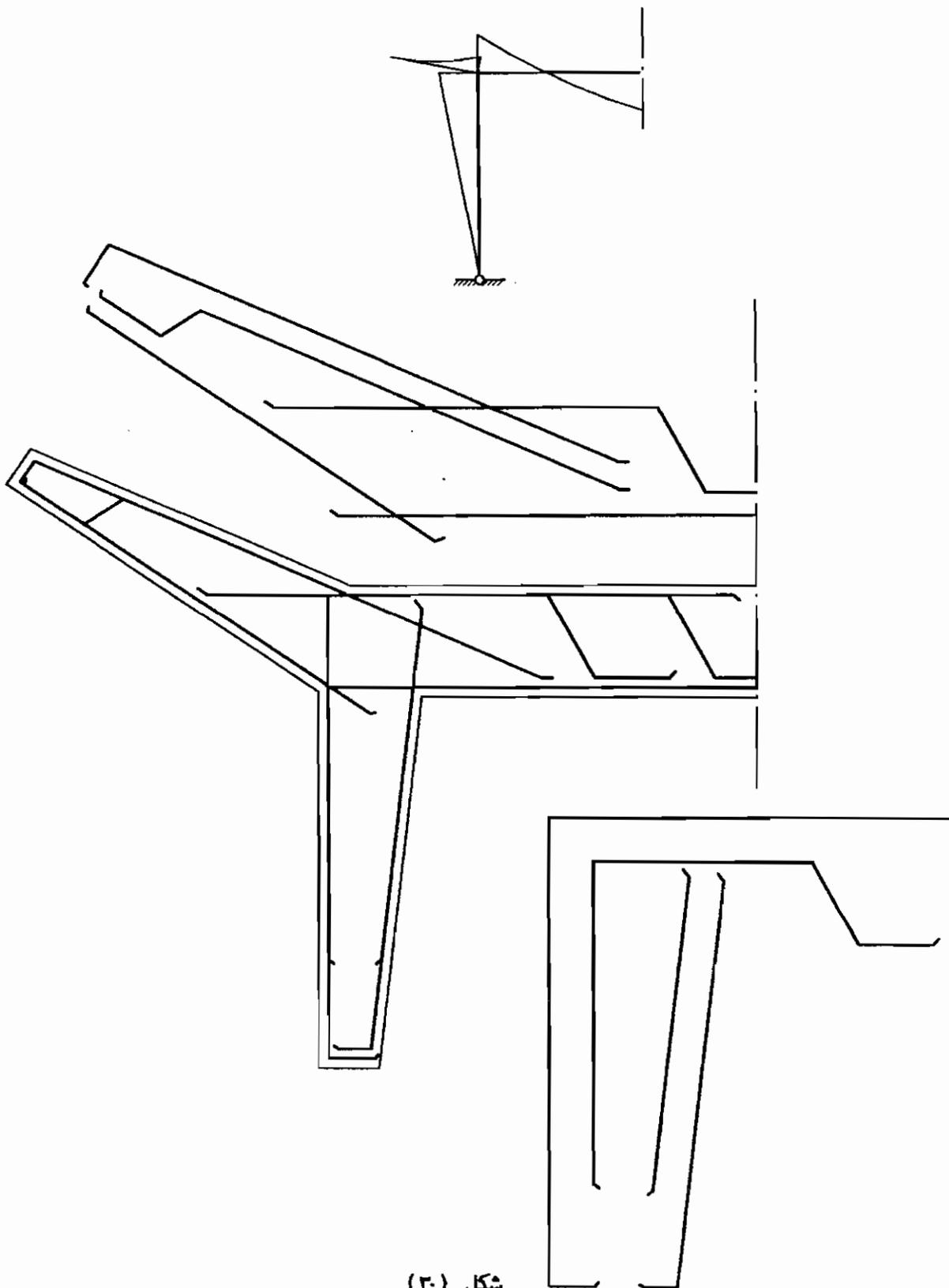


شكل (٢٨)

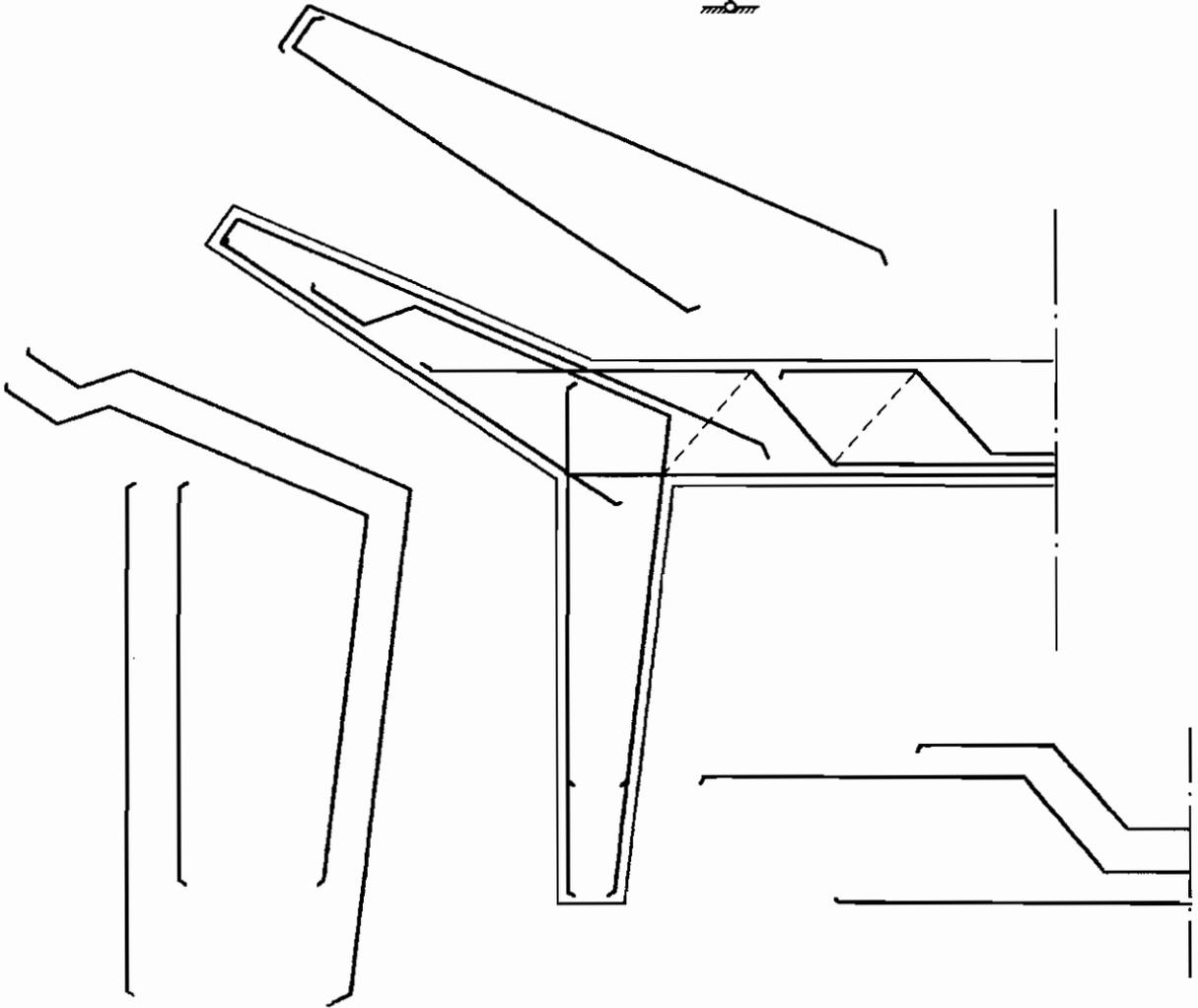
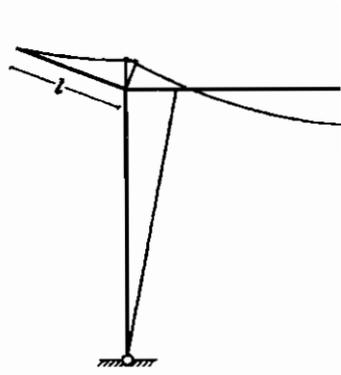


$$A_{dowels} = \frac{x}{0.8f_y \lambda_s}$$

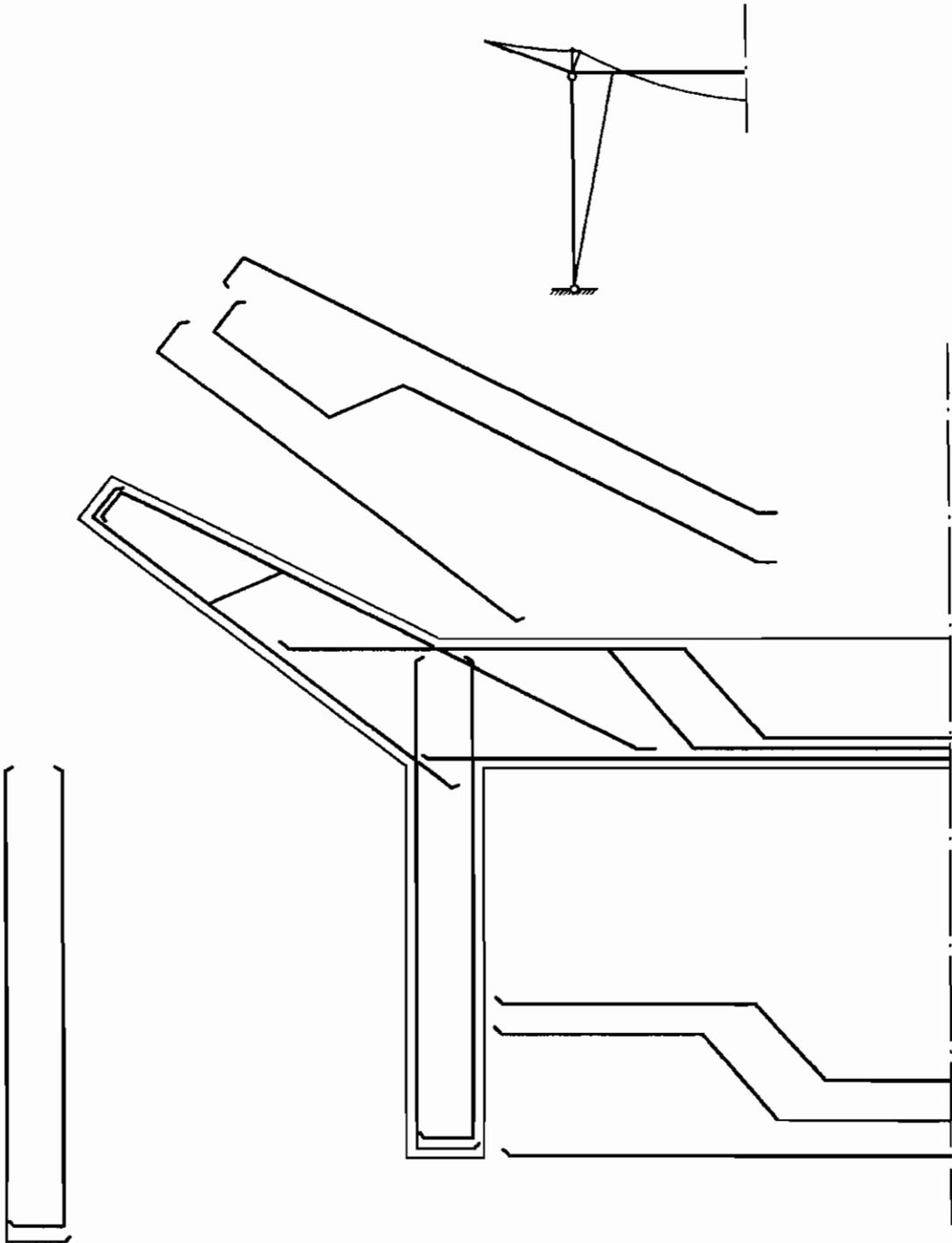
شكل (٧)



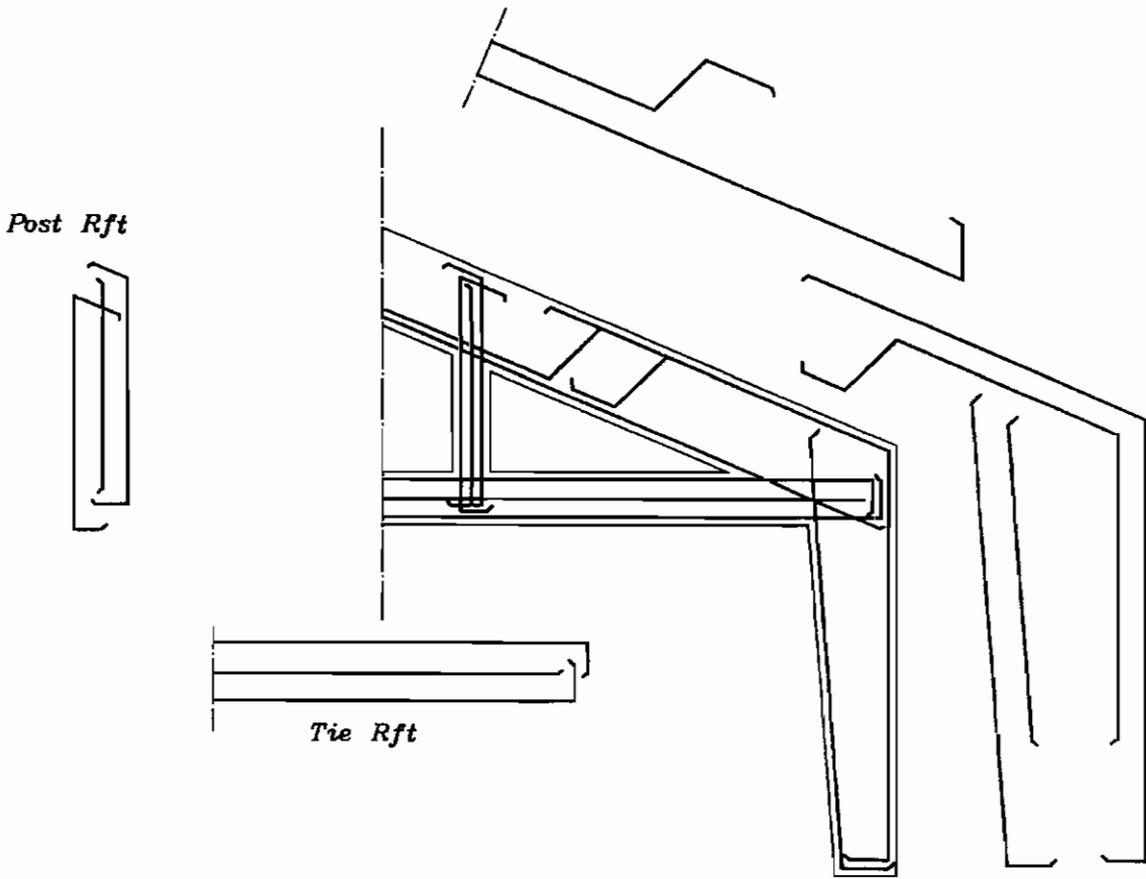
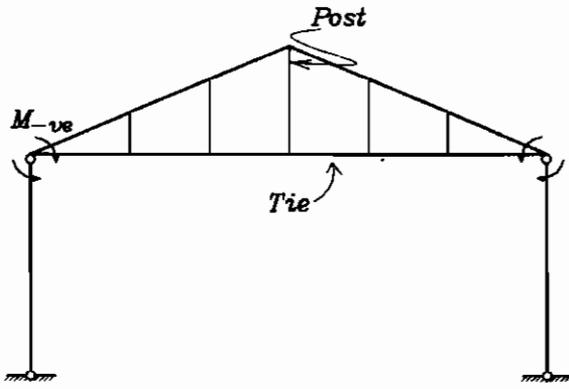
شكل (٣٠)



شكل (٧)



شكل (١٣)



شكل (٣)

السؤال الأول : (٨ %) :

صمم عموداً مستطيلاً مقيداً (braced) مثبتاً عند كلا طرفيه بياناته كالتالي ، ثم ارسم تفاصيل

القطاع :

$$P_{D.L} = 100 \text{ t}$$

$$P_{L.L} = 63 \text{ t}$$

$$f_{cu} = 250 \text{ kg/cm}^2$$

$$f_y = 2400 \text{ kg/cm}^2$$

$$H_o = 4.0 \text{ m} .$$

السؤال الثاني (١٢ %) :

صمم عموداً دائرياً قصيراً ذا كانة حلزونية بياناته كالتالي ، ثم أرسم تفاصيل القطاع :

$$P_{D.L} = 400 \text{ ton} .$$

$$P_{L.L} = 400 \text{ ton} .$$

$$f_y = 3600 \text{ kg/cm}^2$$

$$f_{cu} = 250 \text{ kg/cm}^2$$

$$f_{yp} = 2400 \text{ kg/cm}^2$$

السؤال الثالث (١٠ %) :

أحسب العزم التصميمي للعمود غير المقيد (Unbraced) ذي البيانات الآتية ، علماً بأن طرفه

العلوي مثبت Fixed وطرفه السفلي مفصلي hinged :

$$M_u = 30 \text{ m.t}$$

$$H_o = 4.0 \text{ m}$$

$$N_u = 150 \text{ t} .$$

السؤال الرابع (١٠ %) :

صمم قطاعاً خرسانياً معرضاً للأحمال الآتية :

$$N_u = + 20 \text{ t} . (\text{ tension force }) .$$

$$M_u = 50 \text{ m.t} .$$

علماً بأن بيانات القطاع كما يلي :

$$b = 30 \text{ cm} .$$

$$f_{cu} = 250 \text{ kg/cm}^2 .$$

$$f_y = 3600 \text{ kg/cm}^2 .$$

المسألة الخامسة (٤٠ %) :

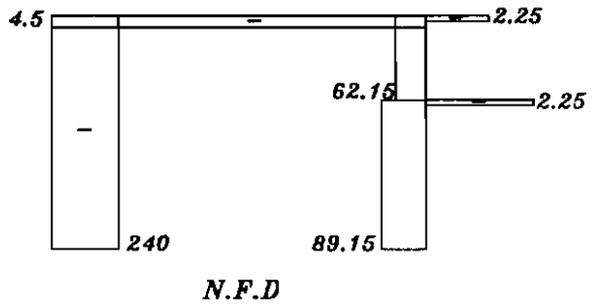
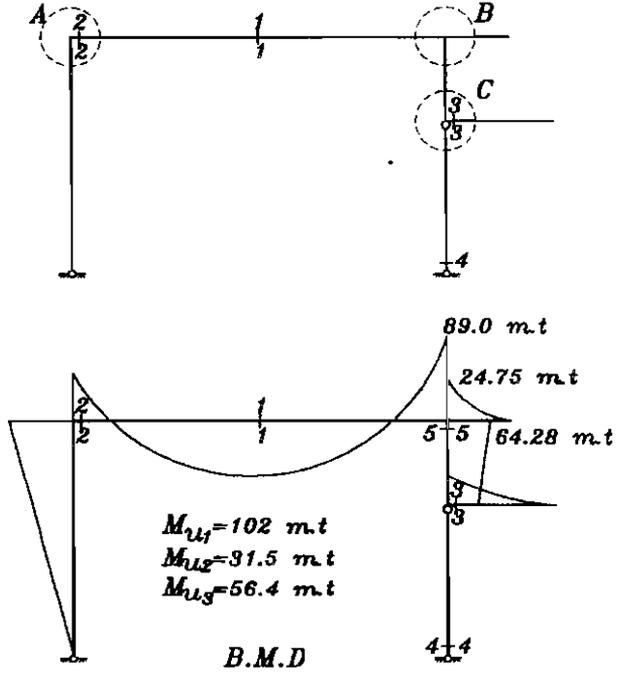
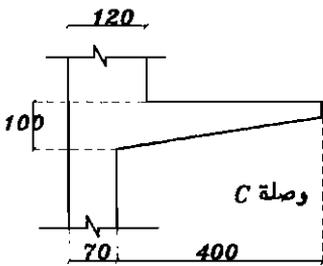
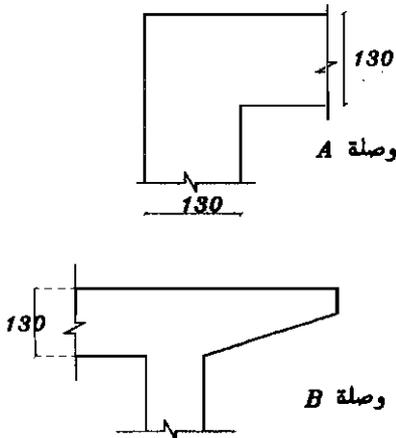
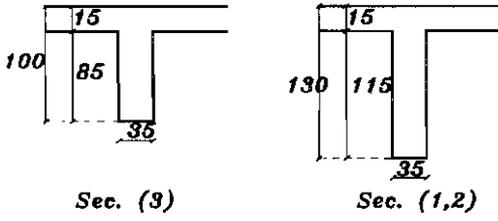
الإطار (Frame) الموضح معرض لقوى عمودية وعزوم انحناء :

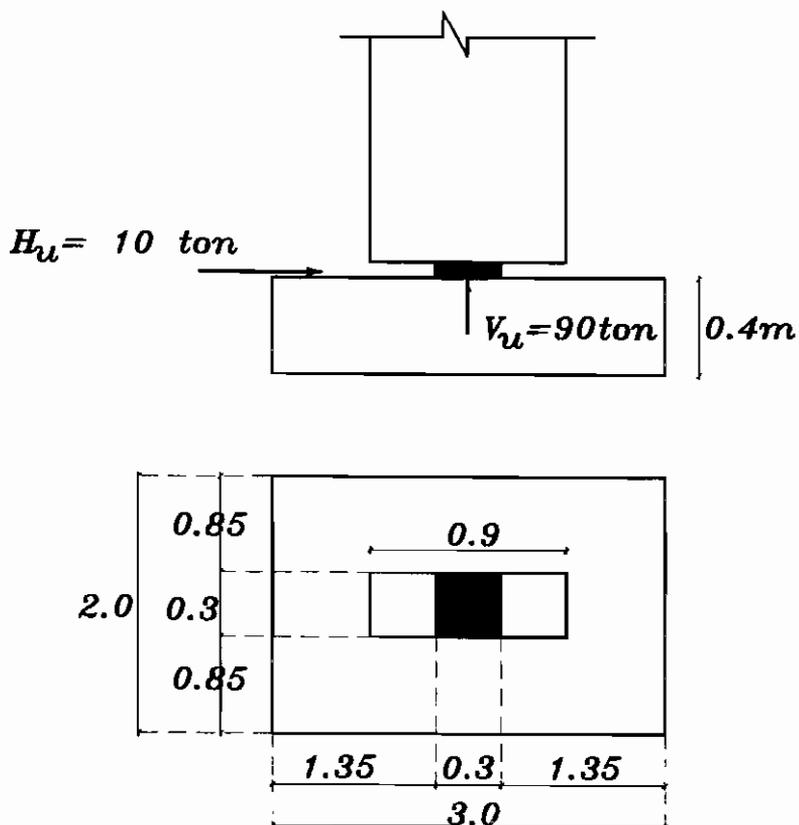
Normal force & Bending Moments.

طبقا لما هو معطى علي الرسم والمطلوب :

١ - تصميم القطاعات أرقام (1, 2, 3, 4, 5) فقط .

٢ - التوضيح بمقياس رسم مناسب تفاصيل الوصلات (Joints) A, B, C .





- الشكل الموضح لوح رصاص Lead Plate يمثل الركيذة المفصلية لرجل إطار Frame :

- ١ - تحقق من قيمة إجهادات التحميل Bearing Stresses .
- ٢ - أحسب مساحة وعدد الأثاير المطلوبة dowels .
- ٣ - أحسب مساحة وعدد الكانات الأفقية اللازمة عند أسفل رجل الإطار .
- ٤ - أرسم تفصيلة لما سبق .

$$\begin{aligned} P_u &= 1.4 \text{ d.L.} + 1.6 \text{ L.L} \\ &= 1.4 * 100 + 1.6 * 63. \\ &= 240.8 \text{ ton.} \end{aligned}$$

∴ Braced

∴ Fixation

$$\therefore K = 0.75$$

$$H_e = 0.75 * 4.0 = 3.0 \text{ m.}$$

$$\lambda = \frac{H_e}{b} = \frac{3}{0.25} = 12 < 15$$

∴ Short.

$$P_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$\text{Assume } A_s = 1 \% A_c .$$

$$240.8 * 10^3 = 0.35 * 250 * A_c + 0.67 * 2400 * \frac{A_c}{100} .$$

$$= A_c (87.5 + 16.08) = 103.58 A_c$$

$$\therefore A_c = 2324.77 \text{ cm}^2 .$$

$$\therefore t = \frac{2324.77}{25} = 93 \text{ cm}$$

Take 25 * 95

$$\therefore A_{sc} = \frac{1}{100} * 25 * 95 = 23.25 \text{ cm}^2$$

Choose: 12 ∅ 16

$$A_{schoon} = 24.12 \text{ cm}^2 .$$

Check of $A_{s \min}$

$$A_{s \min} = \frac{0.8}{100} * 25 * 93 = 18.6 \text{ cm}^2$$

$$\text{or } = \frac{0.6}{100} * 25 * 95 = 14.25 \text{ cm}^2$$

وكليهما أقل من المساحة المختارة :

$$A_{s \text{ chosen}} = 24.12 > 18.6 \quad (\text{O.K.})$$

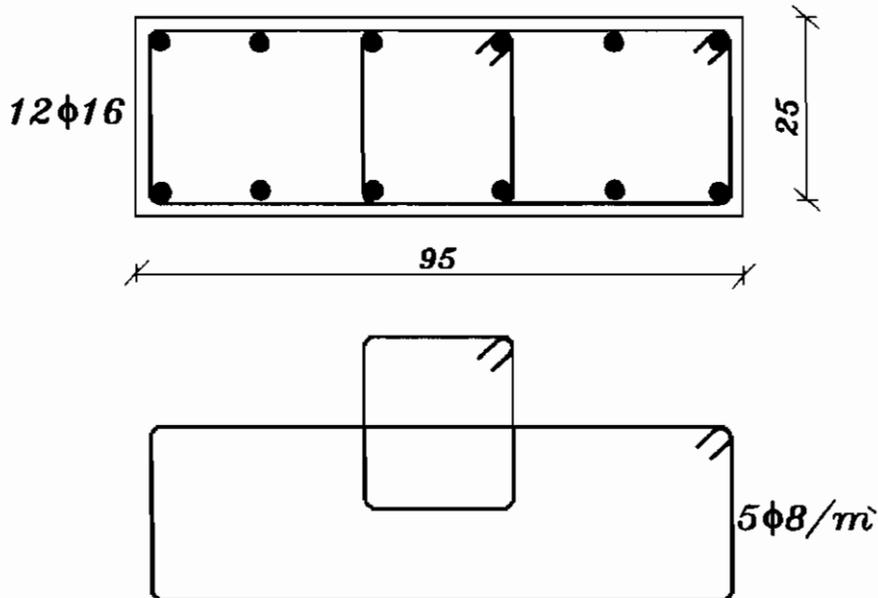
Choose: $5 \phi 8/m$ as stirrups.

Check of volume of stirrups

$$V_{st} = \text{area} * \text{length} = 0.503 * (4 * 20 + 2 * 90 + 2 * 15) * 5 = 729.35 \text{ cm}^3 .$$

Check:

$$V_{\min} = \frac{0.25}{100} * 25 * 95 * 100 \\ = 593.75 \text{ cm}^3 < V_{st} \rightarrow \text{O.K}$$



$$\begin{aligned}P_u &= 1.4 d.L + 1.6 L.L \\ &= 1.4 * 400 + 1.6 * 400 \\ &= 1200 \text{ t} .\end{aligned}$$

∴ Short

∴ No add moment.

$$\begin{aligned}P_u &= 0.4 f_{cu} . A_c + 0.76 A_{sc} f_y \rightarrow (I) \\ &= 0.35 f_{cu} . A_k + 0.67 A_{sc} f_y + 1.38 V_{sp} f_{yp} \rightarrow (II)\end{aligned}$$

بالتطبيق في المعادلة (II) وفرض :

$$V_{sp} = 1.0 \% A_k .$$

$$A_{sc} = 1.2 \% A_k .$$

$$\therefore 1200 * 10^3 = A_k (0.35 * 250 + 0.67 * \frac{1.2}{100} * 3600 + 1.38 * \frac{1}{100} * 2400$$

$$\therefore A_k = \frac{1200 \times 10^3}{149.56} = 8023.5 \text{ cm}^2$$

$$= \frac{\pi}{4} D_k^2$$

$$\therefore D_k = 101.09 \text{ cm}$$

$$= 105 \text{ cm}.$$

$$\therefore A_k = \frac{\pi(105)^2}{4} = 8659 \text{ cm}^2$$

$$\therefore A_{s_c} = \frac{1.2}{100} * 8659 = 103.9 \text{ cm}^2 = 22 \text{ } \phi 25$$

$$\therefore D = 110 \text{ cm}$$

$$A_c = \frac{\pi D^2}{4} = 9503.3 \text{ cm}^2.$$

هنا يتم التأكد من أن المعادلة (I) مساوية :

$$P_u = 0.4 f_{cu} \cdot A_c + 0.76 A_{sc} \cdot f_y$$

$$= 0.4 * 250 * 9498.5 + 0.76 * 103.86 * 3600 = 1234.6 \text{ t} > P_{\text{applied}} \text{ (O.K.)}$$

Check of V_{sp} :

$$\begin{aligned} \mu_{sp, \min} &= 0.36 \frac{f_{cu}}{f_{yp}} \left(\frac{A_c}{A_k} - 1 \right) \\ &= 0.36 \frac{250}{2400} \left(\frac{9503.3}{8659} - 1 \right) = 0.00366 \end{aligned}$$

$$V_{sp, \min} = \mu_{sp, \min} * A_k$$

$$= 0.00345 * 8659 = 31.66$$

$$\text{But : } V_{sp, \text{act}} = \frac{1}{100} A_k = 86.6 > \min \rightarrow \text{(O.K.)}$$

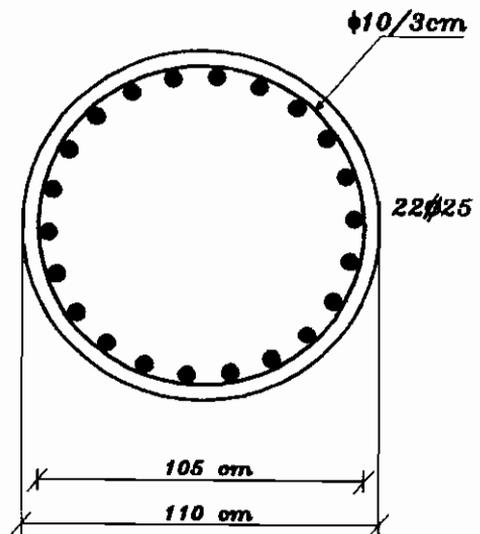
$$V_{sp} = \frac{\pi A_{sp} D k}{P}$$

$$86.6 = \frac{\pi * 105 * A_{sp}}{P}$$

use $\phi 10$

$$\therefore A_{sp} = 0.785 \text{ cm}^2$$

$$P = \frac{3.14 * 105 * 0.785}{86.6} = 3 \text{ cm.}$$



$$K = 1.6 \quad (\text{case 1 , case 3}) \quad \text{E.C.P.}$$

$$\begin{aligned} H_e &= KH_0 \\ &= 1.6 * 4 \\ &= 6.4 \text{ m.} \end{aligned}$$

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

$$\frac{H_e}{b} = \frac{6.4}{0.25} = 25.6 > 23 \quad \text{وهي قيمة أكبر من المسموح}$$

Increase (b) upto 30 cm .

$$\lambda_b = \frac{H_e}{b} = \frac{6.4}{0.3} = 21.33 < 23 \rightarrow (O.K)$$

$$\therefore 10 < \lambda_b < 23 \quad \text{long col.}$$

$$\therefore M_{add} = P \times \delta_{av}$$

$$\delta_{av} = \frac{\lambda^2 b}{2000} = \frac{(21.33)^2 * 0.3}{2000} = 0.068 \text{ m}$$

$$\begin{aligned} M_{add} &= P \cdot \delta_{av} \\ &= 150 * 0.068 \\ &= 10.24 \text{ t.m} \end{aligned}$$

$$\begin{aligned} \therefore M_{design} &= M + M_{add} \\ &= 30 + 10.24 \\ &= 40.24 \text{ t.m} \end{aligned}$$

$$(\text{or}) : M_{desy} = P \cdot e_{min} = 150 * (0.05 \text{ t or } 2) .$$

} أيهما أكبر

∴

P =	150 t
M =	40.24

$$d_o = C_1 \sqrt{\frac{M}{f_{cu} b}}$$

$$= 3 \sqrt{\frac{50 \times 10^5}{250 \times 30}} = 77 \text{ cm.}$$

$$d = 0.9 d_o = 0.9 * 77 = 70 \text{ cm}$$

$$\therefore t = 75 \text{ cm}$$

$$e = \frac{M_u}{P_u} = \frac{50}{20} = 2.5 \text{ m.}$$

$$\frac{e}{t} = \frac{2.5}{0.75} = 3.33 > 1/2 \text{ (Big.ec)}$$

$$e_s = e - t/2 + \text{cover}$$

$$= 2.5 - \frac{0.75}{2} + 0.05 = 2.175 \text{ m}$$

$$M_u = N_u \cdot e_s = 20 * 2.175 = 43.5 \text{ m.t.}$$

$$R = \frac{M_{us}}{f_{cu} b \times d^2} = \frac{43.5 * 10^5}{250 \times 30 \times (70)^2} = 0.118$$

$$\therefore w = 0.15$$

$$\alpha = 0.3$$

$$A_s = wbd \left(\frac{f_{cu}}{f_y} + p_u / (f_y / \gamma_s) \right)$$

$$= 0.15(30)(70) \left(\frac{250}{3600} + 20 * 10^3 / (3600 / 1.15) \right)$$

$$= 28.26 \text{ cm}^2 \quad (14 \text{ \# } 16)$$

$$A_s^- = 0.3 \left(0.15 * 30 * 70 \frac{250}{3600} \right) = 6.56 \text{ cm}^2 = 4 \text{ \# } 16$$

السؤال الخامس :

تصميم القطاعات :

given:

$$f_{cu} = 180 \text{ kg/cm}^2 .$$

$$f_y = 2400 \text{ kg/cm}^2 .$$

sec . 1 :

t – Section.

$$M_u = 102 \text{ t.m.}$$

$$N_u = - 4.5 \text{ ton.}$$

من الواضح صغر قيمة N_u ويمكن التأكد من ذلك بحساب $0.04 f_{cu} . b.t$

$$\begin{aligned} 0.04 f_{cu} . b.t &= 0.04 * 180 * 35 * 130 \\ &= 32760 \text{ kg} = 32.76 \end{aligned}$$

$$\therefore N_u < 0.04 f_{cu} . b.t$$

$$\therefore \text{neglect}(N_u)$$

$$B = b_o + 16 * t_s$$

$$= 35 + 16 * 15 = 275 \text{ cm} .$$

$$d = 130 - 5 \text{ cm} = 125 \text{ cm}$$

$$\therefore d = C_1 \sqrt{\frac{M_u}{f_{cu} B}}$$

$$\therefore C_1 = \frac{125}{\sqrt{\frac{102 \times 10^5}{180 \times 275}}} = 8.708$$

$$\therefore \frac{c}{d} = \frac{8.708}{125} = 0.069 < 0.125 < \left(\frac{c}{d}\right)_{\min}$$

$$\therefore \text{Take} : \frac{c}{d} = \min = 0.125$$

$$\therefore J = 0.825$$

$$a = 0.8 C .$$

$$\therefore \frac{C}{d} = 0.125$$

$$\therefore C = 0.125 * 125 = 15.625$$

$$\therefore a = 0.8C$$

$$= 0.8 (15.625)$$

$$= 12.5 < t_s . \quad (\text{O.K.})$$

This section is designed as \square^{br} sec

$$A_s = \frac{M_u}{J.d.fy}$$

$$= \frac{102 * 10^5}{0.825 * 125 * 2400}$$

$$= 41.21 \text{ cm}^2 \rightarrow 12\phi 22.$$

Sec.2:

$$M_u = 31.5 \text{ m.t}$$

$$N_u = -4.5 \text{ t.}$$

$$0.04 f_{ck} b l = 32.76$$

$$\therefore 4.5 \ll 32.76$$

\therefore neglect(N_u)

$$d = C_1 \sqrt{\frac{M_u}{f_{ck} \cdot B}}$$

$$C_1 = 6$$

$$C/d = 0.044 < (c/d)_m \quad \therefore \text{take } c/d = \text{min} = 0.125$$

$$J = 0.825$$

$$A_s = \frac{31.5 * 10^5}{0.825 * 125 * 2400} = 12.72 \text{ cm}^2$$

$$\mu = 12.72/35 * 125 = 0.003$$

Check:

$$\mu_{\min} = \frac{11}{f_y} = 0.00458$$

$$\text{Smaller } y : 1.3\mu = 1.3 \frac{A_{s_{req}}}{b.d} = 0.00378$$

$$\& \left\{ \frac{0.25}{100} A_c \rightarrow 24/35 \right.$$

$$\therefore A_s = 0.00378 (35) (125) = 16.545 \text{ cm}^2 = 3\phi 19 + 3\phi 22$$

Sec. 3:

Rectangle section:

$$t = 35 \text{ cm .}$$

$$M_u = 56.4 \text{ m.t}$$

$$N_u = - 2.25 \text{ t} \rightarrow \text{Small (neglected) .}$$

$$\therefore R = \frac{M}{f_{cu} b d^2} = \frac{56.4 * 10^5}{180 * 35 * 95^2} = 0.099$$

$$\therefore w = 0.13$$

$$\begin{aligned} A_s &= w.b.d \frac{f_{cu}}{f_y} = 0.13 * 35 * 95 * \frac{180}{2400} \\ &= 32.42 \text{ cm}^2 \rightarrow 9\phi 22 \end{aligned}$$

Sec .4 :

$$N_u = - 89.15 \text{ t}$$

Design as a column 35 * 70

$$H = 350 \text{ cm}$$

Assume braced

$$H_e = 1 * 350 = 350$$

$$\lambda = \frac{H_e}{b} = \frac{350}{35} = 10 < 15 \rightarrow \text{No additional moment}$$

$$\text{assume } \mu = 0.8\% = \frac{A_s}{A_c} = A_s = \frac{0.8}{100} A_c$$

$$P_u = 0.35 f_{cu} A_c + 0.67 A_{sc} f_y$$

$$89.1 * 10^3 = (0.35 * 180 + 0.67 * \frac{0.8}{100} * 2400) A_c$$

$$\therefore A_c = 1174.47 \text{ cm}^2$$

$$A_s = \frac{0.8}{100} * 1174.47 = 9.4 \text{ cm}^2$$

Check:

$$A_s < \frac{0.6}{100} * 35 * 70 = 14.7 \text{ cm}^2$$

$$\therefore \text{ use } A_s = 14.7 \text{ cm}^2 \quad 6\phi 19$$

Answer Q 5:

1 - Bearing check:

$$A_1 = b \cdot t_e / 3 = 30(90/3) = 900 \text{ cm}^2$$

$$f = V_u / A_1 = 90 \cdot 10^3 / 900 = 100 \text{ kg/cm}^2$$

$$f_b = 0.67 f_{cu} / \gamma_c = 111.67 \text{ kg/cm}^2$$

$$A_2 = (2h + t_e / 3) (2h + b)$$

$$= (2 \cdot 40 + 90/3) (2 \cdot 40 + 30) = 12100 \text{ cm}^2$$

$$0.67 f_{cu} / \gamma_c \sqrt{A_2 / A_1} = 405.4 \text{ kg/cm}^2$$

$$\therefore f_b = 111.67 > 0.67 f_{cu} / \gamma_c \sqrt{A_2 / A_1} \quad (\text{O.K.})$$

$$\therefore f < f_b \quad \text{Safe Dimension}$$

2 – Area of dowles:

$$A_s \text{ dowels} = X / (0.8 f_y / \gamma_s)$$

$$= 10 \cdot 10^3 / (0.8 \cdot 3600 / 1.15)$$

$$= 4 \text{ cm}^2 \text{ use } 3\phi 16 \quad (6 \text{ cm}^2)$$

3 – Horizontal Stirrups : it will be distributed to height

$$t = V / 5 = 18 \text{ t}$$

$$A_{sh} = t / (f_y / \gamma_s) = 1.8 \cdot 10^3 / (2400 / 1.15)$$

$$= 8.625 \text{ cm}^2 = 7\phi 13 / t_e$$

Example (1) :

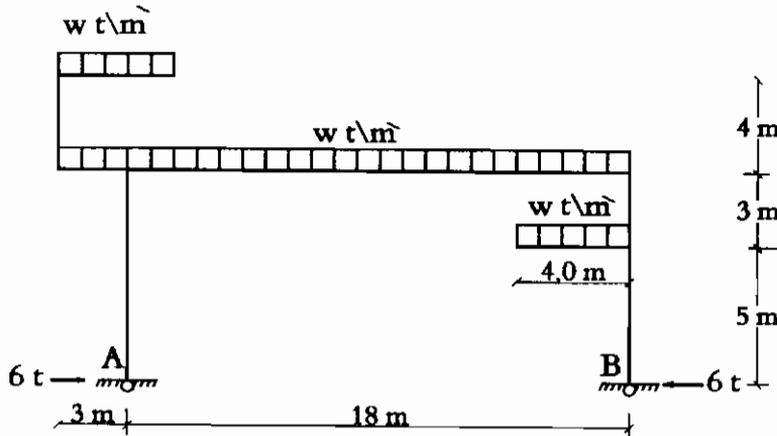
Draw straining action diagrams, and design the critical section, then give full details for the following frames:

Frame (1) :

Data:

- $t_s = 12 \text{ cm}$
- $b = 35 \text{ cm}$
- $w_{D.L} = 3 \text{ t/m}$
- $f_y = 3600 \text{ kg/cm}^2$
- $w_{L.L} = 1 \text{ t/m}$
- $o.w = 1 \text{ t/m}$
- $f_{cu} = 250 \text{ kg/cm}^2$

The frame may be considered braced in each direction:



Solution:

$$t_g = \frac{1800}{12 \rightarrow 16} = 140 \text{ cm}$$

$$t_{c \text{ (upper)}} = 1 \rightarrow 0.8 t_g = 110 \text{ cm}$$

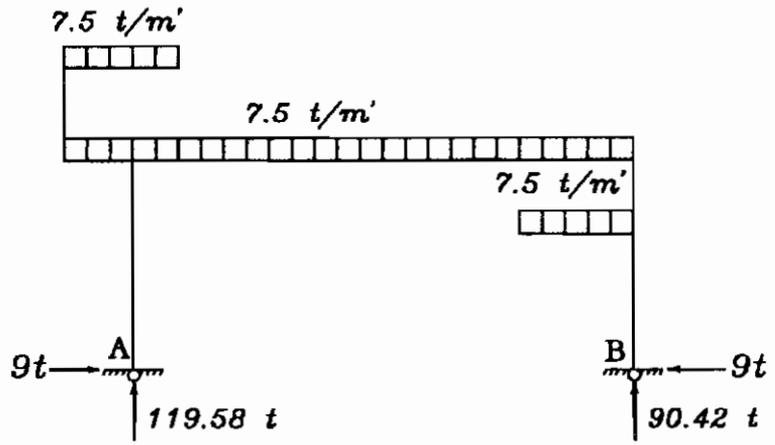
$$t_{c \text{ (lower)}} = 80 \text{ cm}$$

$$t_{\text{cantilver}} = 100 \text{ cm}$$

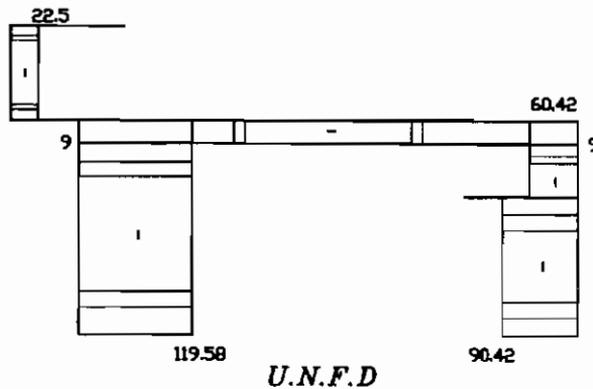
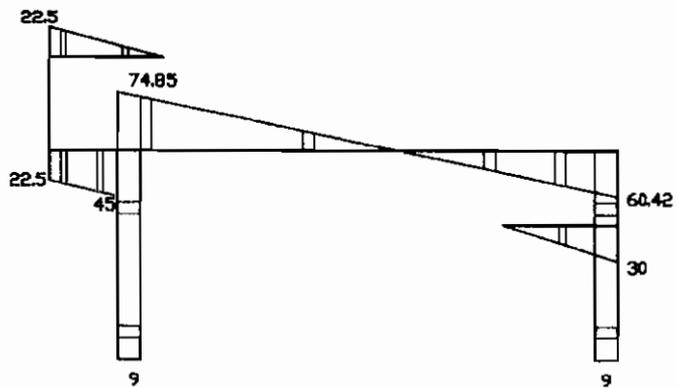
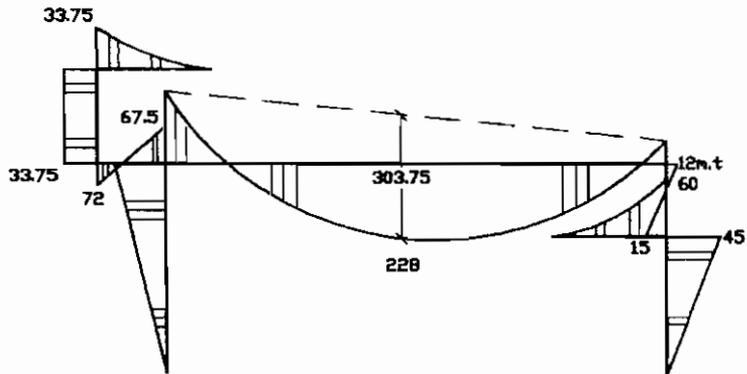
Loads:

$$w = 3 + 1 + 1 = 5 \text{ t/m}$$

$$w_u = 1.5 * 5 = 7.5 \text{ t/m}$$

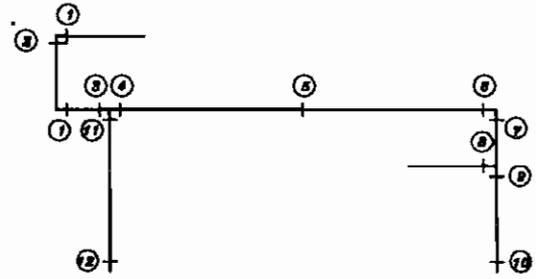


Straining Actions



Design of section:

Sec	M_u	N_u
1	33.75	0
2	33.75	-22.5
3	67.5	0
4	139.5	-9
5	228	-9
6	12	-9
7	12	-60.4
8	60	0
9	45	-90.42
10	0	-90.42
11	72	-119.58
12	0	-119.58



Sec (1) : 35 * 100 cm □^{er}

$$M_u = 33.75 \text{ m.t}$$

$$N_u = 0$$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.0427 \rightarrow \omega = 0.053$$

$$A_s = \omega b d \frac{f_{cu}}{f_y} = 12.24 \text{ cm}^2$$

$$A_{s, \min} = \frac{11}{f_y} b d = 10.16 \text{ cm}^2 < A_s \text{ o.k}$$

(use 4ϕ22)

Sec (2) : 35 * 100 cm □^{er}

$$M_u = 33.75 \text{ m.t}$$

$$N_u = -22.5 \text{ t}$$

$$\frac{N_u}{f_{cu} b t} = 0.026 < 0.04 \rightarrow \text{neglect } N_u$$

$$A_s = 12.24 \text{ cm}^2 \rightarrow A_s \text{ of sec(1)}$$

(use 4ϕ22)

Sec (3) : 35 * 140 cm □^{tr}

$$M_u = 67.5 \text{ m.t}$$

$$N_u = 0$$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.0423 \rightarrow w = 0.051$$

$$A_s = w b d \frac{f_{cu}}{f_y} = 16.73 \text{ cm}^2 \rightarrow \text{use } (6\text{ff}22)$$

Sec (4) : 35 * 140 cm □^{tr}

$$M_u = 139.5 \text{ m.t}$$

$$N_u = -9 \text{ t}$$

$$\frac{N_u}{f_{cu} b t} = 0.007 < 0.04 \rightarrow \text{neglect } N_u$$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.087 \rightarrow w = 0.113$$

$$A_s = w b d \frac{f_{cu}}{f_y} = 37.1 \text{ cm}^2 \rightarrow \text{use } (6\text{ff}22)$$

Sec (5) : 35 * 140 cm T - sec

$$M_u = 228 \text{ m.t}$$

$$N_u = -9 \text{ t} \rightarrow \text{neglected as sec (4)}$$

$$B = \text{Smallest of} \quad \begin{aligned} 16 t_s + b &= 227 \text{ cm} \\ C_L \text{ to } C_L &= 500 \text{ cm} \\ \frac{0.8 L}{S} + b &= 323 \text{ cm} \end{aligned}$$

$$\therefore B = 227 \text{ cm}$$

$$d = C_1 \sqrt{\frac{M_u}{f_{cu} B}} \rightarrow C_1 = 6.74 \quad \text{take } \frac{C}{d_{\min}} = 0.125$$

$$\therefore C = 16.875 \text{ cm}$$

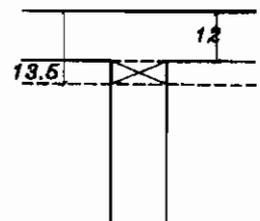
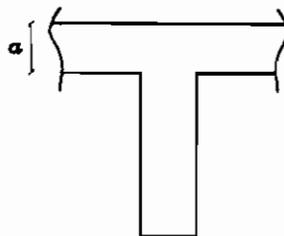
$$\therefore a = 0.8 C = 13.5 \text{ cm} > t_s$$

$$\therefore \text{take } a = t_s$$

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

$$\therefore A_s = 56.46 \text{ cm}^2$$

$$\therefore \text{use } (12\text{ff}25) \text{ or } (6\text{ff}25 + 8\text{ff}22)$$



Sec (6) : 35 * 140 cm □^{tr}

$$M_u = 12 \text{ m.t}$$

$$N_u = -9 \text{ t} \rightarrow \text{neglected}$$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.0075 \rightarrow w = 0.01$$

$$A_s = 3.3 \text{ cm}^2$$

$$\text{use } A_{s, \min} = \frac{11}{f_y} \rightarrow b d = 14.4 \text{ cm}^2 \quad \text{use (4ff22)}$$

Sec (7) : 35 * 110 cm □^{tr}

$$M_u = 12 \text{ m.t}$$

$$N_u = -60.42 \text{ t}$$

$$\frac{N_u}{f_{cu} b t} = 0.063 > 0.04$$

$$e = \frac{M_u}{N_u} = 0.1986 \text{ m} \rightarrow \frac{e}{t} = 0.18 > 0.05$$

$$\frac{M_u}{f_{cu} b t^2} = 0.011$$

$$\text{Interaction Diag } \alpha = 0.6 \quad \zeta = 0.9 \quad f_y = 3600 \text{ kg/cm}^2$$

$$\rho < 1 \rightarrow \text{Tension failure}$$

$$e_s = e + \frac{t}{2} - 0.05 = 0.6986 \text{ m}$$

$$M_{us} = N_u \cdot e_s = 42.42 \text{ m.t}$$

$$R = \frac{M_{us}}{f_{cu} b d^2} \xrightarrow{\alpha=0} w = 0.054$$

$$A_s = w b d \frac{f_{cu}}{f_y} - \frac{N_u}{f_y / \gamma_s} = -v_e$$

$$\therefore \text{use } A_{s, \min} = \frac{11}{f_y} b d = 11.23 \text{ cm}^2$$

$$\text{(use 4ff22)}$$

Sec (8) : 35 * 100 cm □^{cr}

$$M_u = 60 \text{ m.t}$$

$$N_u = 0 \text{ t}$$

$$R = \frac{M_u}{f_{cx} b d^2} = 0.076 \rightarrow w = 0.097$$

$$A_s = w b d \frac{f_{cx}}{f_y} = 22.11 \text{ cm}^2 \rightarrow \text{use } (5\phi\phi 25)$$

Sec (9) :

$$T = 80 + 30 * \frac{6}{9} = 100 \text{ cm}$$

Sec (9) : 35 * 100 cm □^{cr}

$$M_u = 45 \text{ m.t}$$

$$N_u = -90.42 \text{ t}$$

$$\frac{N_u}{f_{cx} b t} = 0.103 > 0.04$$

$$e = \frac{M_u}{N_u} = 0.498 \rightarrow \frac{e}{t} = 0.493 > 0.05$$

$$\frac{M_u}{f_{cx} b t^2} = 0.051$$

Interaction Diagram $\alpha = 0.6$ $\zeta = 0.9$ $f_y = 3600 \text{ kg/cm}^2$

$\rho < 1 \rightarrow$ Tension failure

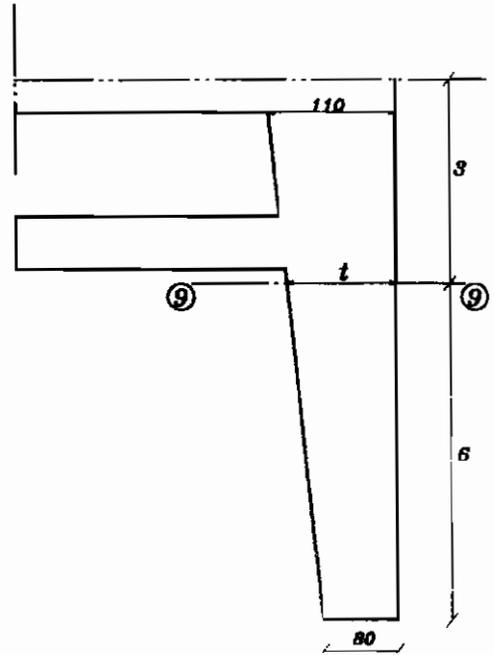
$$e_s = e + \frac{t_s}{2} - 0.05 = 0.948 \text{ m}$$

$$M_{us} = N_u e_s = 85.7 \text{ m.t}$$

$$R = 0.108 \xrightarrow{\alpha=0} w = 0.146$$

$$A_s = 4.83 \text{ cm}^2$$

$$A_{s, \min} = \frac{11}{f_y} b d = 10.16 \text{ cm}^2 \quad (4\phi\phi 22)$$



Sec (10) : 35 * 80 cm □^{er}

$$M_u = 0$$

$$N_u = -90.42 \text{ t} \quad (A_s \text{ short col.})$$

$$N_u = P_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$90.42 * 1000 = 0.35 * 250 * 35 * 80 + 0.67 * 3600 A_{sc}$$

$$A_{sc} = - V_e$$

$$\therefore \text{use } A_{s \min} = 0.6\% A_c = 16.8 \text{ cm}^2$$

Sec (11) : 35 * 110 cm □^{er}

$$M_u = 72 \text{ t}$$

$$N_u = -119.58 \text{ t}$$

$$\frac{N_u}{f_{cu} b t} = 0.124 > 0.04$$

$$e = \frac{M_u}{N_u} = 0.6 \text{ m} \quad \rightarrow \frac{e}{t} = 0.547 > 0.05$$

$$\frac{M_u}{f_{cu} b t} = 0.068$$

$$\text{Interaction diag } \alpha = 0.6 \quad \zeta = 0.9 \quad f_y = 3600 \text{ kg/cm}^2$$

$\rho < 1 \rightarrow$ Tension failure

$$e_s = e + t/2 - 0.05 = 1.102 \text{ m}$$

$$M_{us} = N_u \cdot e_s = 131.8 \text{ mt}$$

$$R = 0.137 \xrightarrow{\alpha=0.1} w = 0.19$$

$$A_s = w b d \frac{f_{cu}}{f_y} - \frac{N_u}{f_y / \gamma_s} = 10.3 \text{ cm}^2$$

$$A_{s \min} = \frac{11}{f_y} b d = 11.23 \text{ cm}^2 \quad (4\text{ff}22)$$

Sec (12) : 35 * 80 cm □^{er}

$$N_u = -119.58t$$

$$N_u = P_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$A_{sc} = -ve$$

$$\therefore \text{use } A_{s\min} = 0.6 \% A_c = 16.8 \text{ cm}^2$$

Check of shear:

Critical sec is sec (4) 35 * 140 cm

$$Q_u = 74.85 \text{ t.}$$

$$\therefore q_u = \frac{Q_u}{bd} = 15.84 \text{ kg/cm}^2$$

$$q_{cu} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}} = 9.68 \text{ kg/cm}^2$$

$$\therefore q_{su} = q_u - \frac{1}{2} q_{cu} = 11.0 \text{ kg/cm}^2$$

Assume usin g stirrups 5ϕ10/m⁻ (2 – branches)

$$q_{st} = \frac{A_{st} f_y / \gamma_s}{b.s} = \frac{2(0.785) * 2400 / 1.15}{35 * 20} = 4.68 \text{ kg/cm}^2$$

$$\therefore q_{sub} = 114.68 = 6.32 \text{ kg/cm}^2$$

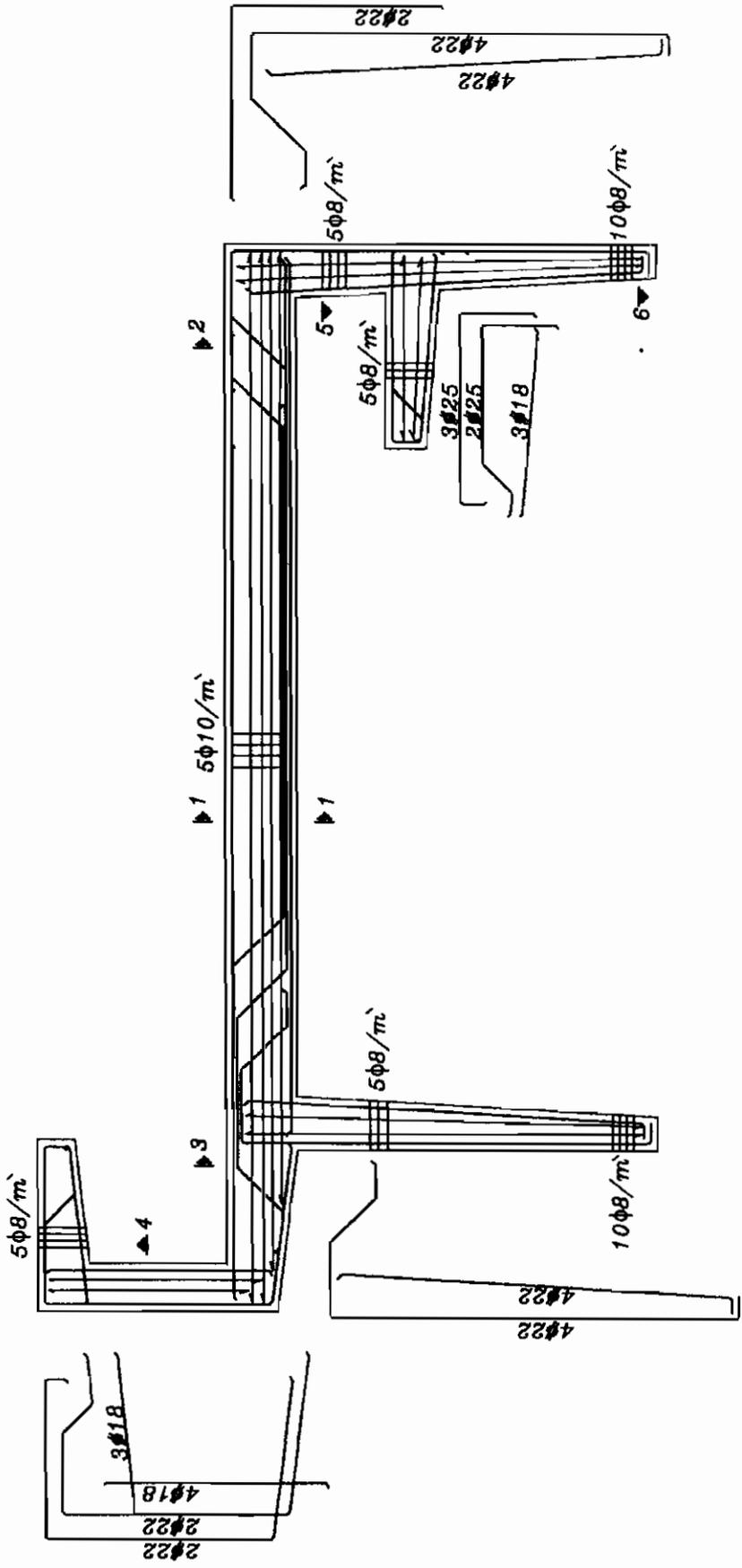
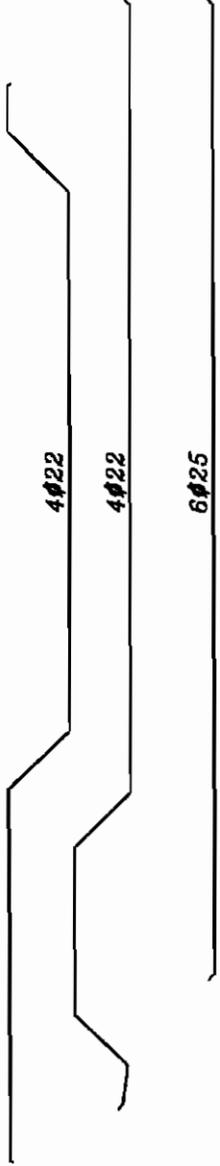
$$A_{sb} = \frac{q_{sub} \cdot b.d}{f_y / \gamma_s \sin \alpha} = 13.5 \text{ cm}^2 / \text{raw} \quad (\text{use } 4\phi 22)$$

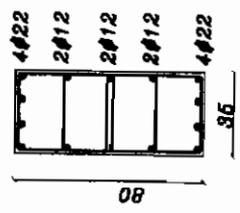
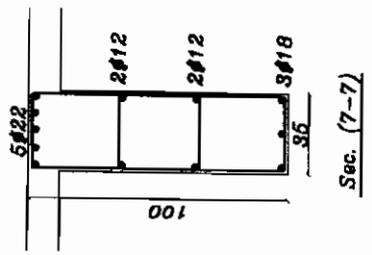
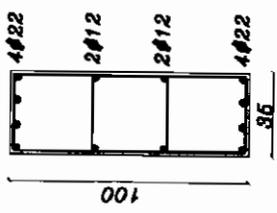
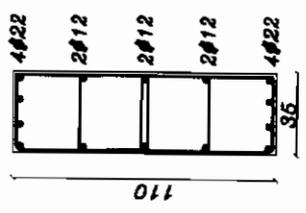
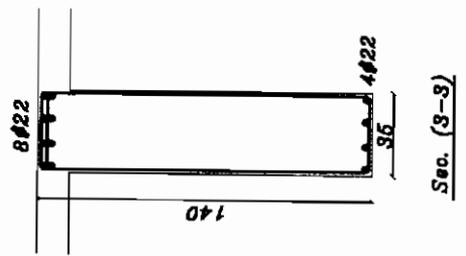
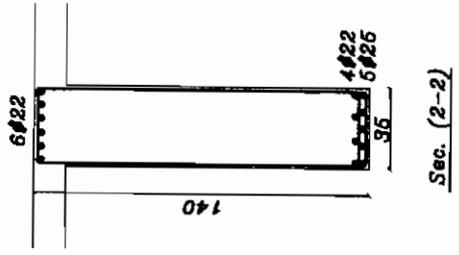
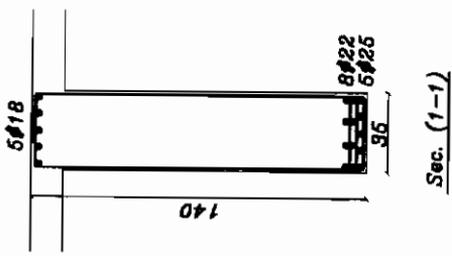
5φ18

4φ22

4φ22

6φ25





Sec. (6-6)

Sec. (7-7)

Example (2) :

Draw straining action diagrams, and design the critical section, then give full details for the following frames:

Frame (2) :

Data:

$t_s = 14 \text{ cm}$

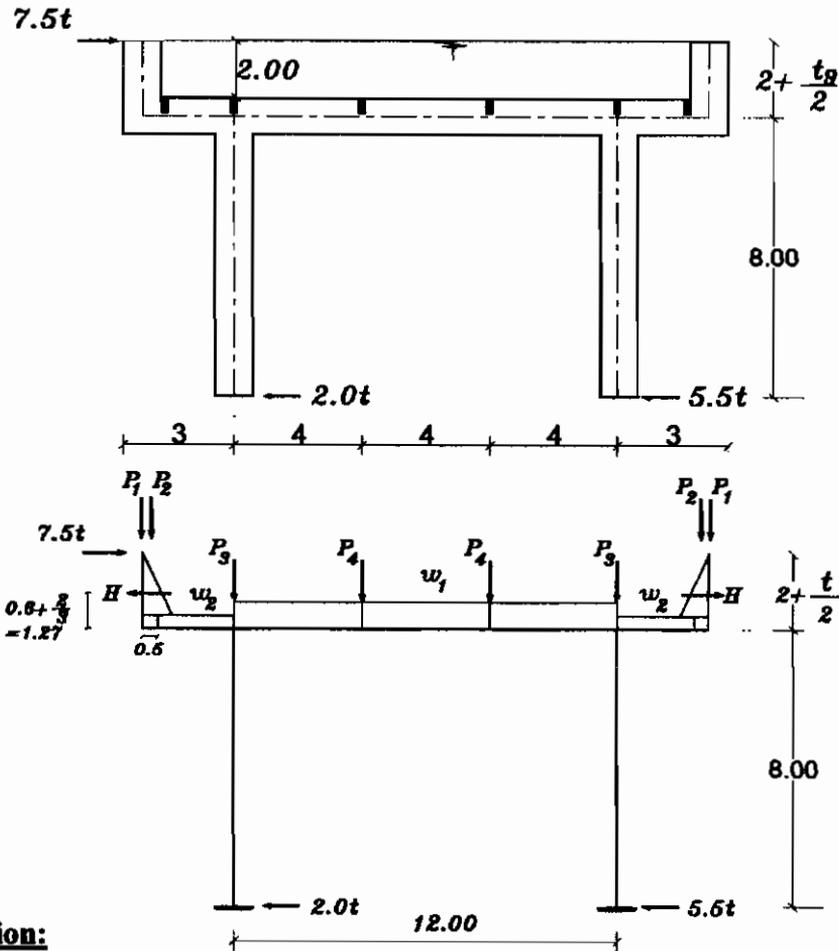
$b = 35 \text{ cm}$

Spacing bet frames = 5 m.

o.w of sec beams – 0.5 t/m^2 .

o.w of frame = 1 t/m^2

The frame is unbraced in its direction and braced in the other direction.



Solution:

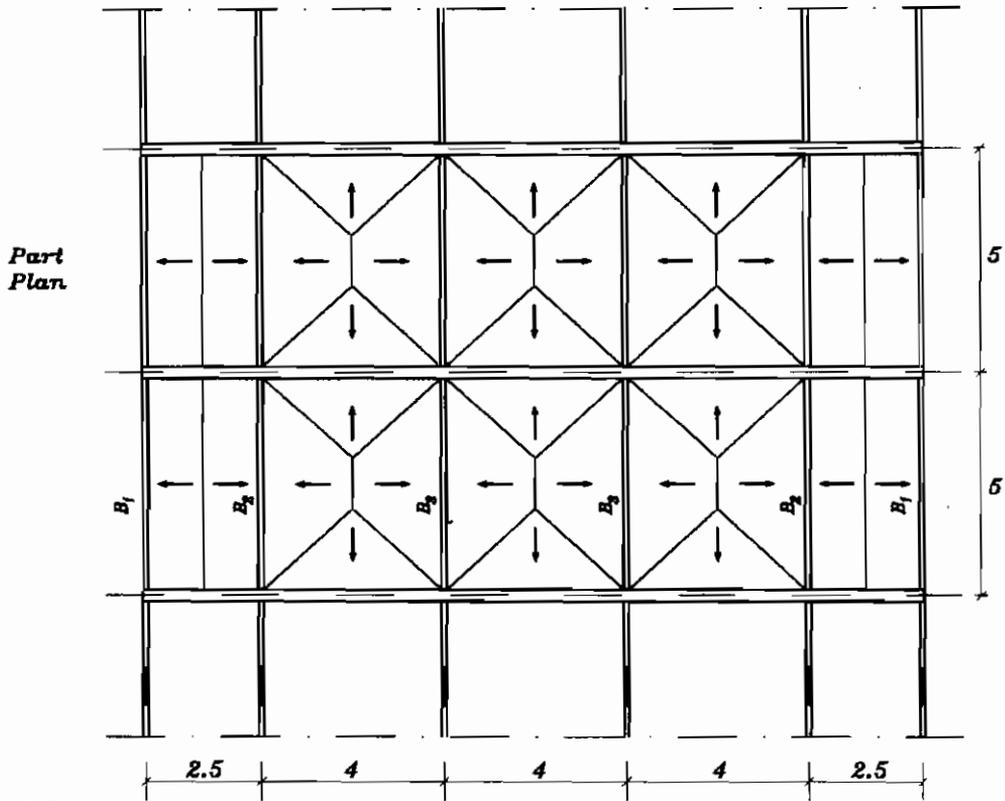
$t_g = \frac{1200}{12 \rightarrow 16} = 100 \text{ cm}$ in it to 120 cm for add loads

$t_c(\text{upper}) = 100 \text{ cm}$

$t_c(\text{lower}) = 70 \text{ cm}$

$t_{ve(\text{stiff})} = 80 \text{ cm}$

Ultimate Loads:



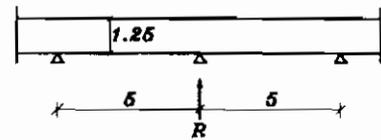
Slab Loads:

$$\begin{aligned}
 w_s &= o.w + \gamma h \\
 &= 0.14 * 2.5 + 2 = 2.35 \text{ t/m}^2 \\
 &= 4.76 \text{ t/m}^-
 \end{aligned}$$

Beam B₁ :

$$\begin{aligned}
 w_{u1} &= o.w + \text{slab load} \\
 &= 0.25 * 4.4 + 1.25 * 3.525 \\
 &= 4.76 \text{ t/m}^-
 \end{aligned}$$

$$P_2 = R = w_u * 5 = 23.8 \text{ t}$$

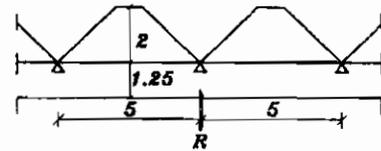


Beam B₂ :

$$\begin{aligned}
 w_{u2} &= o.w + \text{slab load} \\
 \frac{L}{2x} &= \frac{5}{4} = 1.25 \rightarrow B = 0.6
 \end{aligned}$$

$$\therefore w_{u2} = 0.25 * 1.4 + 1.25 * 3.525 + 0.6 * 3.525 * 2 = 8.99 \text{ t/m}^-$$

$$P_3 = R = w_{u2} * 5 = 44.9 \text{ t}$$



Beam B₃ :

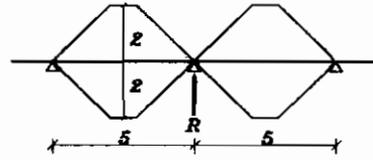
$$w_{us} = o.w + \text{slab load}$$

$$\frac{L}{2x} = 1.25 \rightarrow B = 0.6$$

$$w_{u3} = 0.25 * 1.4 + 2 * 0.6 * 3.525 * 2 = 8.81 \text{ t/m}^-$$

$$P_4 = R = w_{u3} * 5 = 44.1 \text{ t}$$

$$P_1 = o.w \text{ of wall} = 1.4 [1 * 2 + 0.14 * 2.5 * 2 * 5] = 7.7 \text{ t}$$

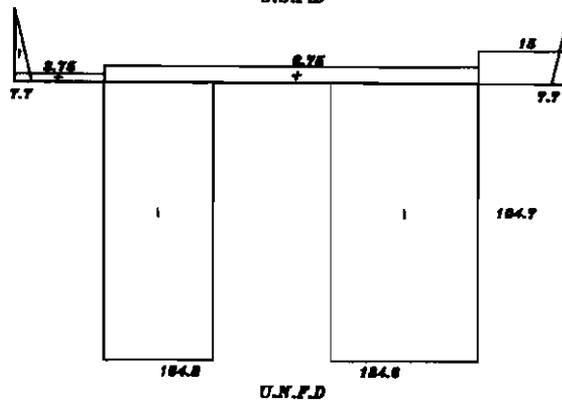
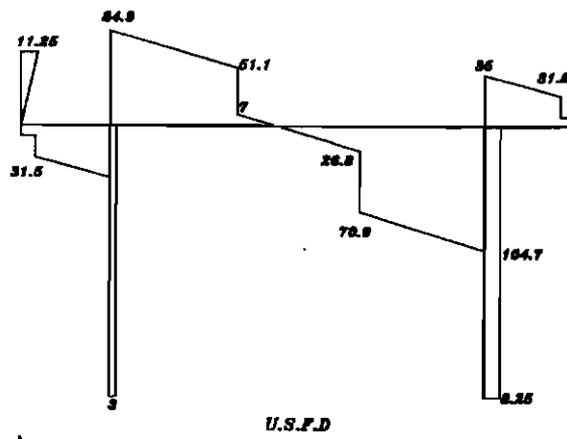
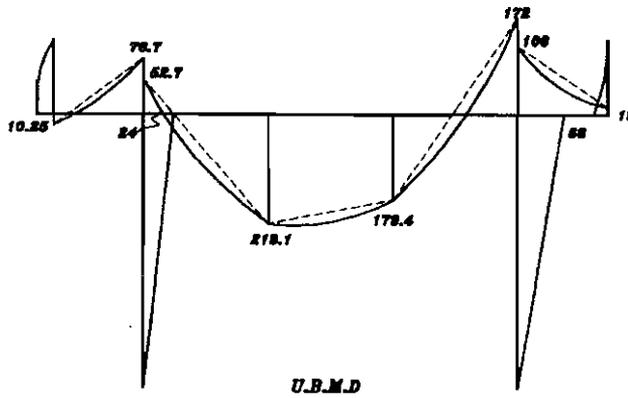
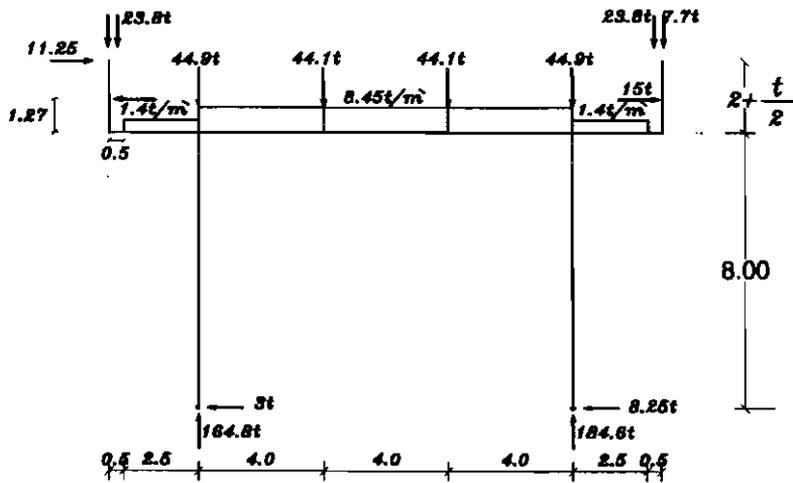


$$w_1 = o.w + \text{slab load} = 1.4 * 1 + \frac{6 * \frac{1}{2} * 4 * 2}{12} * 3.525 = 8.45 \text{ t/m}^-$$

$$w_2 = o.w = 1 * 1.4 = 1.4 \text{ t/m}^-$$

$$H = \frac{\gamma h^2}{2} * \text{spacing} = \frac{1(2)^2}{2} * S = 10 \text{ t}$$

$$H_u = 1.5 * 10 = 15 \text{ t}$$



Design of sections:

Sec (1) 35 * 100 cm (I)

$$M_u = 10.25 \text{ m.t} \quad N_u = + 3.75 \text{ t}$$

$$e = \frac{M_u}{N_u} = 2.73 \text{ m}$$

$$e/t = 2.73 > 0.5 \text{ Big ecc}$$

$$e_s = e - t/2 + 0.05 = 2.28 \text{ m}$$

$$M_{us} = N_u - e_s = 8.56 \text{ m.t}$$

$$R = \frac{M_{us}}{f_{cu} b d^2} = 0.011 \rightarrow w = 0.013$$

$$A_s = w b d \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 4.2 \text{ cm}^2$$

$$A_{s, \min} = \frac{11}{f_y} b d = 10.16 \text{ cm}^2$$

$$\therefore \text{use } A_{s, \min} = (4 \text{ } \Phi \text{ } 22)$$

Sec (2) 35 * 100 cm ^{Lcr}

$$M_u = 19 \text{ m.t}$$

$$N_u = + 15 \text{ t}$$

$$e = 1.27 \text{ m} \quad \frac{e}{t} = 1.27 > 0.5 \quad \text{Big ecc}$$

$$e_s = e - t/2 + 0.05 = 0.817 \text{ m}$$

$$M_{us} = N_u e_s = 12.25 \text{ m.t}$$

$$R = 0.016 \rightarrow w = 0.019$$

$$A_s = w b d \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 9.18 \text{ cm}^2 < A_{s, \min}$$

$$\therefore \text{use } A_{s, \min} = 10.16 \text{ cm}^2 \quad \text{use}(4 \text{ } \Phi \text{ } 22)$$

Sec (3) 35 * 1200 m R:

$$M_u = 76.7 \text{ m.t} \quad , \quad N_u = 13.75 \text{ t}$$

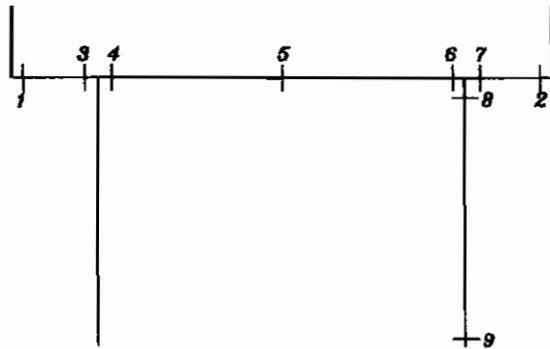
$$e = 20.45 \text{ m} \quad \frac{e}{t} > 0.5 \quad \text{big ecc}$$

$$e_s = e - t/2 + 0.05 = 19.9 \text{ m}$$

$$M_{us} = N_u e_s = 74.6 \text{ m.t}$$

$$R = 0.064 \rightarrow w = 0.81$$

$$A_s = w b d \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 23.84 \text{ cm}^2 \quad (6 \text{ } \Phi \text{ } 25)$$



Sec (4) 35 * 120 cm R

$$\begin{aligned}M_u &= 52.7 \text{ m.t} & N_u &= 6.75 \text{ t} \\e &= 7.81 \text{ m} & e/t &= 6.5 > 0.5 \text{ Big ecc} \\e_s &= e - t/2 + 0.05 = 7.26 \text{ m}\end{aligned}$$

$$\begin{aligned}M_{us} &= N_u \cdot e_s = 48.99 \text{ m.t} \\R &= 0.042 \rightarrow w = 0.051\end{aligned}$$

$$A_s = wbd \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 16.4 \text{ cm}^2 \quad (4\text{ff}25)$$

Sec (5) 35 * 120 cm. T

$$\begin{aligned}M_u &= 219.1 \text{ m.t} & N_u &= +6.75 \text{ t} \\e &= 32.46 \text{ m} & e/t &> 0.5 \\e_s &= e - t/2 + 0.05 = 31.9 \text{ m}\end{aligned}$$

$$\begin{aligned}M_{us} &= N_u \cdot e_s = 215.4 \text{ m.t} \\B &= 16 t_s + b = 259 \text{ cm}\end{aligned}$$

$$d = C_1 \sqrt{\frac{M_{us}}{f_{cu} B}} \rightarrow C_1 = 6.3 \rightarrow \text{take } c/d_{\min} = 0.125$$

$$C = 14.375 \text{ cm} \quad a = 0.8C = 11.5 \text{ cm} < t_s \quad (O.K)$$

$$J = 0.826 \quad \therefore A_s = 65.15 \text{ cm}^2$$

\therefore use (14ff25)

Sec (6) 35 * 120 □^{Lcr}

$$\begin{aligned}M_u &= 172 \text{ m.t} & N_u &= +6.75 \text{ t} \\e &= 25.48 \text{ m} & e/t &> 0.5 \\e_s &= e - t/2 + 0.05 = 24.93 \text{ m}\end{aligned}$$

$$M_{us} = N_u \cdot e_s = 168.3 \text{ m.t}$$

$$R = 0.145 \xrightarrow{\alpha=0.1} w = 0.2$$

$$A_s = 58.06 \text{ cm}^2 \quad (12\text{ff}25)$$

Sec (7) 35 * 120 □^{Ler}

$$M_u = 106 \text{ m.t} \quad N_u = +15 \text{ t}$$

$$e = 707 \text{ m} \quad e/t > 0.5$$

$$e_s = e - t/2 + 0.05 = 6.517 \text{ m}$$

$$M_{us} = N_u e_s = 97.75 \text{ m.t}$$

$$R = 0.084 \rightarrow w = 0.109$$

$$A_s = 35.26 \text{ cm}^2 \quad (8 \text{ ff } 25)$$

Sec (8) 35 * 100 □^{Ler}

$$M_u = 66 \text{ m.t} \quad N_u = -184.64 \text{ t}$$

Buckling:

$$H_0 = 8.0 - 0.6 = 7.40 \text{ m.}$$

Top End condition	$t_g > t_c$	case (1)
Bottom End condition	hinged	case (3)

$$\text{Table (6 - 10) } \rightarrow K = 1.6$$

$$\lambda = \frac{1.6 * 740}{90} = 13.16 > 10 \quad \text{Long}$$

$$\delta = \frac{\lambda^2 b}{2000} = \frac{(13.16)^2 * 0.9}{2000} = 0.0775 \text{ m}$$

$$M_{add} = N_u \cdot \delta = 14.4 \text{ m.t}$$

$$M_u = 66 + 14.4 = 80.4 \text{ m.t}$$

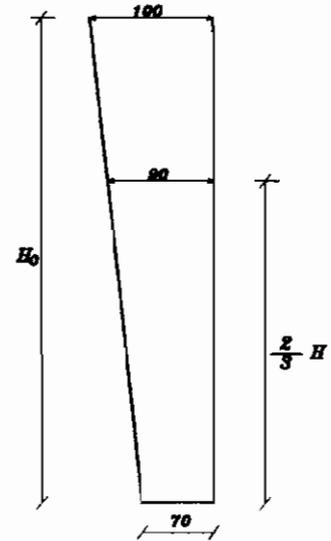
$$\frac{N_u}{f_{cu} b t} = 0.23 > 0.04$$

$$e = 0.436 \text{ m} \rightarrow e/t = 0.436 > 0.05$$

$$\frac{M_u}{f_{cu} b t^2} = 0.092$$

$$\text{Interaction Diag } \alpha = 0.6 \quad \eta = 0.9 \quad f_y = 3600$$

$$\text{Comp failure } \rho = 1.8$$



$$\mu = 0.45 \% \rightarrow \mu_t = (1 + \alpha)\mu = 0.72\%$$

$$\mu_{\min} = 0.85 + 0.052\lambda = 0.93\%$$

\therefore use $A_{s \min}$

$$A_s = \frac{0.0093}{1.6} * 35 * 100 = 20.44 \text{ cm}^2$$

$$A_s^- = 0.6 A_s = 12.26 \text{ cm}^2$$

sec (9) 35 * 70 cm

$$N_u = -184.6 \text{ t} \quad (A_s \text{ short column})$$

$$N_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$\therefore A_{sc} = -v_c$$

$$\therefore \text{use } A_{s \min} = 0.6\% A_c = 14.7 \text{ cm}^2$$

Check of shear sec (6) 35 * 120 cm

$$Q_u = 104.7 \text{ t}$$

$$q_u = \frac{Q_u}{bd} = 26. \text{ kg/cm}^2$$

$$q_{cu(\max)} = 2.2 \sqrt{\frac{f_{cu}}{\gamma_c}} = 28.4 \text{ kg/cm}^2 > q_u \quad (\text{o.k.})$$

$$q_{cu} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}} = 9.68 \text{ kg/cm}^2$$

$$\therefore q_{su} = q_u - \frac{1}{2} q_{cu} = 21.16 \text{ kg/cm}^2$$

Assume using stirr (8 ϕ 10/m)

$$\therefore q_{st} = \frac{A_{st} \cdot f_y / \gamma_s}{b \cdot s} = \frac{2 * 0.785 * 2400 / 1.15}{35 * 12.5} = 7.49 \text{ kg/cm}^2$$

$$\therefore q_{sub} = 21.16 - 7.49 = 13.67 \text{ kg/cm}^2$$

$$\therefore A_{sb} = \frac{q_{sub} \cdot b \cdot d}{f_y / \gamma_s \sin \alpha} = 24.85 \text{ cm}^2 \quad (5\phi\phi 25)$$

(OR) Assume using 4 $\phi\phi$ 25 bent bars

$$\therefore q_{sub} = 10.8 \text{ kg/cm}^2$$

$$\therefore q_{st} = 21.16 - 10.8$$

$$A_{st} = \frac{q_{st} \cdot b \cdot s}{f_y / \gamma_s} \quad \text{use } f_y = 2800 \text{ kg/cm}^2$$

using stirrups ϕ 10

$$\therefore S = 10.55 \text{ cm}$$

\therefore using stirrups (10 ϕ 10/m)

3φ20

4φ25

4φ25

6φ25

10φ10/π'

▶ 1

▶ 2

▶ 3

5

8

8φ8/π'

8φ8/π'

5φ8/π'

5φ8/π'

3φ18

4φ22

3φ18

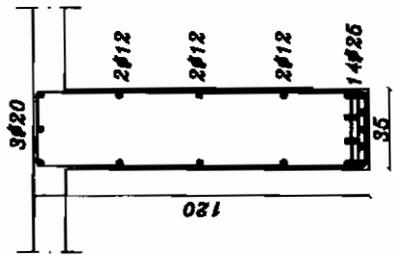
4φ22

5φ25

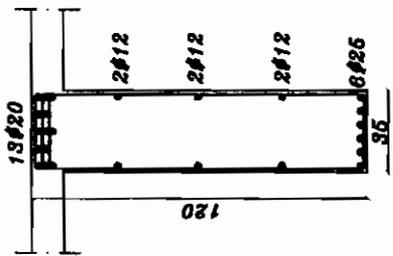
4φ22

4φ22

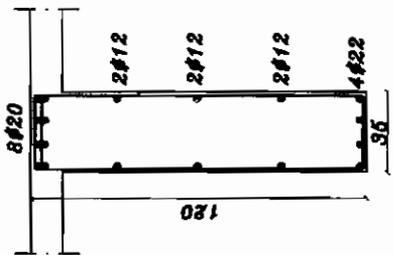
4φ22



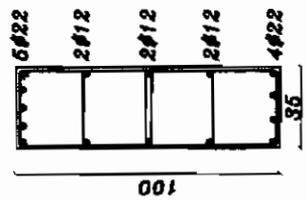
Sec. (1)



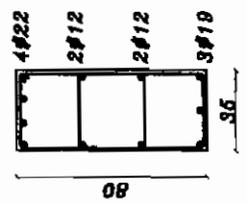
Sec. (2)



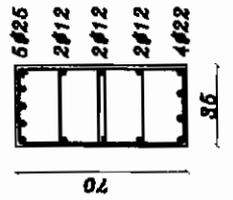
Sec. (3)



Sec. (5)



Sec. (4)



Sec. (6)

Example (3) :

Draw straining action diagrams, and design the critical section, then give full details for the following frames:

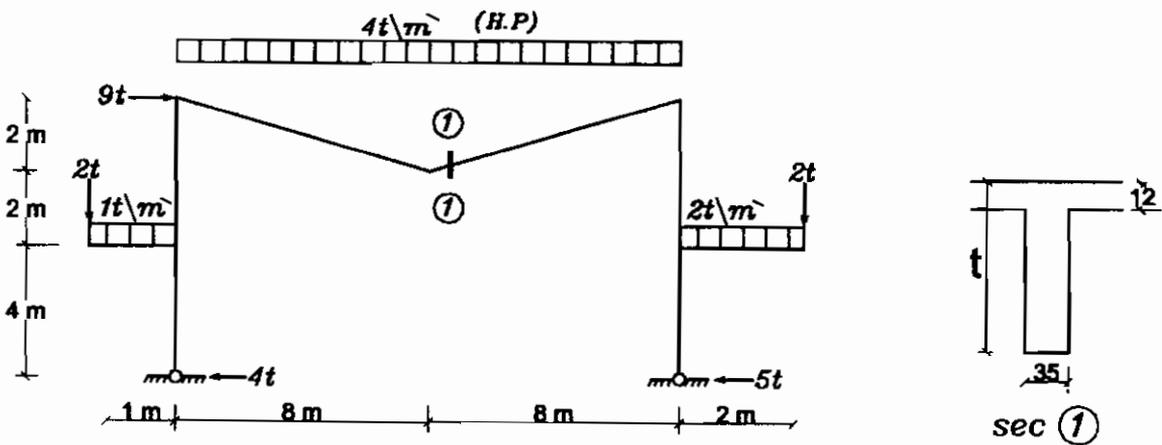
Frame (3) :

Data:

$t_s = 12 \text{ cm}$
 $b = 35 \text{ cm}$

$f_{cu} = 250 \text{ kg/cm}^2$
 $f_y = 3600 \text{ kg/cm}^2$

The frame may be considered braced in each direction.



Solution:

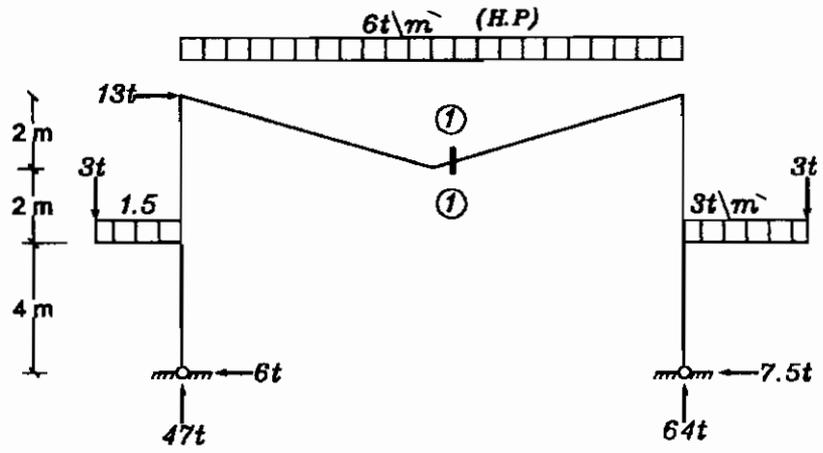
Dimensioning:

$$t_g = \frac{1600}{12 \rightarrow 16} = 120 \text{ cm}$$

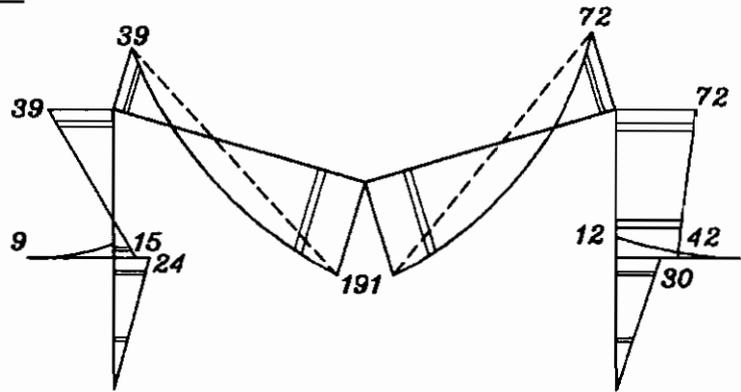
$$t_{c(\text{upper})} = 100 \text{ cm}$$

$$t_{c(\text{lower})} = 70 \text{ cm}$$

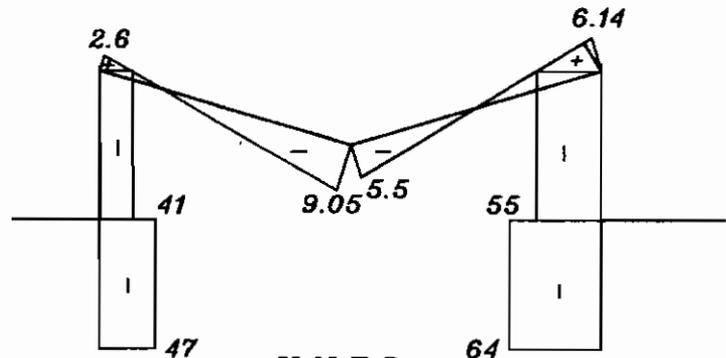
$$t_{\text{cantiver}} = 80 \text{ cm}$$



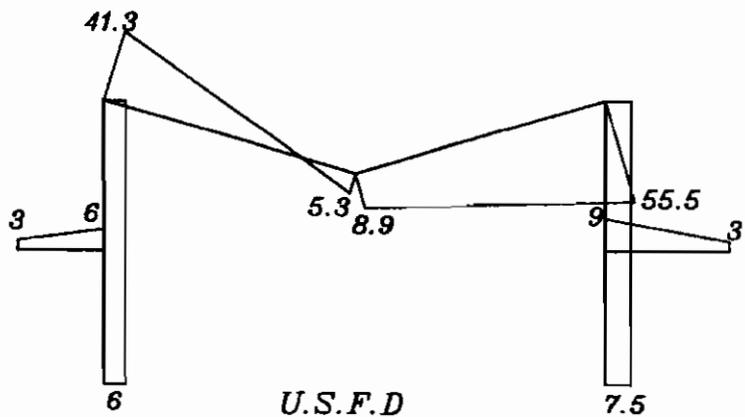
Straining Actions



U.B.M.D



U.N.F.D



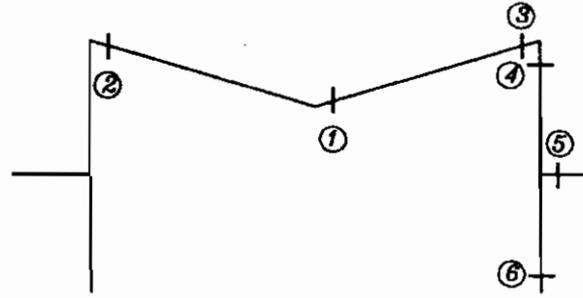
U.S.F.D

Loads:

$$w_u = 1.5 * w_{working}$$

Design of section:

Sec	M_u	N_u
1	191	- 9.05
2	39	+ 2.6
3	72	+ 6.14
4	72	- 55
5	12	0
6	0	64



Sec (1) 35 * 120 T – sec:

$$B = \text{Smallest of } \begin{cases} 16 t_s + b = 227 \text{ cm} \\ C_L \text{ to } d \\ \frac{L}{10} + b \end{cases}$$

$$M_u = 191 \text{ m.t}$$

$$N_u = -9.05 \text{ t}$$

$$\frac{N}{f_{cu} b t} = 0.009 < 0.04 \quad \therefore \text{neglect } N_u$$

$$d = C_1 \sqrt{\frac{M_u}{f_{cu} B}} \rightarrow C_1 = 6.27 \quad \therefore \text{Take } c/d_{min} = 0.125$$

$$\therefore C = 0.125 d = 14.375 \text{ cm} \rightarrow a = 0.8 c = 11.5 \text{ cm} < t_s \text{ (O.K)}$$

$$J = 0.826$$

$$A_s = \frac{M_u}{f_y J d} = 55.7 \text{ cm}^2 \quad (12 \phi 25)$$

Sec (2) : 35 * 120 cm \square^{ler}

$$M_u = 39 \text{ m.t}$$

$$N_u = + 2.6 \text{ t}$$

$$e = \frac{M_u}{N_u} = 15 \text{ m} \rightarrow \frac{e}{t} = 12.5 > 0.5 \quad \text{Big. ecc}$$

$$e_s = e - t/2 + 0.05 = 14.45 \text{ m}$$

$$M_{us} = N_u - e_s = 37.6 \text{ m.t}$$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.032 \rightarrow w = 0.039$$

$$A_s = wbd \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 11.73 \text{ cm}^2$$

$$A_{s, \min} = \frac{11}{f_y} bd = 12.3 \text{ cm}^2$$

\therefore use $A_{s, \min}$ (4ϕ22)

Sec (3) : 35 * 120 cm □^{ler}

$$M_u = 72 \text{ m.t}$$

$$N_u = 6.14 \text{ t}$$

$$e = \frac{M_u}{N_u} = 11.73 \text{ m} \rightarrow \frac{e}{t} = 9.77 > 0.5 \text{ Big ecc}$$

$$e_s = e - t/2 + 0.05 = 11.176 \text{ m}$$

$$M_{us} = N_u e_s = 68.62 \text{ m.t}$$

$$R = 0.059 \rightarrow w = 0.074$$

$$\therefore A_s = wbd \frac{f_{cu}}{f_y} + \frac{N_u}{f_y / \gamma_s} = 22.65 \text{ cm}^2 \quad (\text{use } 6\phi 22)$$

Sec (4) : 35 * 100 cm □^{ler}

$$M_u = 72 \text{ m.t}$$

$$N_u = -55 \text{ t}$$

$$\frac{N_u}{f_{cu} bt} = 0.063 > 0.04$$

$$e = \frac{M_u}{N_u} = 1.31 \text{ m} \rightarrow \frac{e}{t} = 1.31 > 0.05$$

$$\frac{M_u}{f_{cu} bt^2} = 0.082$$

$$\text{Interaction Diag } \alpha = 0.6 \quad \zeta = 0.9 \quad f_y = 3600 \text{ kg/cm}^2$$

$\rho < 1 \rightarrow$ Tension failure

$$e_s = e + \frac{t}{2} - 0.05 = 1.76 \text{ m}$$

$$M_{us} = N_u e_s = 96.75 \text{ m.t}$$

$$R = \frac{M_{us}}{f_{cu} bd^2} = 0.123 \xrightarrow{\alpha=0} w = 0.171$$

$$A_s = wbd \frac{f_{cu}}{f_y} - \frac{N_u}{f_y / \gamma_s} = 21.9 \text{ cm}^2 \quad (6\text{ff}22)$$

Sec (5) : 35 * 80 cm (Rect)

$$M_u = 12 \text{ m.t}$$

$$R = 0.024 \rightarrow w = 0.029$$

$$A_s = 5.3 \text{ cm}^2 .$$

$$A_{s \min} = \frac{11}{f_y} bd = 8 \text{ cm}^2$$

$$\therefore \text{use } A_{s \min} \quad (4\text{ff}19)$$

Sec (6) : 35 * 70 cm

$$N_u = - 64 \text{ t}$$

Design as short column

$$N_u = P_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$64 * 1000 = 0.35 * 250 * 35 * 70 + 0.67 * 3600 A_{sc}$$

$$A_{sc} = - \text{ve}$$

$$\therefore \text{use } A_{sc \min} = 0.6 \% A_c = 14.7 \text{ cm}^2 .$$

Check of shear:

$$Q_u = 55.5 \text{ t}$$

$$q_u = \frac{Q_u}{bd} = 13.79 \text{ kg/cm}^2$$

$$q_{cu} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}} = 9.68 \text{ kg/cm}^2$$

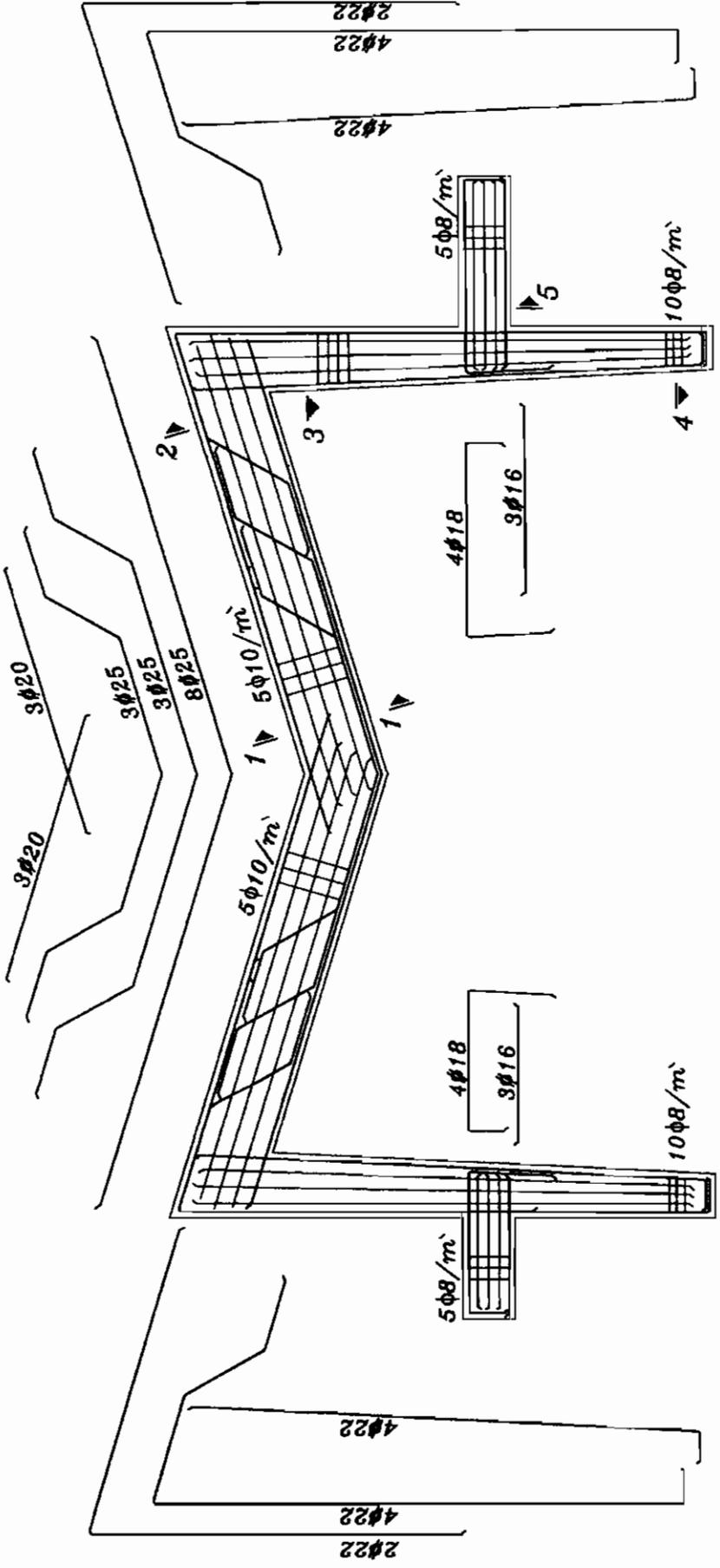
$$q_{su} = q_u - \frac{1}{2} q_{cu} = 8.95 \text{ kg/cm}^2$$

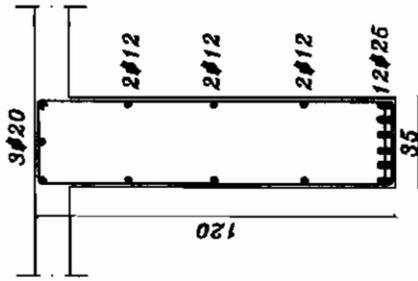
Assume using stirrups 5 ϕ 10 / m⁻ (2 - branches)

$$\therefore q_{st} = \frac{A_{st} f_y / \gamma_s}{b_s} = 4.68 \text{ kg/cm}^2$$

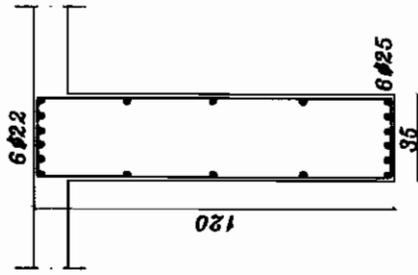
$$q_{sub} = 8.95 - 4.68 = 4.24 \text{ kg/cm}^2$$

$$A_{sb} = \frac{q_{sub} b.d}{f_y / \gamma_s \sin \alpha} = 7.8 \text{ cm}^2 \quad (3\text{ff}22)$$

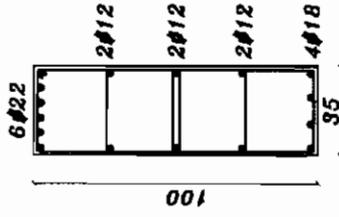




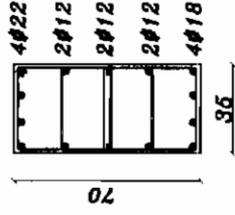
Sec. (1-1)



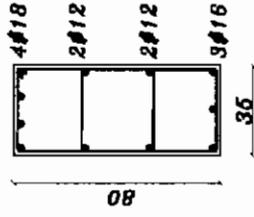
Sec. (2-2)



Sec. (3-3)



Sec. (4-4)



Sec. (5-5)

Example (4) :

Draw straining action diagrams, and design the critical section, then give full details for the following frames:

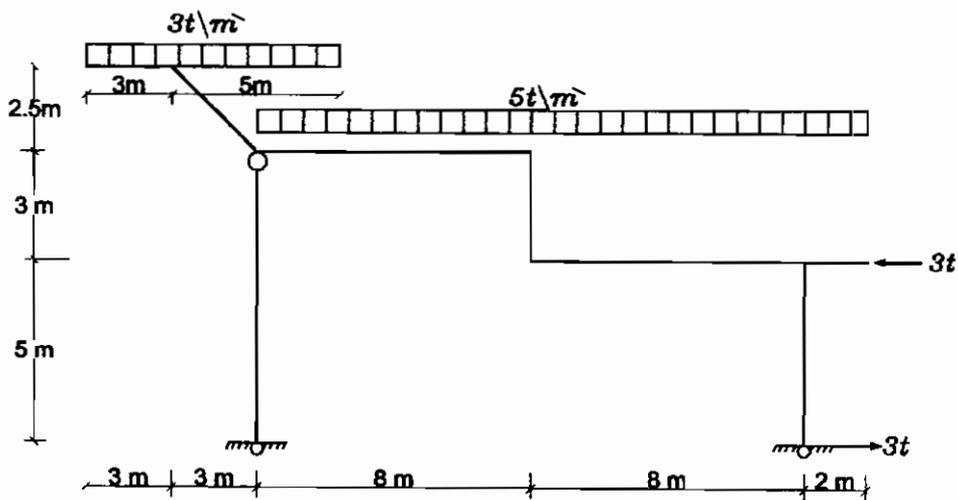
Frame (4) :

Data:

$t_s = 12 \text{ cm}$
 $b = 40 \text{ cm}$

$f_{cu} = 250 \text{ kg/cm}^2$
 $f_y = 3600 \text{ kg/cm}^2$

The frame is unbraced in its direction and braced in the other direction.



Solution:

Dimensioning:

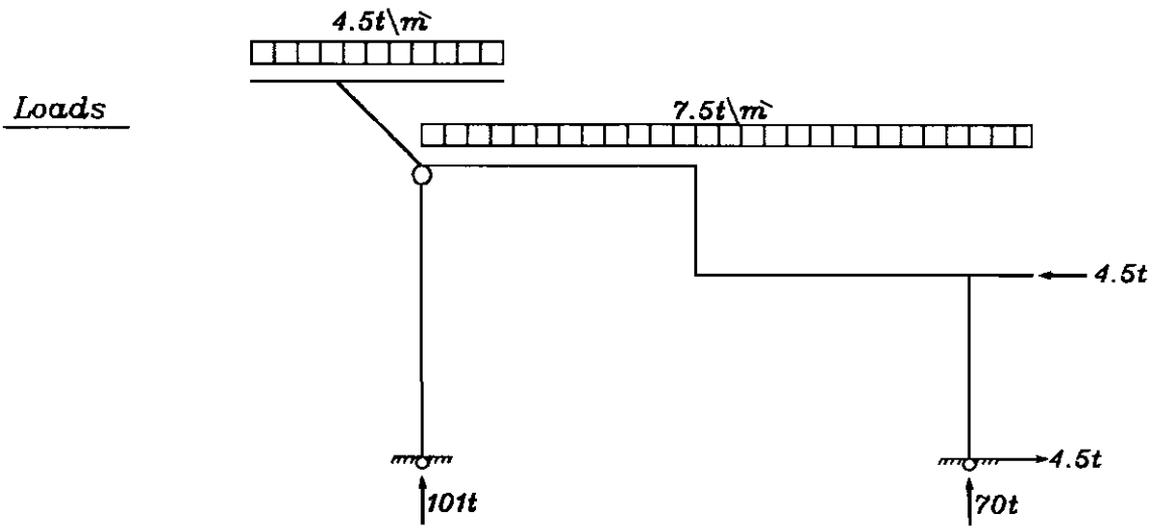
$t_g = \frac{1600}{12 \rightarrow 16} = 120 \text{ cm}$

$t_{c(\text{upper})} = 100 \text{ cm}$ & $t_{c(\text{lower})} = 70 \text{ cm}$

$t_{(\text{link})} = \text{Bigger of } 0.4 t_g = 48 \text{ cm}$

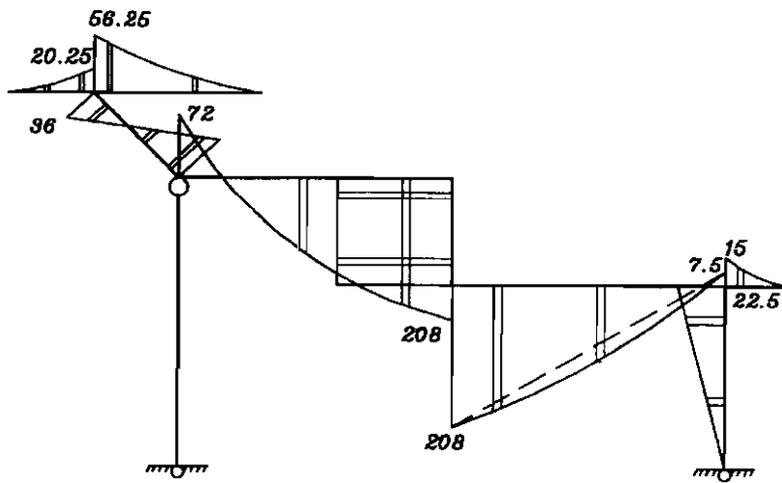
$\frac{1}{20} = 80 \text{ cm}$

$t_{(\text{Link})} = 80 \text{ cm}$

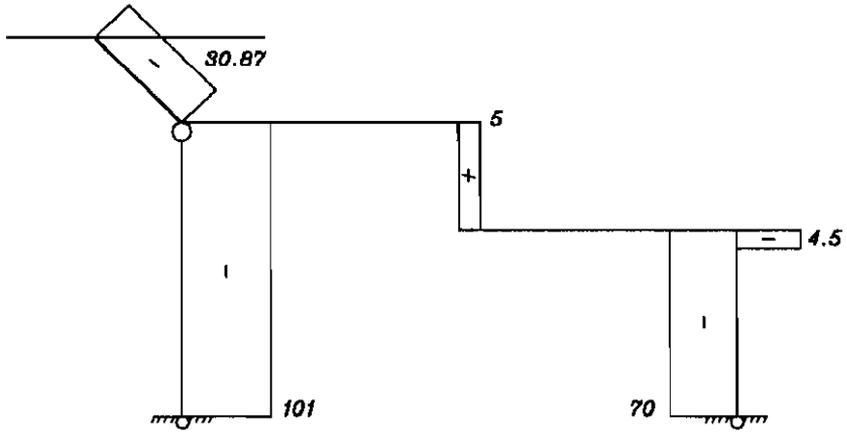


$Ultimate\ Load = Working\ Load * 1.5$

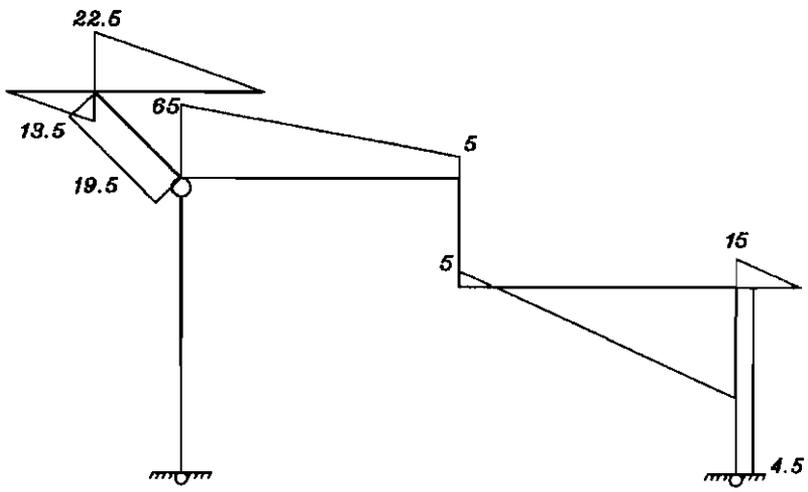
Straining Actions



U.B.M.D



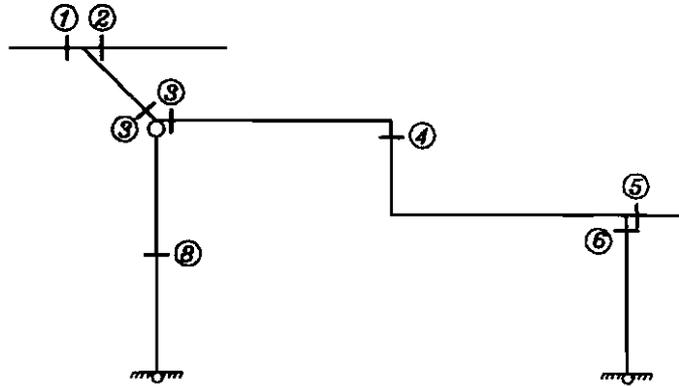
U.N.F.D



U.S.F.D

Design of section:

Sec	M_u	N_u
1	20.25	0
2	56.25	0
3	72	-30.87
4	208	+5
5	15	0
6	22.5	-70
7	0	-70
8	0	-101



Sec (1) 40 * 120 cm □^{ler}

$M_u = 20.25 \text{ m.t}$
 $N_u = 0$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.015 \rightarrow w = 0.02$$

$$A_s = w b d \frac{f_{cu}}{f_y} = 6.39 \text{ cm}^2$$

$$A_{s, \min} = \frac{11}{f_y} b d = 14 \text{ cm}^2 > A_s$$

\therefore use $A_{s, \min}$ (4ff22)

Sec (2) 40 * 120 cm □^{ler}

$M_u = 56.25 \text{ m.t}$

$$R = \frac{M_u}{f_{cu} b d^2} = 0.043 \rightarrow w = 0.053$$

$$\therefore A_s = w b d \frac{f_{cu}}{f_y} = 16.93 \text{ cm}^2 \quad (6ff22)$$

Sec (3) 40 * 120 cm □^{ler}

$$M_u = 72 \text{ m.t}$$

$$N_u = 30.87 \text{ t}$$

$$\frac{N_u}{f_{cu}bt} = 0.026 < 0.04 \rightarrow \text{neglect } N_u$$

$$\therefore R = \frac{M_u}{f_{cu}bd^2} = 0.054 \rightarrow w = 0.067$$

$$\therefore A_s = 21.4 \text{ cm}^2 \text{ (6}\phi\text{22)}$$

Sec (4) 40 * 120 cm □^{ler}

$$M_u = 208 \text{ m.t}$$

$$N_u = + 5 \text{ t}$$

$$e = \frac{M_u}{N_u} = 41.6 \text{ m} \rightarrow \frac{e}{t} > 0.5 \rightarrow \text{Big ecc}$$

$$e_s = e - t/2 + 0.05 = 41.05 \text{ m}$$

$$M_{us} = N_u \cdot e_s = 205.25 \text{ m.t}$$

$$R = \frac{M_{us}}{f_{cu}bd^2} = 0.1552 \xrightarrow{\alpha=0.2} w = 0.21$$

$$A_s = wbd \frac{f_{cu}}{f_y} + \frac{N_u}{f_y/\gamma_s} = 68.7 \text{ cm}^2 \quad (14\phi\text{25})$$

$$A_s^- = 0.2 A_s = 13.74 \text{ cm}^2 \quad (4\phi\text{22})$$

Sec (5) 40 * 120 cm □^{ler}

$$M_u = 15 \text{ m.t}$$

$$\text{Use } A_{s \text{ min}} = 14 \text{ cm}^2 \quad (4 \text{ \#}22)$$

Sec (6) 40 * 100 cm □^{ler}

$$M_u = 22.5 \text{ m.t}$$

$$N_u = 70 \text{ t.}$$

Check additional moment due to buckling In plane

$$H_o = 5 - 0.6 = 4.4 \text{ m.}$$

Top End Condition case (1)

$$t_g > t_c$$

Bottom End condition case (3)

Hinge

Table (6 - 10) → K = 1.6

$$t_{avr} = 70 + 30 * \frac{2}{3} = 90 \text{ cm}$$

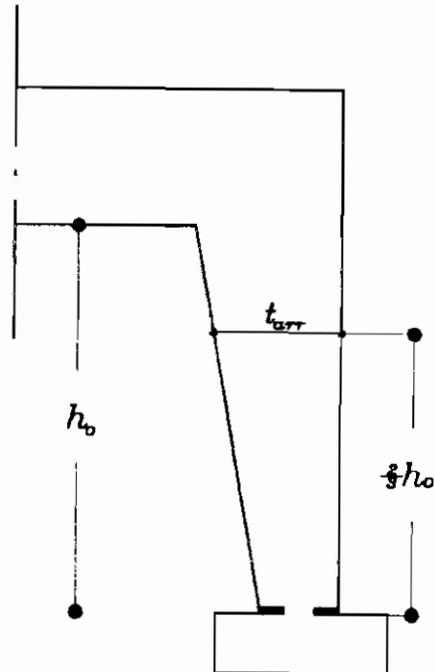
$$\lambda_b = \frac{1.6 H_o}{t_{avr}} = \frac{1.6 * 440}{80} = 7.8 < 10 \therefore \text{short}$$

no additional moments

$$\frac{N_u}{f_{cu} bt} = 0.07 > 0.04$$

$$e = \frac{M_u}{N_u} = 0.32 \quad e/t > 0.05$$

$$\frac{M_u}{f_{cu} bt^2} = 0.016$$



Interaction Diag:

$$\alpha = 0.6 \quad \zeta = 0.9 \quad f_y = 3600 \text{ kg/cm}^2$$

$$\rho < 1.0 \rightarrow \text{tension failure}$$

$$e_s = e + \frac{t}{2} - 0.05 = 0.32 + 0.5 - 0.05 = 0.77$$

$$M_{us} = N_u e_s = 53.9 \text{ mt}$$

$$R = \frac{M_{us}}{f_{cu} b d^2} = 0.0597 \xrightarrow{\alpha=0.5} w = 0.071$$

$$A_s = w b d \frac{f_{cu}}{f_y} - \frac{N_u}{f_y / \gamma_s} = -ve$$

$$\therefore \text{use } A_{s \min} = \frac{0.6\%}{1.6} b t = 18 \text{ cm}^2 \quad (6\#22)$$

Sec (7) 40 * 70 cm

$$N_u = - 70 \text{ t.}$$

$$N_u = P_u = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$A_{sc} = - ve$$

$$\therefore \text{use } A_{s \min} = 0.6\% A_c = 16.8 \text{ cm}^2$$

Sec (8) 40 * 80 cm

$$N_u = - 101 \text{ t.}$$

Check on additional moment due to buckling. (in plane)

$$H_o = 8 - 0.6 = 7.4 \text{ m}$$

Top End condition

case (1) $t_b > t_c$

Bottom End condition

case (3) Hinge.

Table (6 - 10) $\rightarrow K = 1.6$

$$\therefore \lambda_b = \frac{1.6 \times 740}{80} = 14.8 > 10 \text{ long}$$

$$\delta = \frac{\lambda_b^2 b}{2000} = \frac{(14.8)^2 * 0.8}{2000} = 0.088 \text{ m}$$

$$M_{add} = N_{us} = 8.85 \text{ m.t} = M_u$$

$$\frac{N_u}{f_{cu} b t} = 0.126 > 0.04$$

$$e = \frac{M_u}{N_u} = 0.088 \text{ m} \quad e/t = 0.11 > 0.05$$

$$\frac{M_u}{f_{cu} b t^2} = 0.014$$

Interaction diagrams $\alpha = 0.1$ $\zeta = 0.9$ $f_y = 3600$

$$\rho < 1.0$$

\therefore use $A_{s \min}$

$$M_{\min} = 0.25 + 0.052 \lambda_b = 1.02 \%$$

$$A_{s \min} = 32.6 \text{ cm}^2$$

Check of shear:

Sec (3) 40 * 120 cm .

$$Q_u = 65 t$$

$$\therefore q_u = 14.13 \text{ kg/cm}^2$$

$$q_{cu} = 9.68 \text{ kg/cm}^2$$

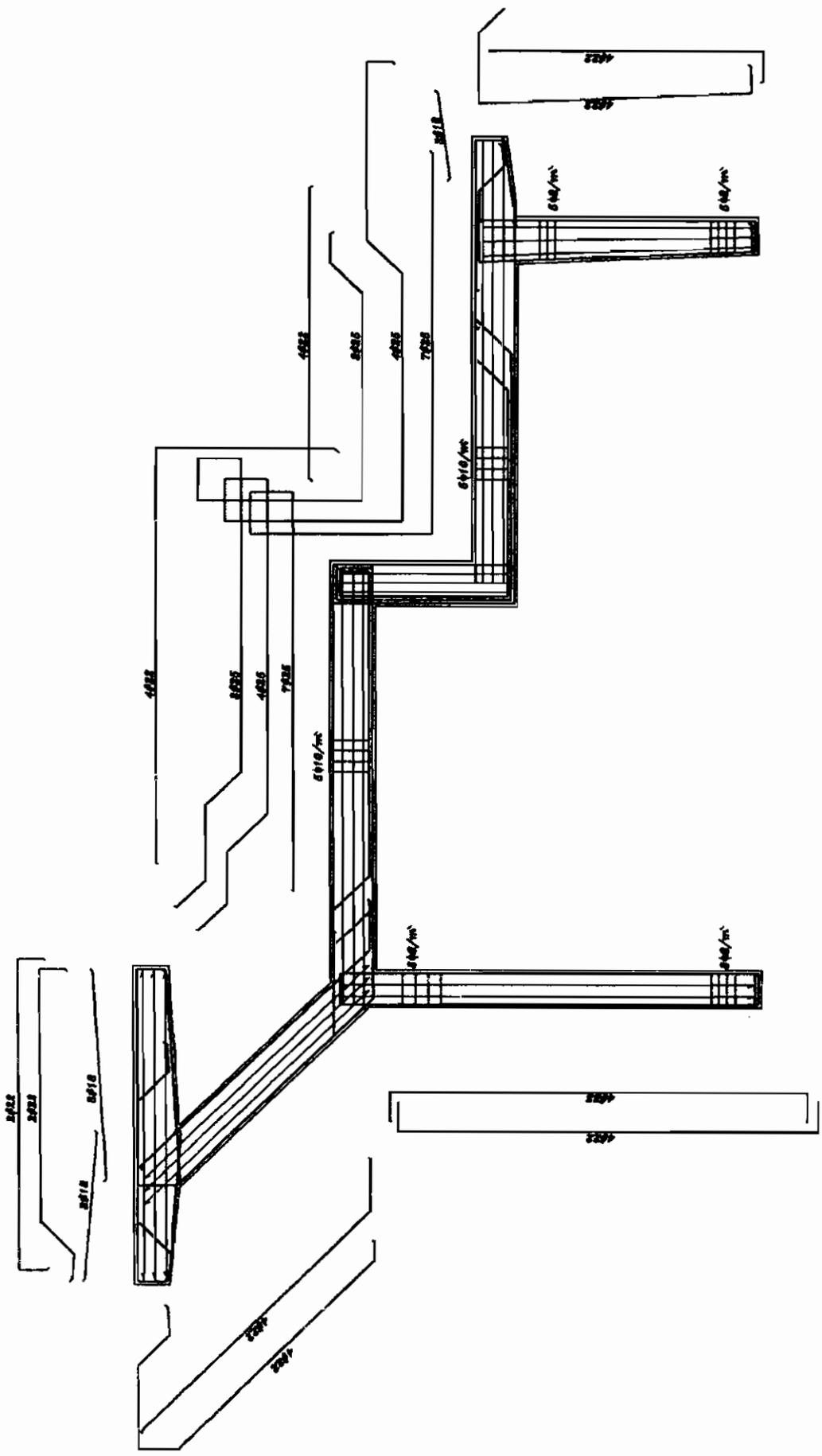
$$q_{su} = q_u - 0.5 q_{cu} = 9.29 \text{ kg/cm}^2$$

Assume using stirr (5ϕ10/m²)

$$\therefore q_{st} = \frac{A_{st} f_y / \gamma_s}{b.s} = 5.42 \text{ kg/cm}^2$$

$$\therefore q_{sub} = 3.87 \text{ kg/cm}^2$$

$$A_{sb} = \frac{q_{sub} . b . d}{f_y / \gamma_s \sin \alpha} = 8.04 \text{ cm}^2 \quad (3\phi\phi 22)$$



Example (5) :

- * Design curves and Egyptian code are only allowed material.
- * Maximum grade is 100 points.

General Data:

Concrete grade : $f_{cu} = 250 \text{ kg/cm}^2$.
For reinforcing steel : $f_y = 3600 \text{ kg/cm}^2$.

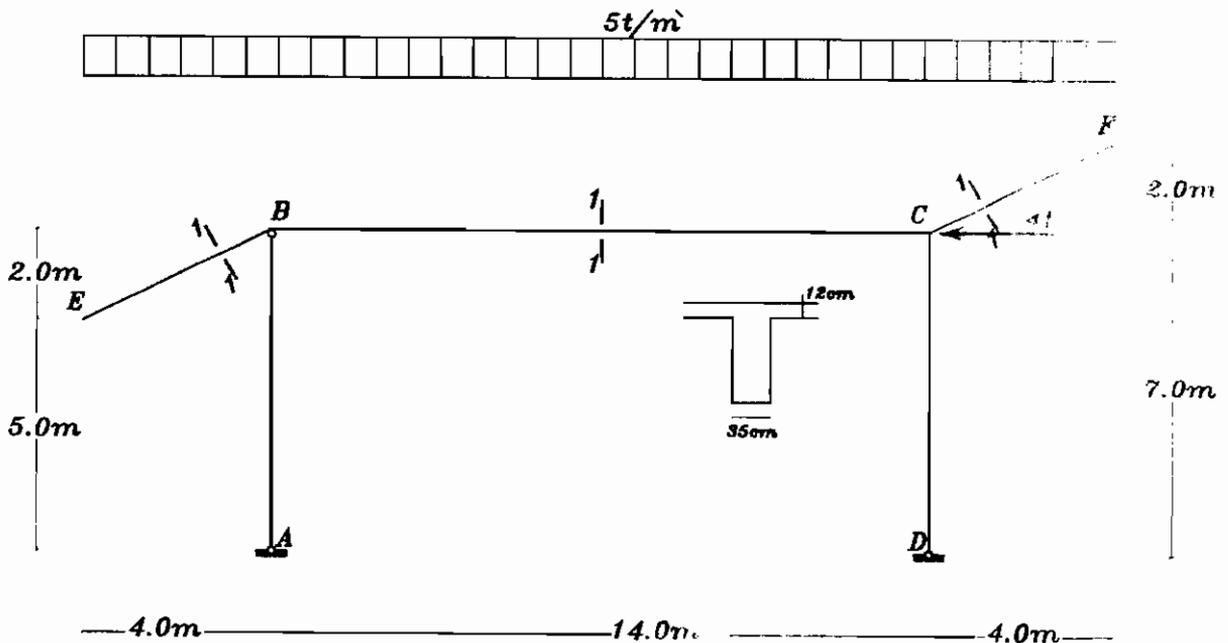
Any data not given may be reasonably assumed.

Question 1 : (65 Points) :

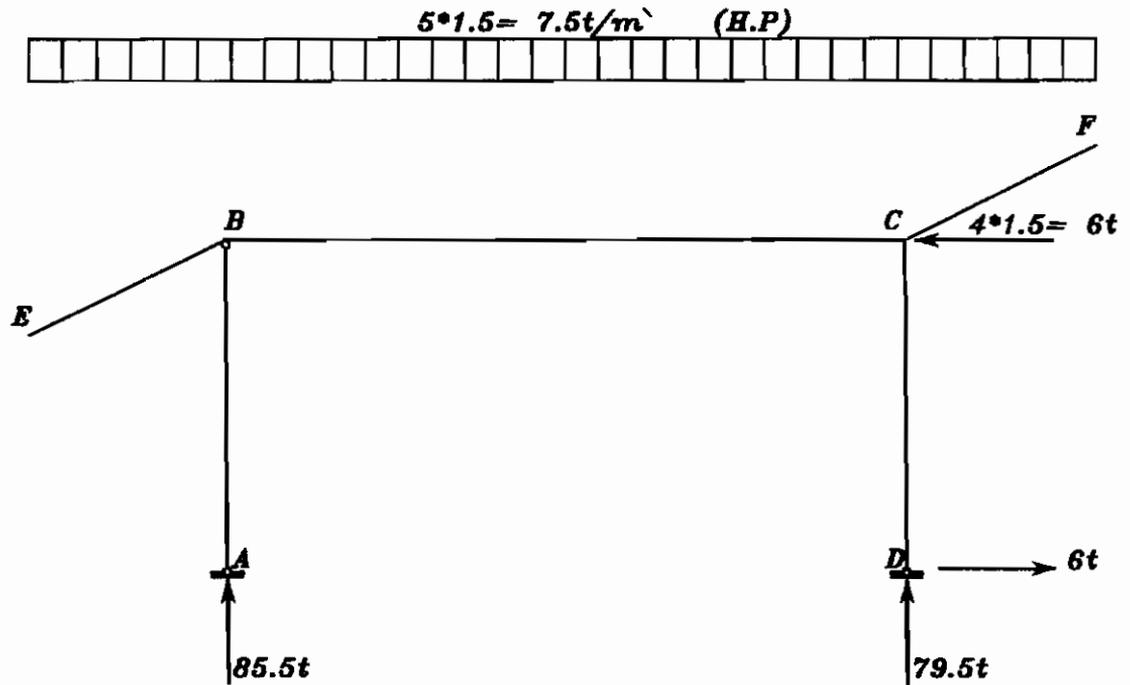
A stadium frame ABCD has two cantilevers BE and CF. The vertical member AB is hinged at both ends A and B, while the vertical member CD is hinged only at the support D. The frame is assumed braced in both direction. Service loads on the frame are 5 t/m horizontal project (including own weight of the frame) between E and F. A horizontal force of 4 tones is also acting at point C as shown in figure.

It is required to:

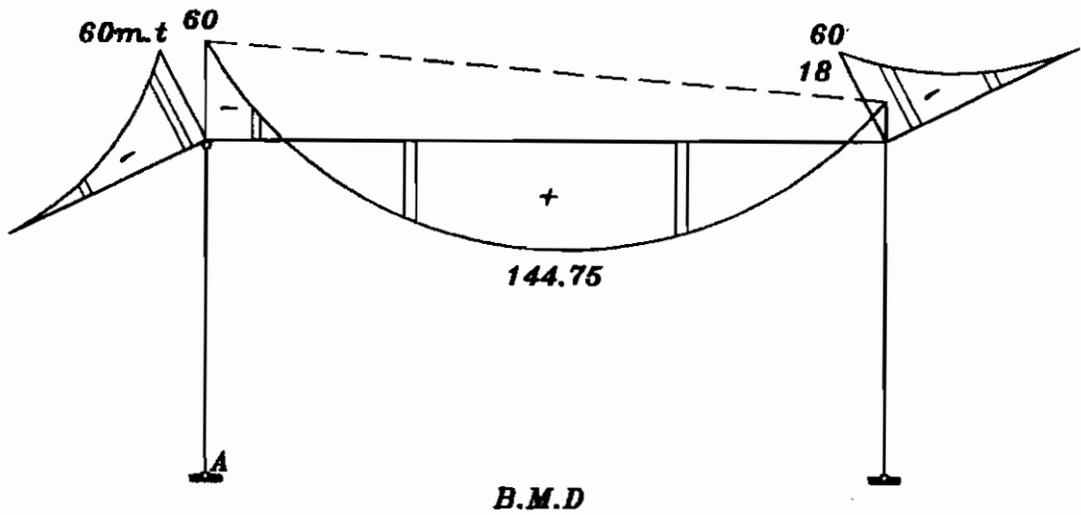
- 1 – Draw the straining actions (B . M . , NF and S . F)
- 2 – Design all critical section.
- 3 – Check shear at section B in girder B.C.
- 4 – Give full details of reinforcement in elevation and cross section.

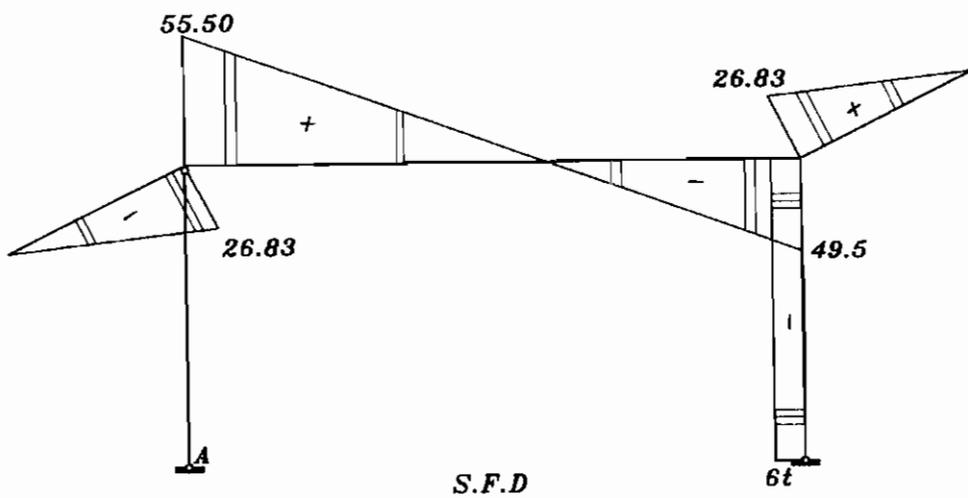
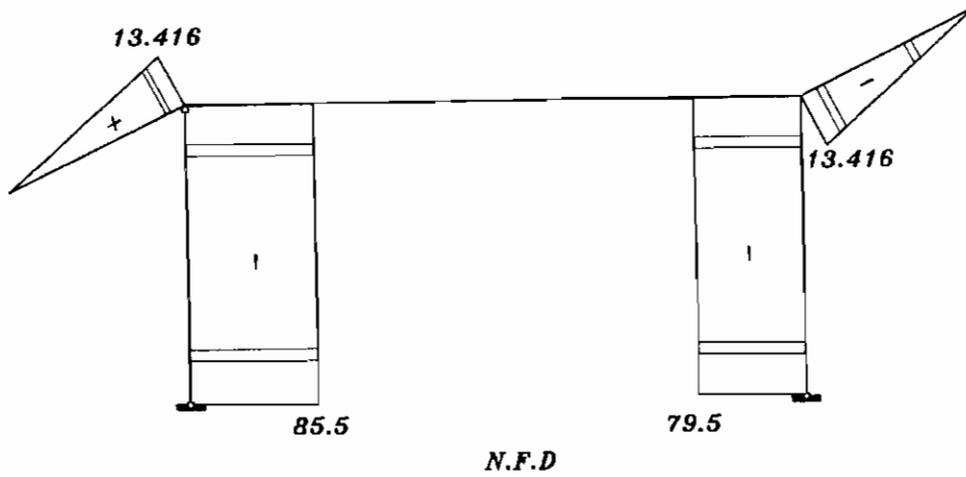


Ultimate Load = 1.5 * Service Load



1) Straining Actions



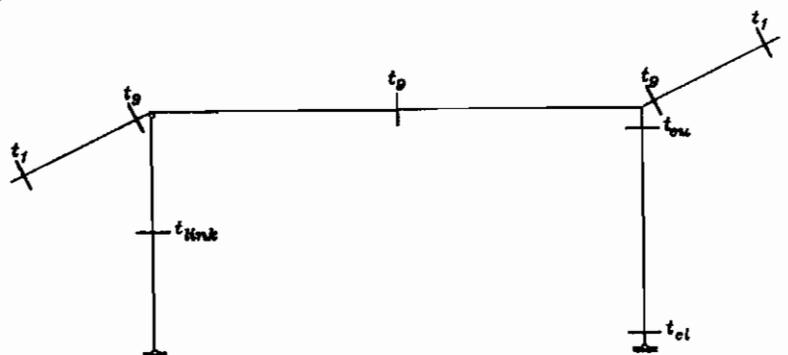


Dimensioning of the Frame

$$t_g = \frac{\text{Span}}{12-16} = \frac{1400}{12} = 117\text{cm} \approx 120\text{cm}$$

$$t_{cu} = (0.8 \sim 1) t_g = 120\text{cm}$$

$$t_{cl} = 0.6 t_{cu} = 75\text{cm}$$



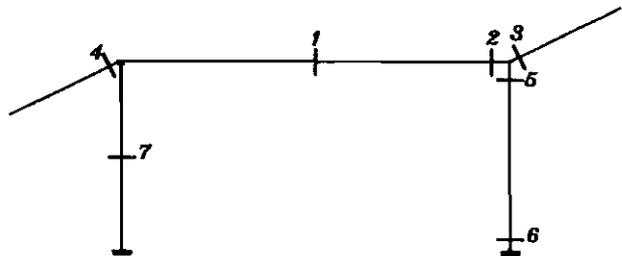
$$t_1 = 0.5 t_g = 60 \text{ cm}$$

$$t_{(link)} = \text{larger of} \begin{cases} 0.4 t_g = 48 \text{ cm} \\ L / 20 = 70 \text{ cm} \end{cases}$$

$$\therefore t_{(link)} = 70 \text{ cm}$$

Design of critical Section:

Sec	M_u	N_u	Sec .type
1	144.75	--	t- sec
2	18	--	□ ^{ler}
3	60	-13.42	□ ^{ler}
4	60	+13.42	□ ^{ler}
5	42	-79.5	□ ^{ler}
6	--	-79.5	□ ^{ler}
7	--	-85.5	□ ^{ler}



Sec 1 - 1 : (T - sec) :

$$M_u 144.75 \text{ m.t} \quad \& \quad N_u = 0.0$$

$$B = \text{Largest of} \begin{cases} 16 t_g + b = 227 \text{ cm} \\ C_L \text{ to } C_L = 500 \text{ cm (spacing bet frames)} \\ \frac{0.7 L}{5} + b = 231 \text{ cm} \end{cases}$$

$$\therefore B = 227 \text{ cm}$$

$$\text{Using (C - J) curve } d = C_1 \sqrt{\frac{M_u}{f_{ca} B}} \rightarrow C_1 = 7.2$$

$$\therefore \frac{C}{d} < \frac{C}{d_{\min}} \rightarrow \text{take } \frac{C}{d} = \frac{C}{d_{\min}} \rightarrow J = 0.826$$

$$A_s = \frac{M_u}{f_y J d} = 42.33 \text{ cm}^2 \quad (10 \phi 25)$$

Sec 2 - 2 : (\square^{er} - sec) (35 * 120)

$$M_u = 18 \text{ m.t} \quad \& N_u = 0.0$$

Using (C - J) curve :

$$d = C_1 \sqrt{\frac{M_u}{f_{cu} b}} \rightarrow C_1 = 8.02$$

$$\therefore \frac{C}{d} < \frac{C}{d_{\min}} \rightarrow \text{use } \frac{C}{d_{\min}} = 0.125$$

$$J = 0.826$$

$$A_s = \frac{M_u}{f_y J d} = 5.26 \text{ cm}^2$$

$$1.3 A_{rq} = 6.84 \text{ cm}^2.$$

$A_{s\min}$ = The greater of

$$\frac{11}{f_y} b d = 12.3 \text{ cm}^2.$$

$$\therefore A_s < A_{s\min} \rightarrow \text{use } A_{s\min} \quad (4 \text{ \#} 25)$$

sec (3 - 3)

$$M_u = 60.00 \text{ m.t} \quad N_u = -13.44 \text{ ton}$$

$$\frac{0.04 f_{cu} A_c}{1000} = 42 \text{ tan} > N_u$$

\therefore Neglect N_u

Using (R - W) curve :

$$R = \frac{M_u}{f_{cu} b d^2} = 0.0518 \rightarrow w = 0.064$$

$$A_s = w b d \frac{f_{cu}}{f_y} = 17.9 \text{ cm}^2 \quad (7\text{ff}22)$$

sec (4 - 4) (35 * 120) (□^{ker} - sec)

$$M_u = 60 \text{ m.t}$$

$$N_u = + 13.42 \text{ ton}$$

$$e = \frac{M_u}{N_u} = 4.47 > \frac{(d - d')}{2} \Rightarrow \text{Large ecc}$$

$$e_s = e - t/2 + \text{cover} = 4.47 - \frac{1.2}{2} + 0.05 = 3.92 \text{ m}$$

$$M_{us} = N_u - e_s = 52.6 \text{ m.t}$$

Using (R - W) curve :

$$R = \frac{M_{us}}{f_{cu} b d^2} = 0.0455 \xrightarrow{\text{chart}} w = 0.057$$

$$A_s = w b d \frac{f_{cu}}{f_y} + \frac{N_u * 1000}{f_y / \gamma_s} = 20.22 \text{ cm}^2$$

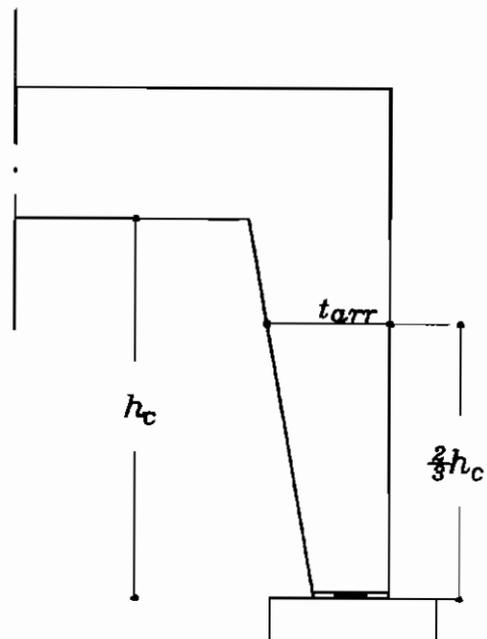
use (6ff25)

Sec (5-5) (35 * 120) column sec :

$$M_u = 42.00 \text{ m.t}$$

$$N_u = -79.5 \text{ ton}$$

Check additional moment due to buckling



In - plane Buckling:

$$H_o = 7 - \frac{1}{2} t_g = 6.40 \text{ m}$$

$$t_{avr} = 0.75 + [1.2 - 0.75] * \frac{2}{3} = 1.05 \text{ m}$$

* Top End Condition $t_g = t_c \rightarrow$ Case (1)

* bottom End condition hinged \rightarrow Case (3)

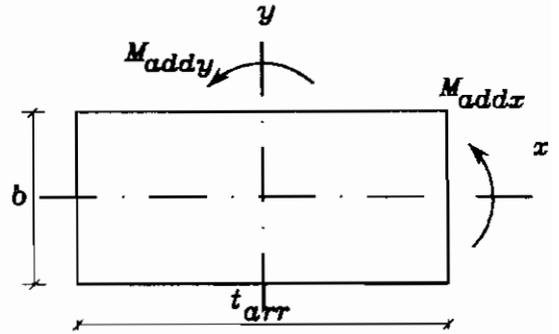
\therefore The frame is braced in both directions

\therefore From table (6- 9)E.C.P $\rightarrow K = 0.9$

$$H_e = 0.9 * 6.40 = 5.76 \text{ m}$$

$$\lambda = \frac{H_e}{t_{av}} = 5.49 < 15 \rightarrow \text{short column}$$

\therefore No add. Moments due to buckling.



Out of plane Buckling:

Assuming existence of wall beams at mid - height of frame connecting frames out of plane.

$$H_1 + H_2 = 7 - 0.6 - 0.6 = 5.8$$

$$\text{Let } H_1 = 3 \text{ m} \quad \& \quad H_2 = 2.8 \text{ m}$$

Top End condition $t_{beam} > b \rightarrow$ case (1).

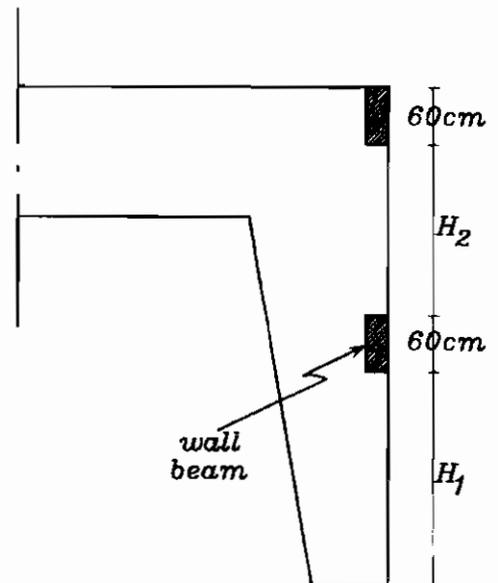
Bottom End Condition case (1).

From table (6 - 9) E . C . P $\rightarrow K = 0.75$

$$H_e = 0.75 * 3 = 2.25$$

$$\lambda = \frac{H_e}{b} = 6.43 < 15 \rightarrow \text{Short column}$$

\therefore No add. Moment due to buckling



Design of sec (5 - 5) :

$$M_u = 42 \text{ m.t}$$

$$N_u = - 79.5 \text{ ton .}$$

Assuming tension failure

$$e = \frac{M_u}{N_u} = 0.53$$

$$e_s = e + t/2 - \text{cover} = 1.08$$

$$M_{us} = N_u \cdot e_s = 85.86 \text{ m.t}$$

Use (R - W) cover :

$$R = 0.074 \quad \frac{\text{table}}{\alpha = 0.5} \quad \therefore w = 0.09$$

$$\therefore A_s = wbd \frac{f_{cu}}{f_y} - \frac{N_u * 1000}{f_y / \gamma_s} = - v_e$$

\therefore The failure is compression failure.

Using Interaction diagram (chart No . 25) ($\alpha = 0.6$)

$$K = \frac{P_u}{f_{cu}bt} = 0.076 \quad \& \quad K \cdot \frac{e}{t} = 0.033$$

$$\rho < 1.00 \quad \therefore \text{take } \rho = 1.00$$

$$\mu = \rho f_{cu} * 10^{-5} = 0.0025 \quad (\text{for } A_s \text{ only})$$

$$\mu_{\min} = 0.006 \rightarrow \text{short column} \quad (\text{for } A_s + A_s^-)$$

$$\mu_{\min} = \frac{0.006}{1.6} = 0.00375 \quad (\text{for } A_s \text{ only})$$

$$\therefore A_s = 0.00375 * bt = 15.75 \text{ cm}^2 \quad (5\text{ff}12)$$

$$A_s^- = \alpha A_s = 0.6 + 15.75 = 9.45 \text{ cm}^2 \quad (5\text{ff}22)$$

Sec (6 - 6) (35*75) column sec

$$N_u = -79.5 \text{ ton}$$

$$M_u = 0.0$$

Short column:

$$N_u * 1000 = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$A_{sc} = -V_w \rightarrow \therefore \text{use } A_{s \text{ min}}$$

$$A_{s \text{ min}} = 0.006 bt = 15.75 \text{ cm}^2 \quad (6\text{ff}22)$$

$$A_s = A_s^- = \quad (3\text{ff}22)$$

sec (7 - 7) (35 * 70) Link member

$$N_u = - 85.8 \text{ ton}$$

$$M_u = 0.0$$

Check moment due to buckling

In - Plane Buckling :

Top End condition hinged case (3)

Bottom End condition hinged case (3)

\therefore from table (6 - 9) $\rightarrow K = 1$

$$H_o = 7 - \frac{1}{2} t_g = 6.40 \text{ m}$$

$$H_e = K.H_o = 6.40 \text{ m}$$

$$\lambda = \frac{H_e}{t} = \frac{6.40}{0.7} = 9.14 < 15$$

∴ Short Column in t – direction (No – add . moment)

out of plane Buckling :

Assume that a wall beam 25 * 60 is used at mid height of link .

So buckling out of plane will be safe and No additional moment (as in sec 5 – 5)

Design as short column:

$$N_u * 1000 = 0.35 f_{cu} A_c + 0.67 f_y A_{sc}$$

$$A_{sc} = - v_e$$

$$\therefore \text{use } A_{s \min} = 0.006 A_c = 14.7 \text{ cm}^2 \quad (14\phi 12)$$

Check of shear:

$$Q_u = 55.50 \text{ ton}$$

Critical section at d/2 from the link face

$$Q_{u \text{ design}} = Q_u - w_u \left[\frac{\text{Link dim}}{2} + \frac{d}{2} \right] = 55.5 - 7.5 \left[\frac{0.7 + 1.15}{2} \right] = 48.56 \text{ t}$$

$$q_u = \frac{Q_{u \text{ design}}}{bd} = 12.065 \text{ kg/cm}^2$$

$$q_{cu} = 0.75 \sqrt{\frac{f_{cu}}{\gamma_c}} = 9.68 \text{ kg/cm}^2$$

$$q_{cu \text{ max}} = 2.2 \sqrt{\frac{f_{cu}}{\gamma_c}} = 28.4 > 30 \text{ kg/cm}^2$$

$$\therefore q_{cu} < q_u < q_{cu \text{ max}}$$

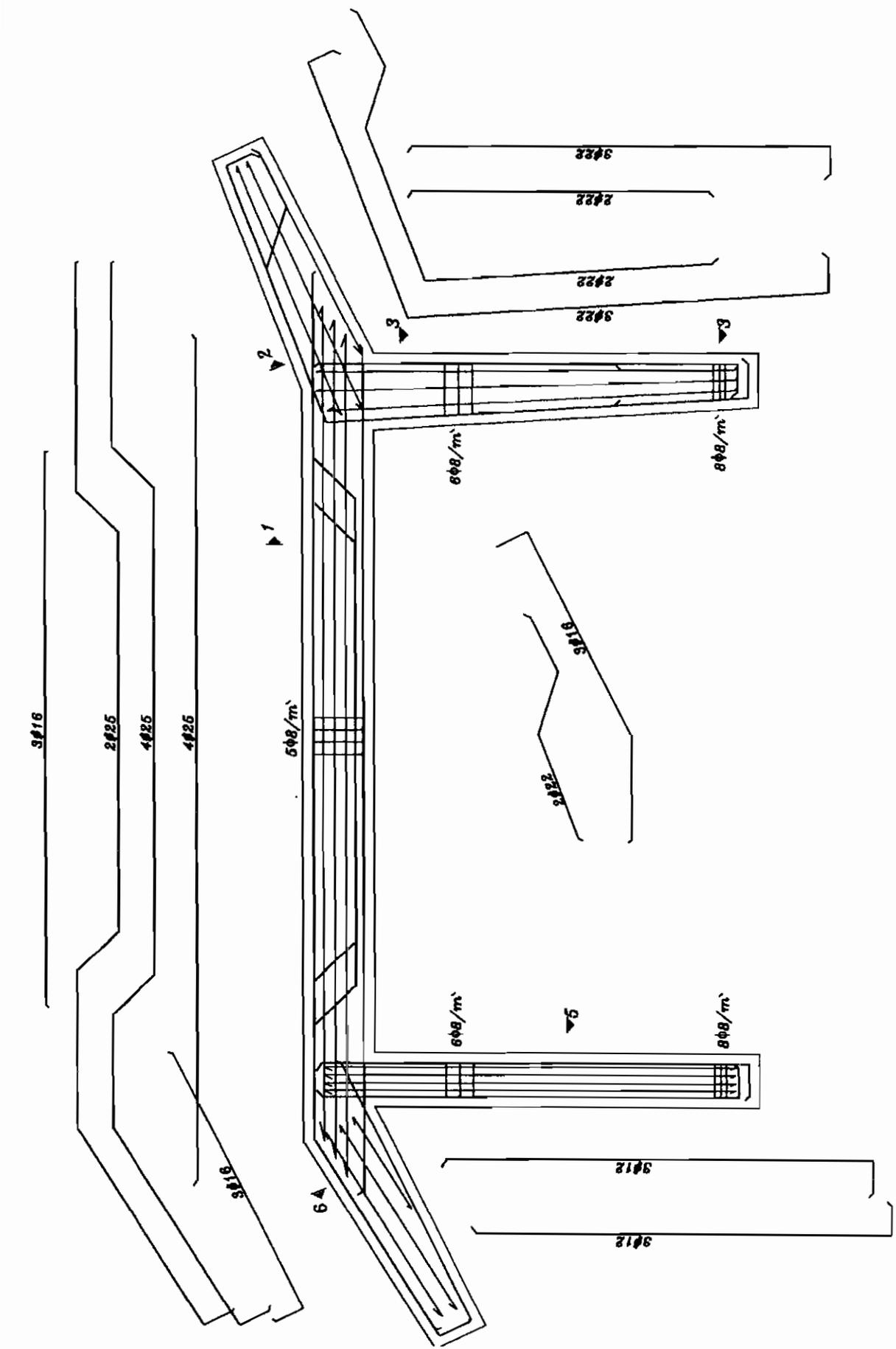
∴ shear reinforcement is needed .

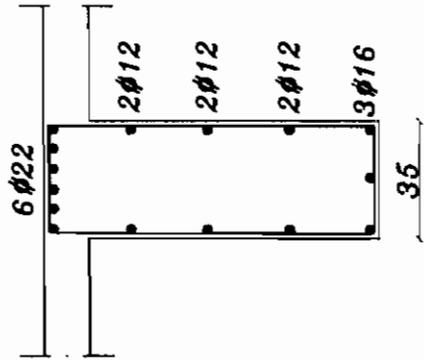
$$q_{su} = q_u - 0.5 q_{cu} = 7.22 \text{ kg/cm}^2 .$$

by using VL stirrups only

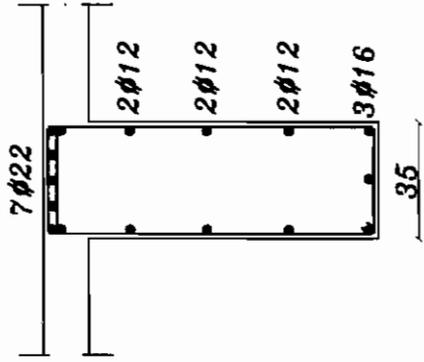
$$A_{st} = \frac{q_{su} b_s}{f_y st / \gamma_s} = \frac{7.22 \times 35 \times 10}{2800 / 1.15} = 1.038 \text{ cm}^2$$

use (10ϕ10/m⁻)

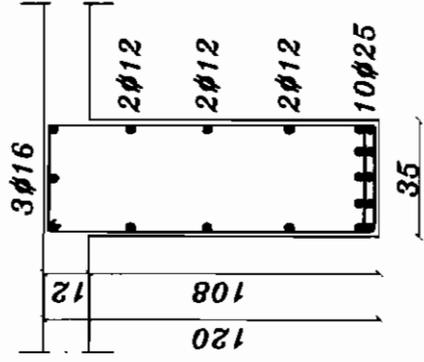




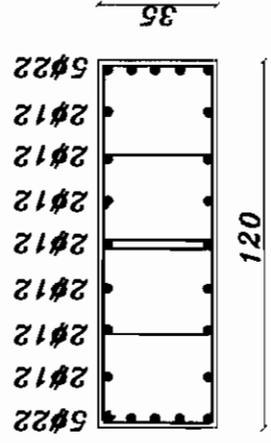
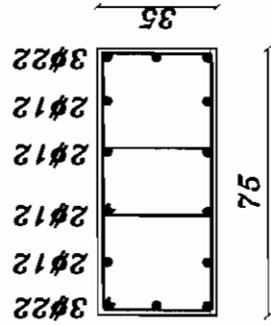
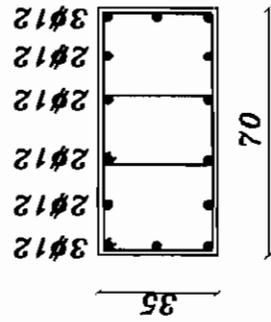
Sec. (6)

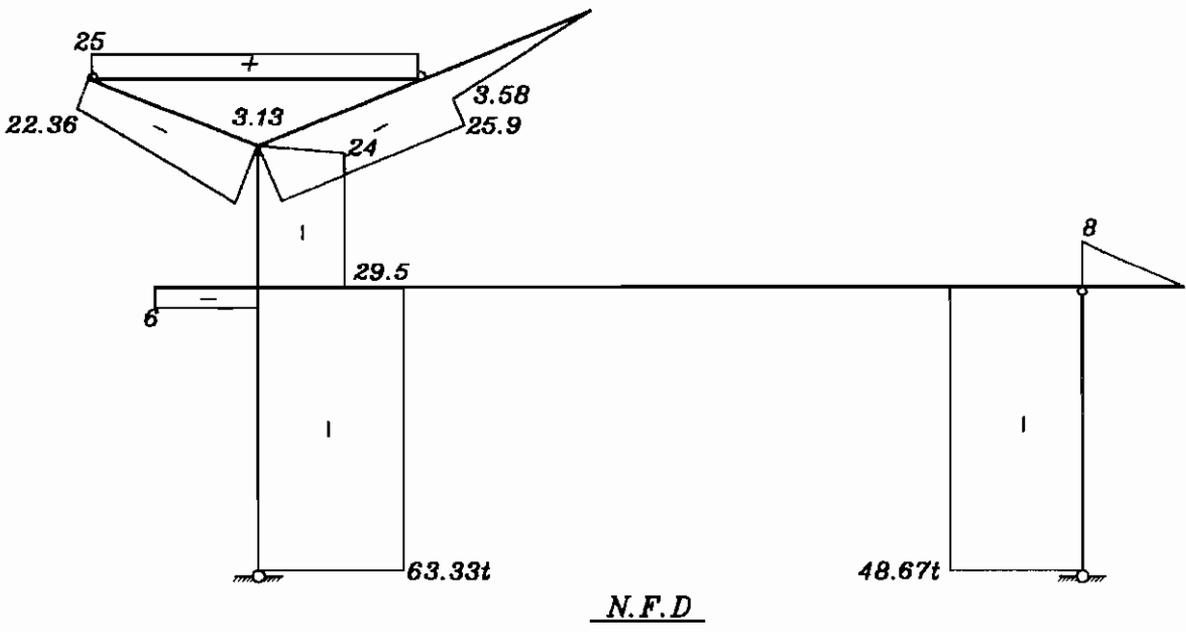
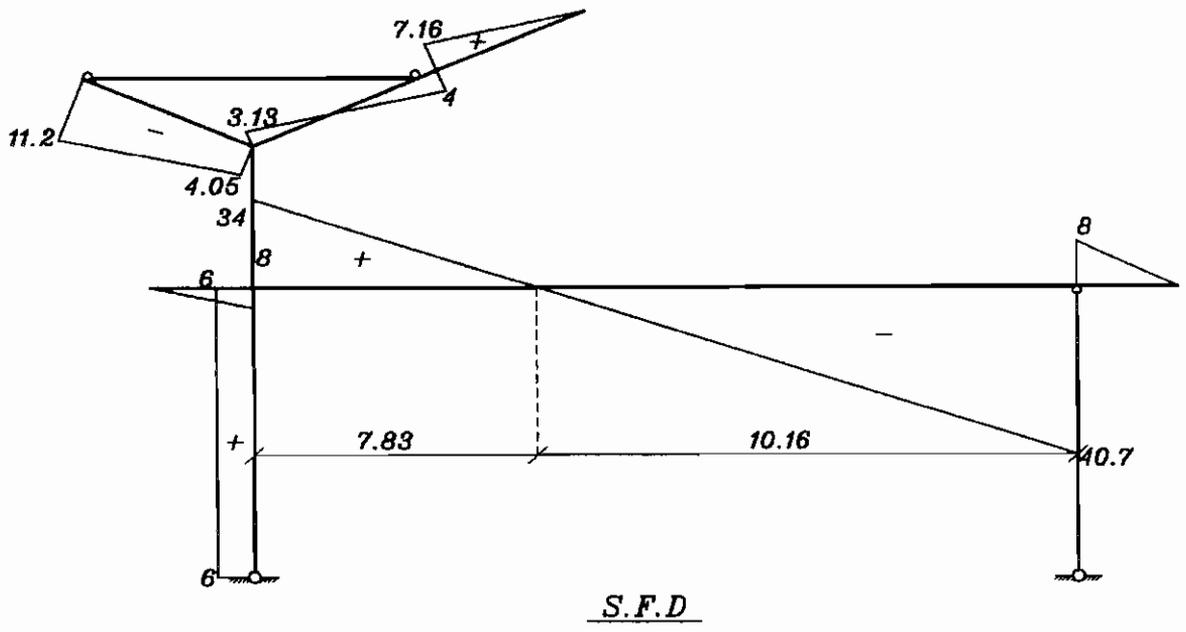


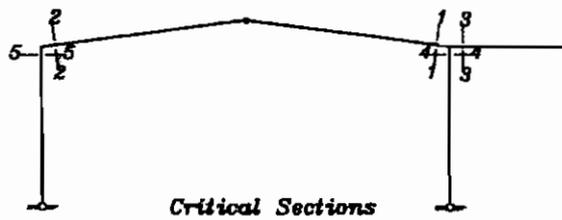
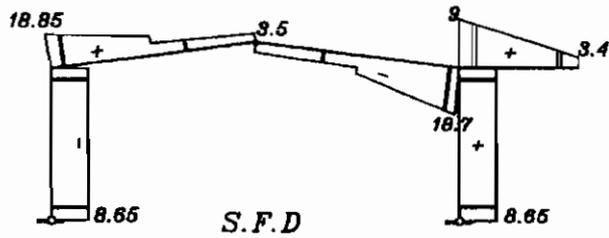
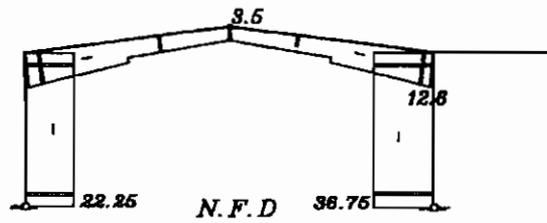
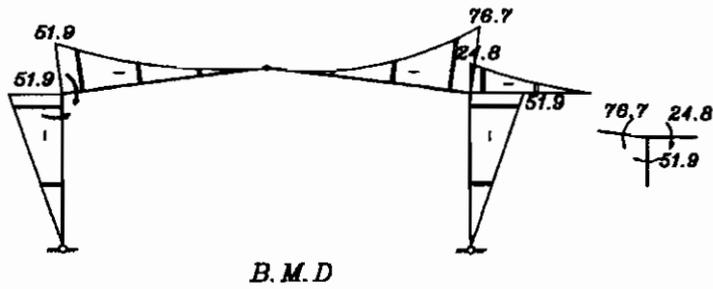
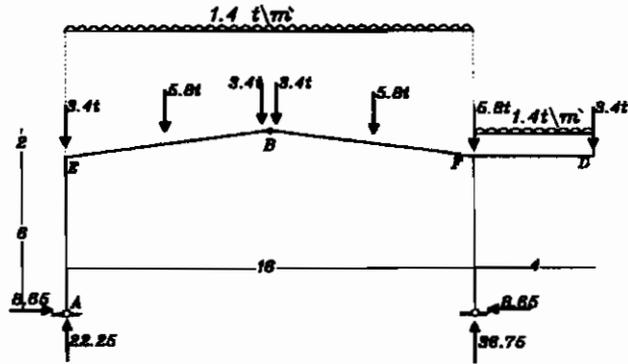
Sec. (2)



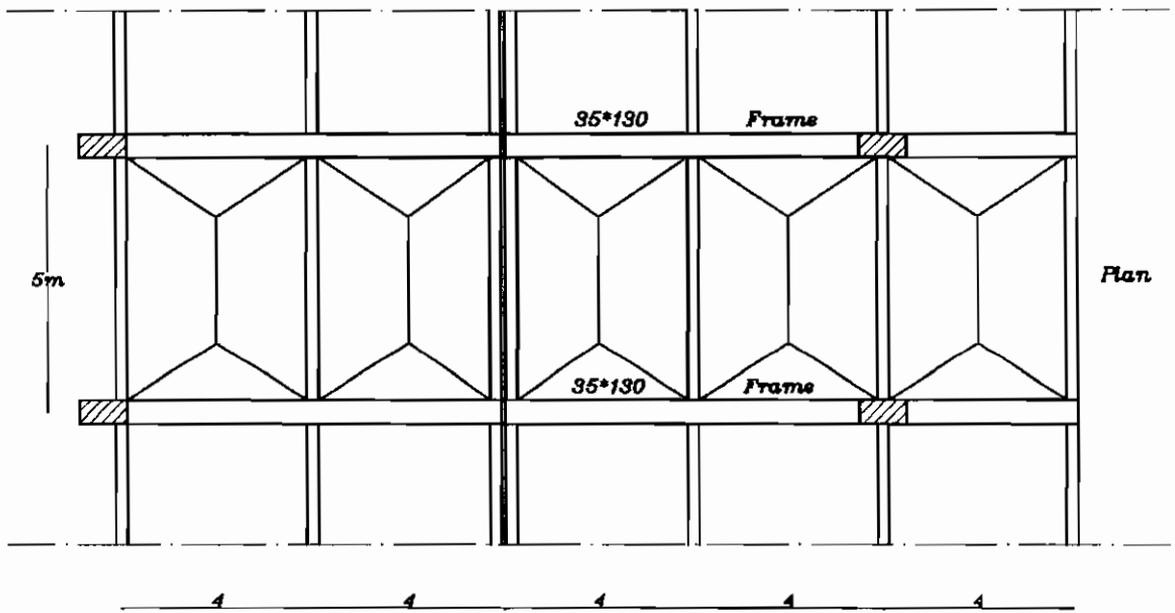
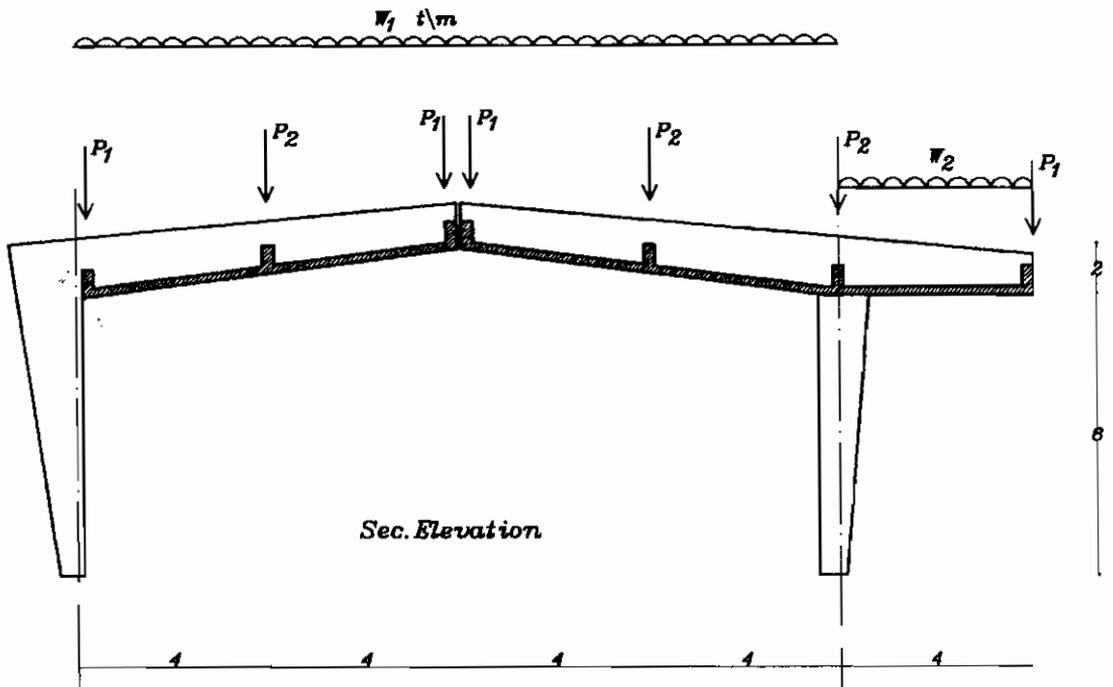
Sec. (1)

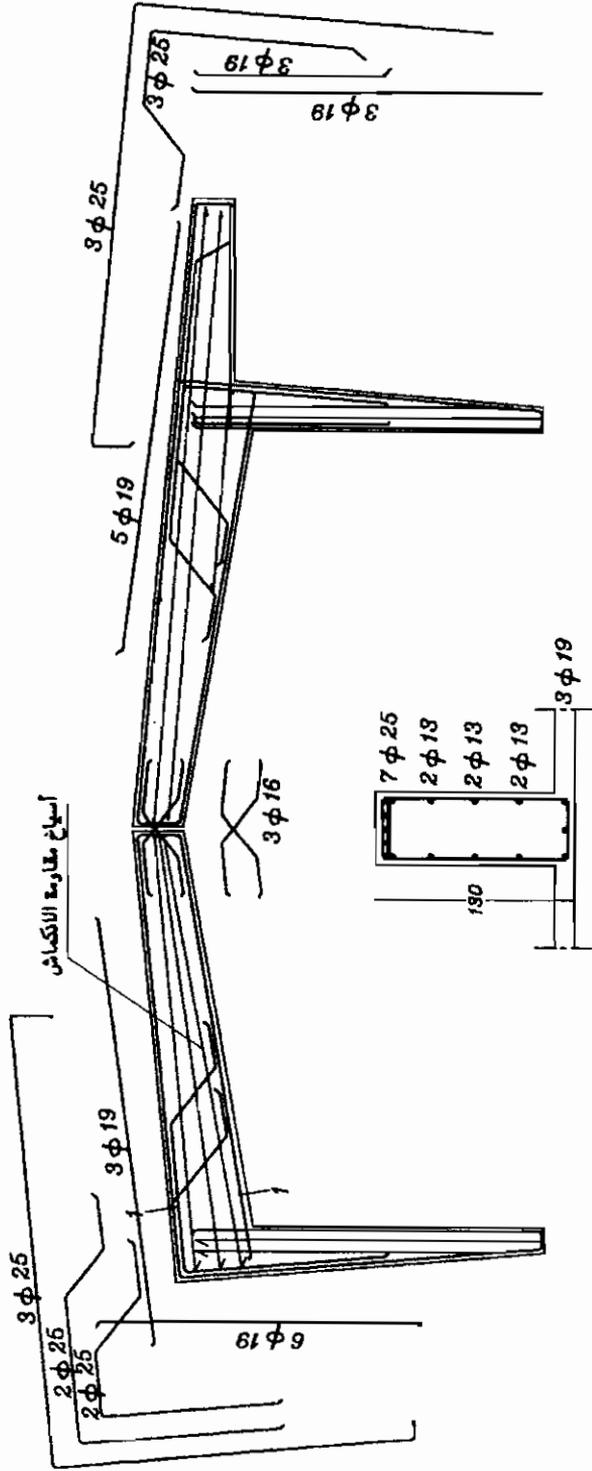
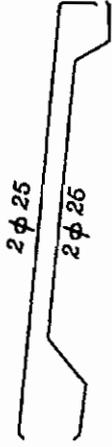
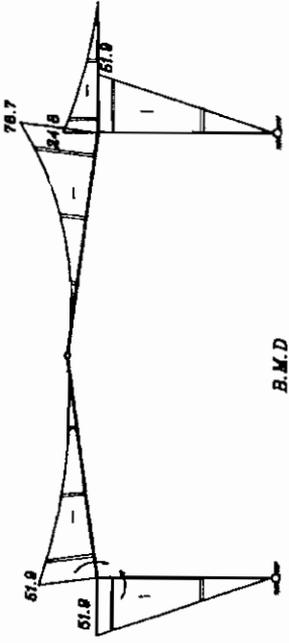




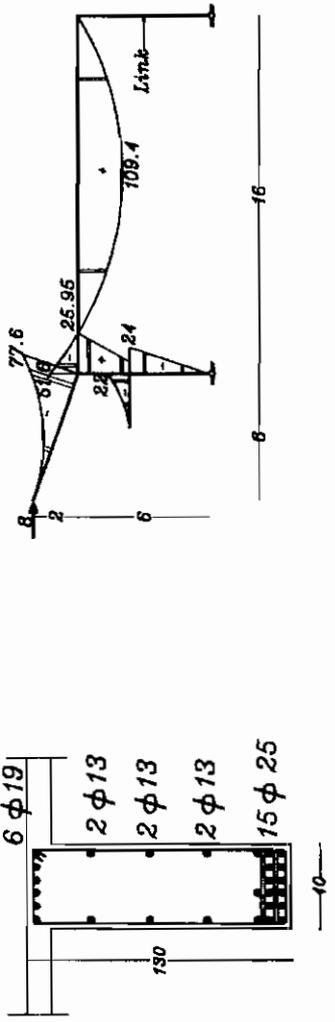


3 - hinged Frame

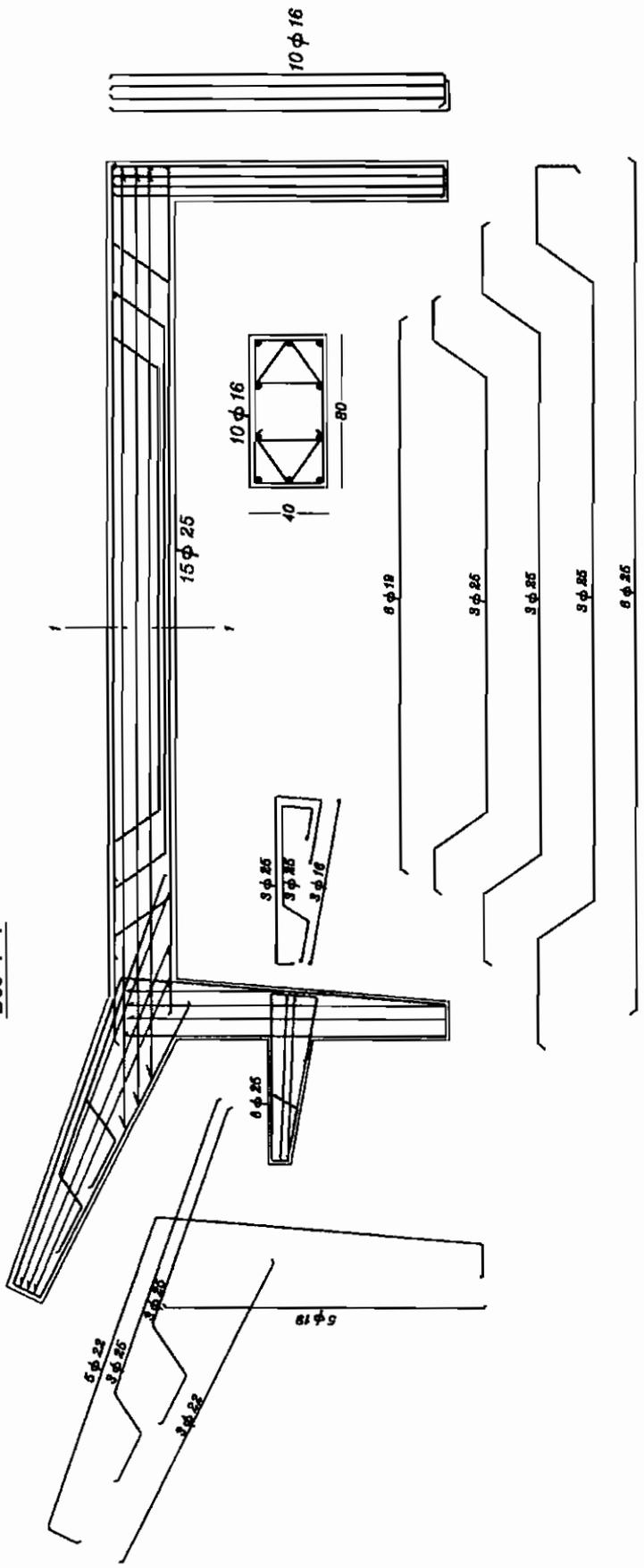


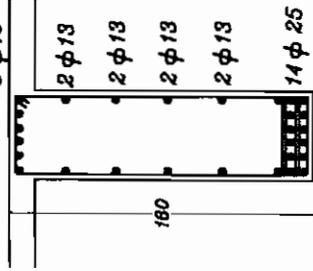
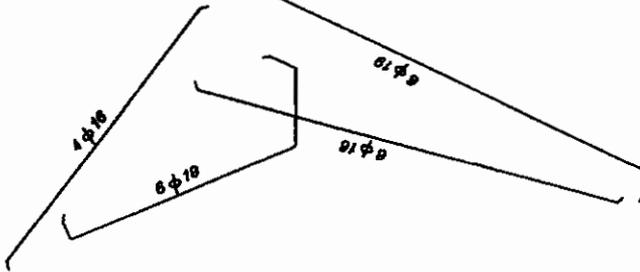
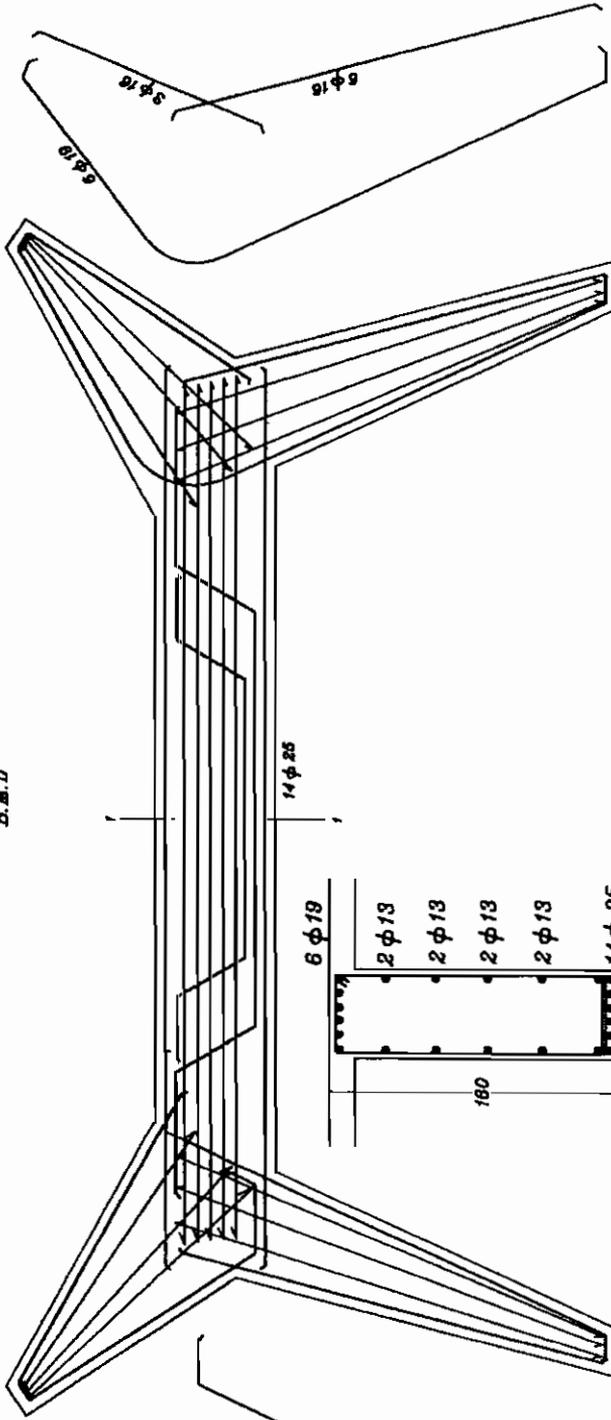
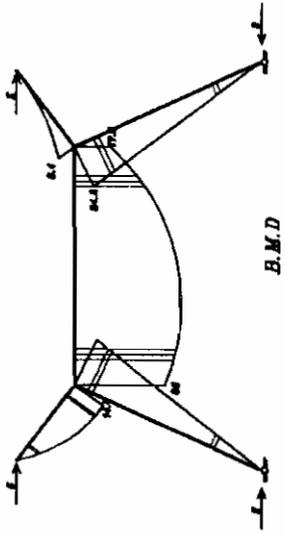


Sec 1-1

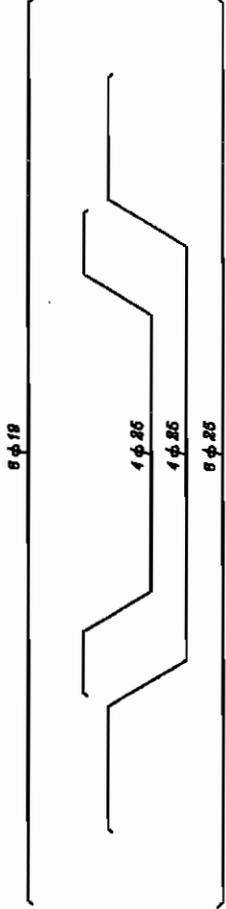


Sec 1-1

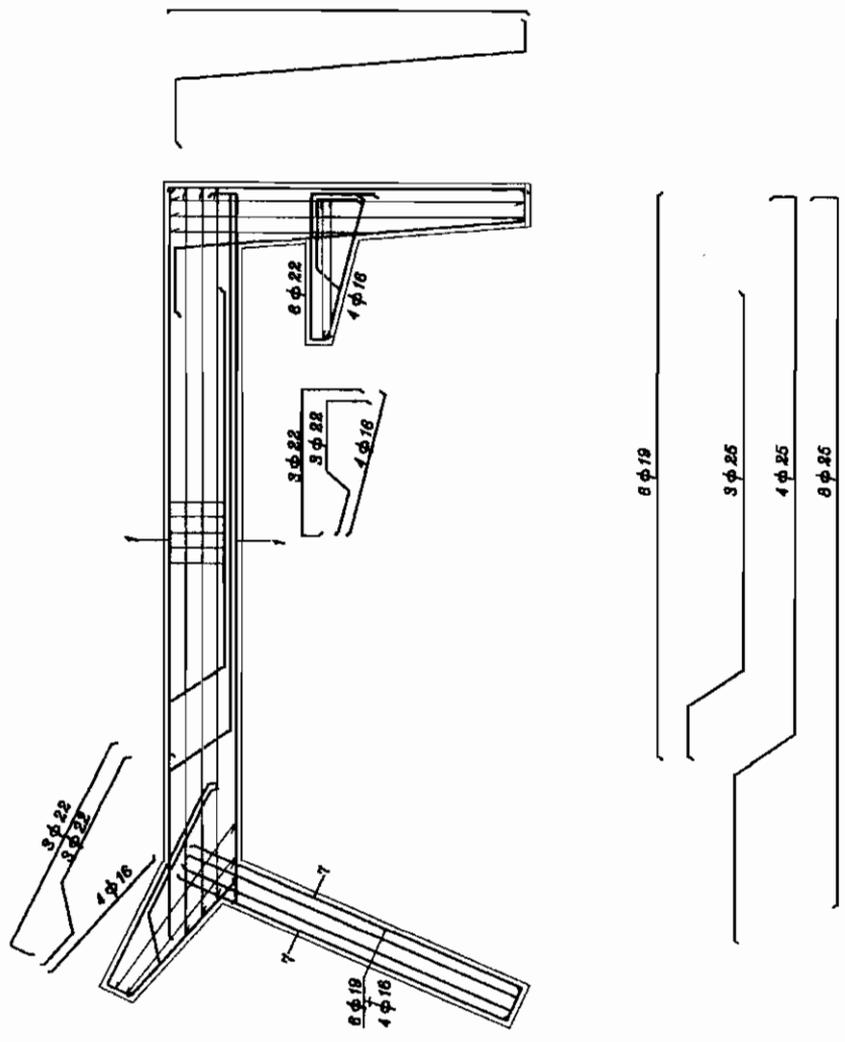
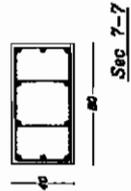
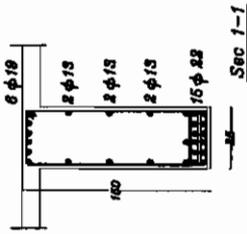
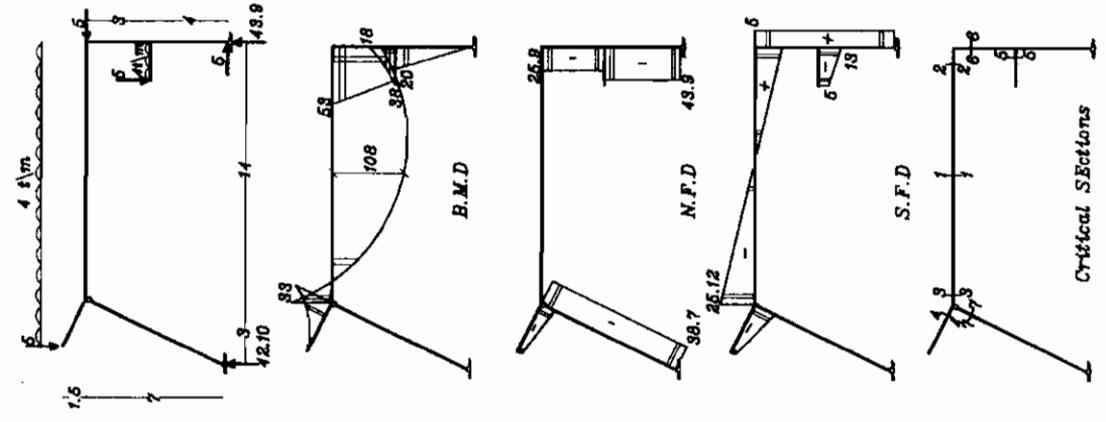




40 ——— Sec 1-1



مثال مطول



مثال محلول

