Term Revision

January 2012

R. Concrete Bridges

راجع سريعا ملخص ما بعد الميدترم ثم :

١- الخرسانة سابقة الإجهاد

٢- مسألتين التمرين فى الـ Main Girder + مسألتين الامتحانات

٣- مسألتين التمرين + مسألة الامتحان فى الـ Cross Girder

٤- مذكره المراجعه لما قبل الميدترم

Design of Stiff X.G.

طريقة السؤال فى الامتحان :

The slab and Girder Bridge shown In figure (1), is simply supported with span L = 22 m. and with clear road width = 7.0 m. The Bridge consists of 4 Main Girders spaced at 2.5 m, while the cross Girders are spaced at 5.50 m. the breadth of M.G = 0.5m, the breath of X.G. = 0.25m

It is required to give statical calculation and design for the stiff cross Girder.

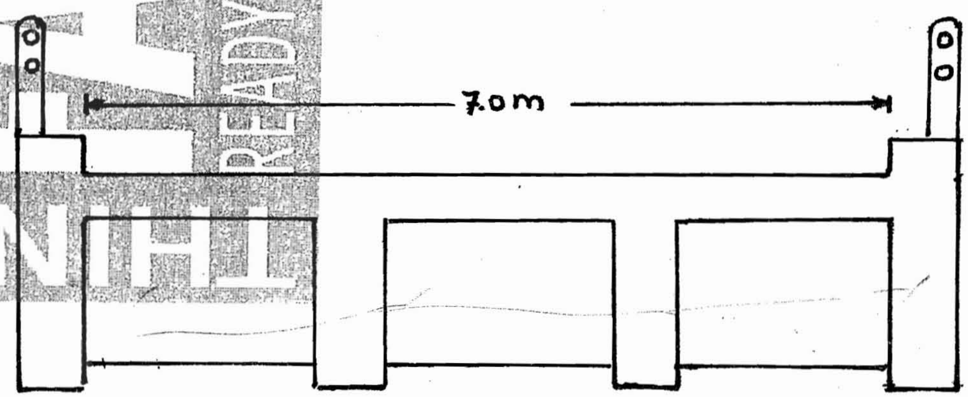


Figure (1)

يجب تحديد البيانات المعطاه من رأس السؤال :

Span of M.G.(L) = Span of Bridge = 22 m.

Spacing of M.G. (a) = 2.5 m.

Spacing of X.G. (b) = 5.50 m.

the breadth of M.G (b_{MG}) = 0.50 m.

the breadth of X.G (b_{XG}) = 0.25 m.

covering = 3 kN/m^2 (If not given)

Dead load:

ثم نحسب الأحمال على (X.G.) :

$$\therefore g_{XG} = (t_s * \gamma_{RC} + covering) * b + (h_{XG} - t_s) * b_{XG} * \gamma_{RC} = \checkmark \quad kN/m'$$

$$g_{SW} = (t_{SW} * \gamma_{RC} + covering) * b = \checkmark \quad kN/m'$$

$$P_{HR} = 2 * b = \checkmark \quad kN$$

يجب تحديد سمك البلاطه (t_s) وسمك الرصيف (t_{sw})

t_s

* لو تم تصميم slabs ، فيكون سمك البلاطة محسوب مسبقاً
* يمكن أن يكون سمك البلاطة معطى مباشرة :
. مثال : (slab thickness = 0.25 m)
* لو لم يكن معطى ، يتم حساب سمك البلاطة كالتالي :

$t_s = \frac{a}{15} = \checkmark$ mm

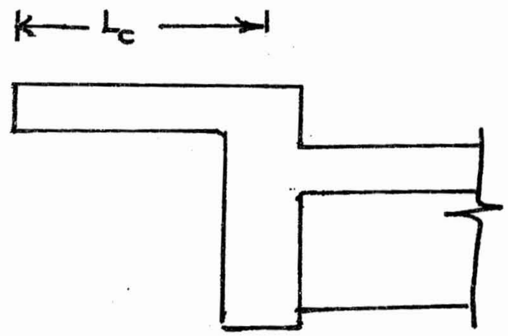
ويتم تقريب الرقم إلى مضاعفات 20 مم للأكبر

$t_s = \frac{a}{15}$

$t_{sw} = \frac{L_c}{10}$

0.2

t_{sw}



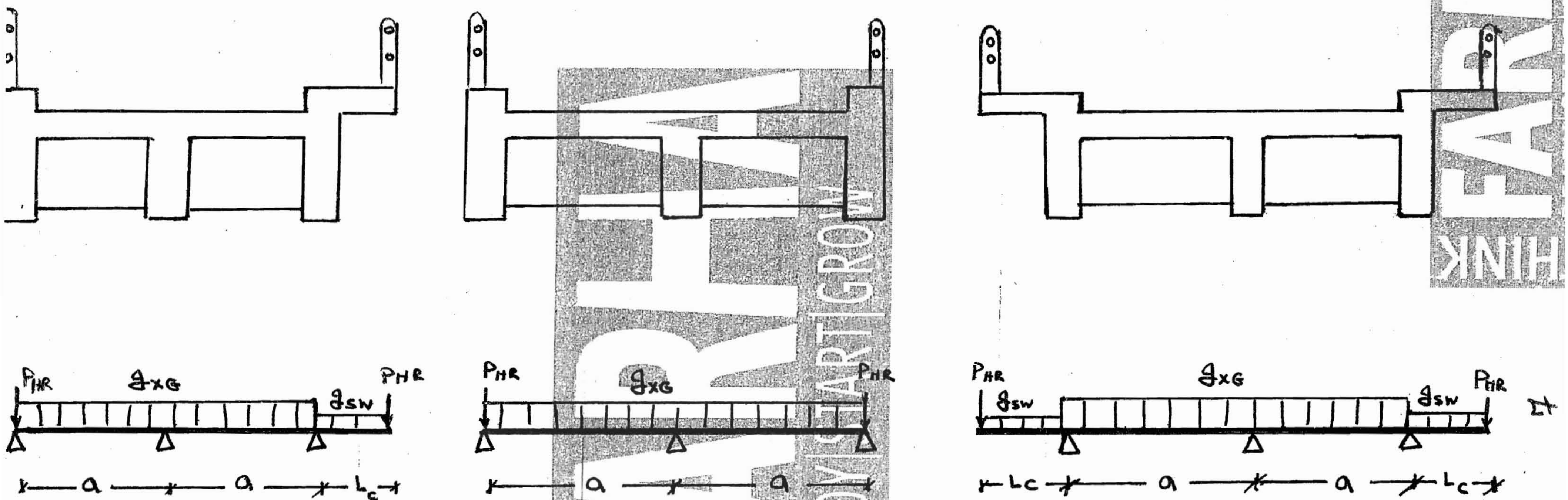
* يتم فرض سمك بلاطة الرصيف :

$t_{sw} = \frac{L_c}{10} = \checkmark$ mm

* يمكن أن يكون سمك الرصيف معطى :

side walk slab thickness = 0.20 m

ثم نحدد النظام الانشائى للكمرة :

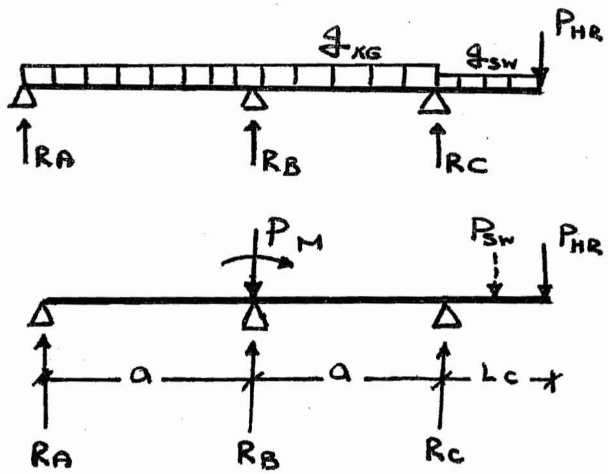


ثم نحسب رد الفعل على كل الكمرات MG (الركائز)

• إذا كانت الأحمال متماثلة

$$\therefore \quad R = \frac{\Sigma \text{ Loads}}{\text{no. of MG.}} = \checkmark \ KN$$

• لو الأحمال غير متماثلـه , يتم حساب رد الفعل على كل ركيزة من القانون :



$$P = g_{xG} * 2a + g_{sw} * L_c$$

$$M = P_{HR} * r + P_{sw} * rr$$

ثم نحسب رد الفعل عند كل ركيزة

$$\therefore R = \frac{P}{n} \pm \frac{M}{\Sigma r^2} * r$$

where : n = number of supports (No. of M.G.)

r = بعد كل ركيزة عن c.G الركائز

$$R_A = \frac{P}{n} - \frac{M}{\Sigma r^2} * \cancel{r}\ a$$

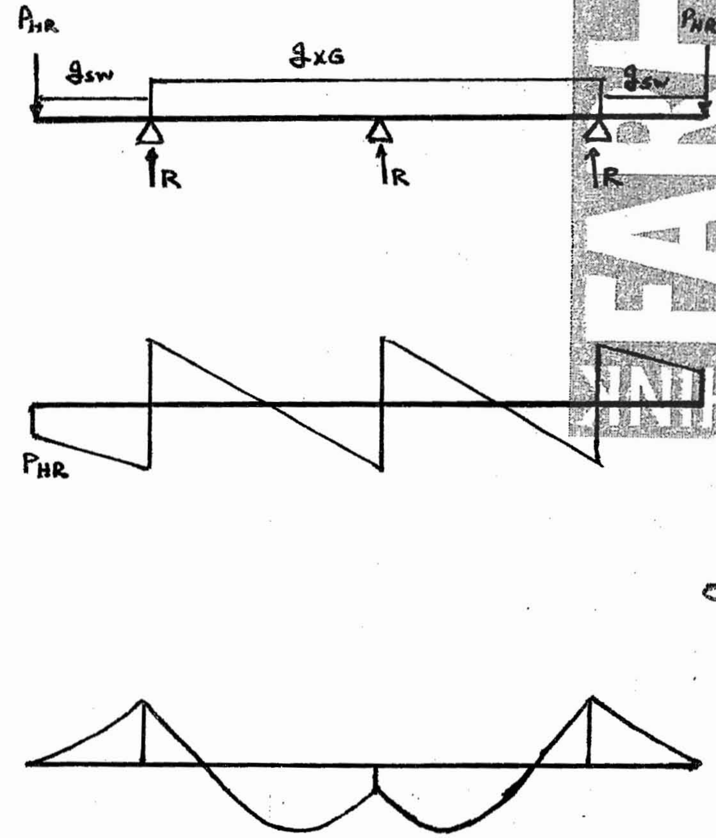
$$R_B = \frac{P}{n} \pm \frac{M}{\Sigma r^2} * \cancel{r}\ \text{Zero}$$

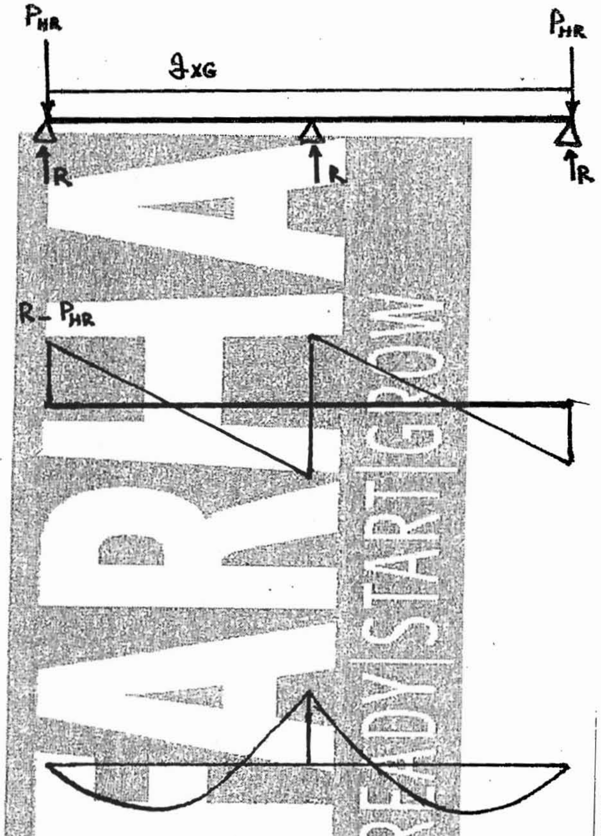
$$R_C = \frac{P}{n} + \frac{M}{\Sigma r^2} * \cancel{r}\ a$$

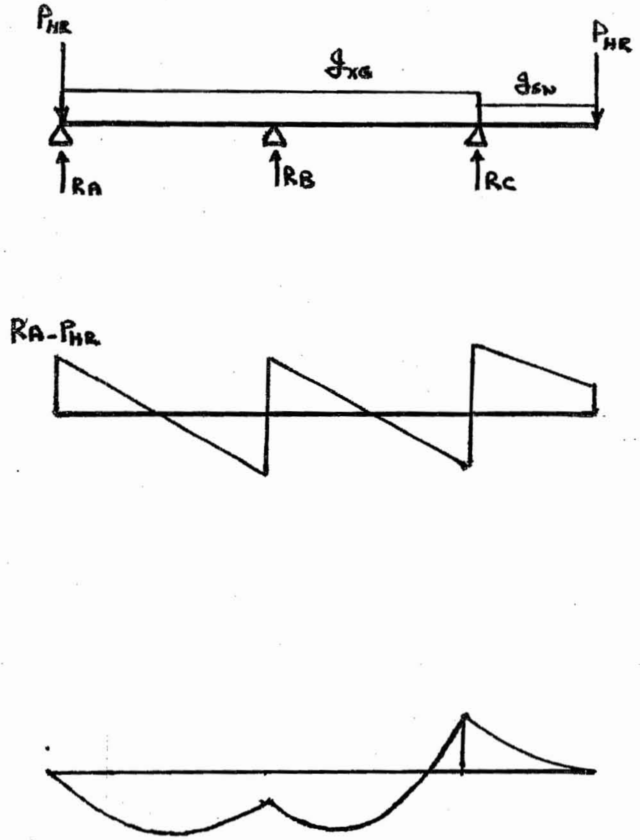
• العزم يزود R_C • ويقلل من R_A

$$\Sigma r^2 = r_1^2 + r_2^2 = a^2 + a^2 = 2a^2$$

ثم يتم رسم شكل القص :







ويتم حساب قيمه العزوم عند أى قطاع عن طريق مساحه شكل القص كما فى الصفحة التالية ؛
يجب حساب مكان zero_shear لحساب مكان أقصى عزم .

ثم يتم حساب قيم العزوم من مساحة القص كالتالى:

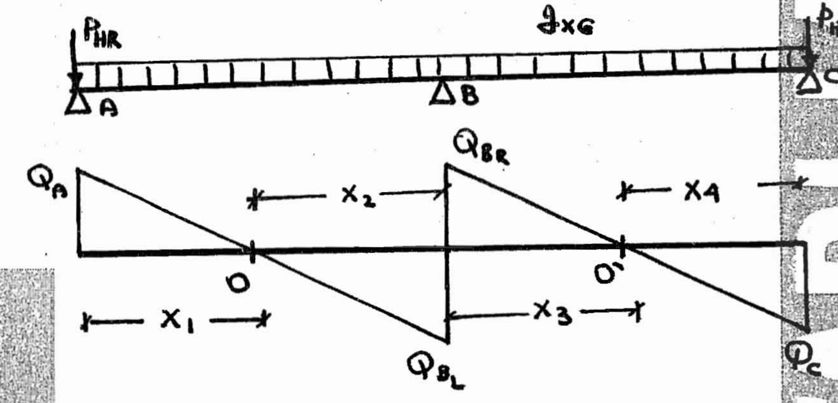
$M_A = 0$

$M_O = \cancel{M_A}^{0} + 0.5 * X_1 * Q_A$

$M_B = M_O + 0.5 * X_2 * Q_{B_L}$ (→ -ve)

$M_{O'} = M_B + 0.5 * X_3 * Q_{B_R}$

$M_C = M_{O'} + 0.5 * X_4 * Q_C = 0$ (→ -ve)

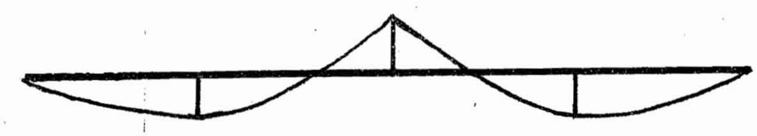


$X_1 = \frac{Q_A}{g \times G}$

$X_2 = \frac{Q_{B_L}}{g \times G}$

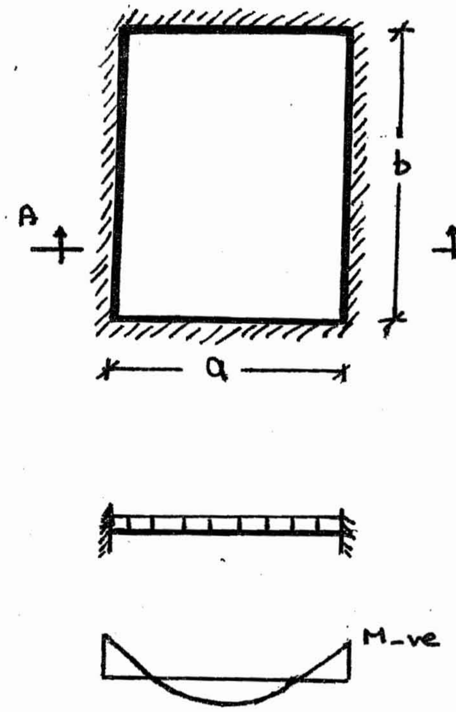
$X_3 = \frac{Q_{B_R}}{g \times G}$

$X_4 = \frac{Q_C}{g \times G}$



ثم يتم حساب العزوم الإضافيه المنقولة من البلاطه إلى X.G كالتالى :

يجب حل البلاطة أولاً حتى مرحلـه العزوم (نحسب العزوم فى الاتجاه القصير)



$r = \frac{b'}{a'} = \frac{0.76\ b}{0.76\ a}$, $g = t_s * \gamma_{RC} + cov$

$r \geq 2$

$\therefore M_{-ve} = \frac{g * a^2}{12}$

$r < 2$

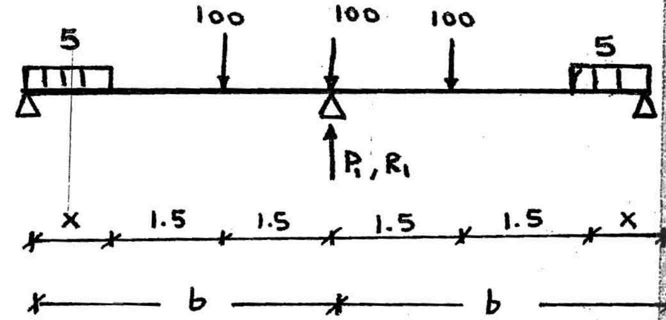
$\alpha = \frac{r^4}{1+r^4}$

$\therefore M_{-ve} = \frac{\alpha g a^2}{12}$

$M_{add} = M_{-ve} * b$ ⟵ عزم موجب يضاف إلى العزوم فى X.G.

Live Load on X.G.

ثم يتم حساب رد فعل البلاطة على X.G.



$$R_1 = 100 + 100 * \frac{b-1.5}{b} * 2$$

$$P_1 = (5 * X) * \frac{X/2}{b} * 2$$

$$R_2 = \frac{R_1}{2}$$

$$P_2 = \frac{3}{5} * P_1$$

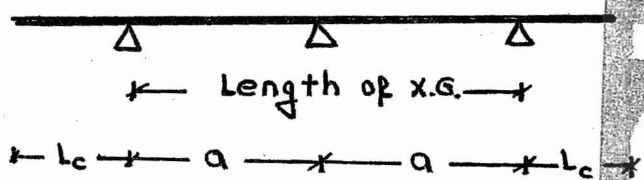
$$P_3 = 3 * b$$

ثم نحسب معامل التأثير الديناميكى I للحمل

$$I = 0.40 - 0.008\ L$$

حيث L هى الأصغر من

1 طول X.G. (Σa)



2 طول التحميل فى الاتجاه العمودى $(2b)$

ثم نحسب :

$R_1(1+I) =$ ✓

$P_1(1+I) =$ ✓

أحمال الحارة الرئيسية تضرب فى $(1+I)$ فقط.

ثم يتم تحميل خطوط تأثير .X.G المعطاه فى الامتحان .. (غالباً فى الامتحان يعطى خط تأثير واحد للقص ، و خطين تأثير للعزوم إحداهما موجب والآخر سالب) .

القاعدة العامة لتحميل خطوط التأثير

- بالنسبه للقص

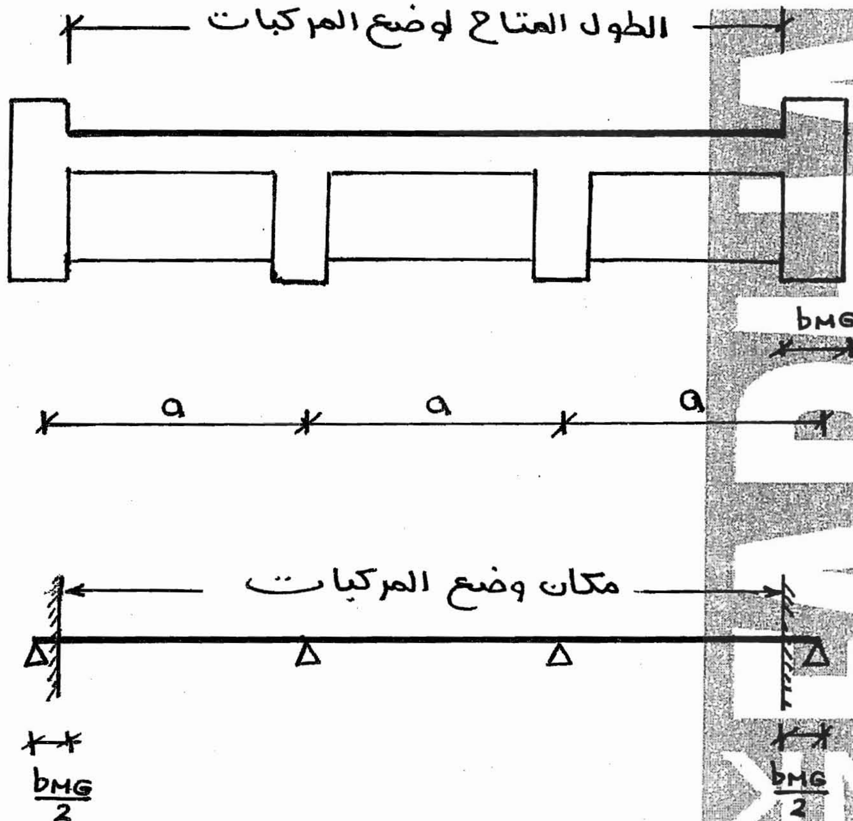
التحميل فى .L.L يتبع إشارة .D.L عند نفس القطاع لكى تعطى أقصى عزم عند كل قطاع .

- بالنسبه للعزوم

التحميل فى L.L يكون عند منتصف البحر موجب (أقصى عزم موجب عند منتصف البحر) وعند الركائز سالب (أقصى عزم سالب عند الركائز) .

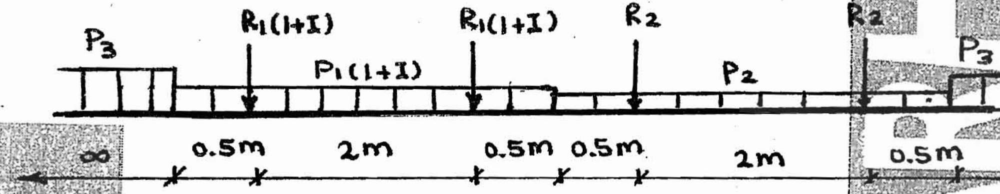
طريقة تحميل المساحة المرغوبة فى المنحنى

يجب تحديد المسافة المتاحة لوضع المركبات

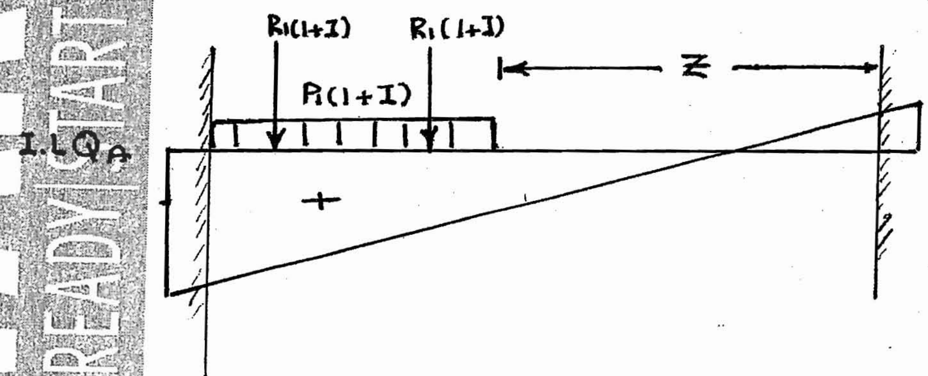


ثم يتم تحميل خطوط التأثير كالتالى :

طريقه تحميل خطوط التأثيـر



١) يتم وضع أقصى حمل عند أقصى قيمـه للدالـة مع مراعاة الحدود المسموح بـها فى وضع المركبات



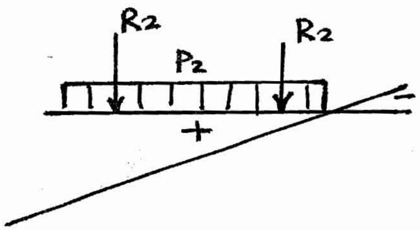
٢) يجب وضع العجلتين $R_1(1+I)$ معاً ؛ ثم تقيس المسافـة (Z)

- إذا كانت Z أقل من 3 متر؛ فلا يصلح وضع المركبة الثانيـة ويوضع الحمل الموزع P_3 فى بقيـه المسافة المراد تحميلها .

- إذا كانت المسافـة Z أكبر من أو تساوى 3 متر فيجب معرفـة إذا كان وجود المركبـة مفيد أم لا .

هناك ٣ إحتمالات

A) العجلتين يقعوا خلال المساحه بالاشاره المطلوبه



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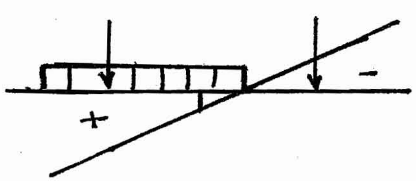
B) أحد العجلتين موجب و الأخرى سالب ؛ لكن المحصلة فى الموجب (لو كان مطلوب تحميل المساحة الموجبة)



يتم أخذ تأثير العجلتين معاً ؛ مع أخذ الحمل الموزع حتى نهايه المساحة الموجبة .

أما إذا كانت محصلـه العجلتين فى السالب فيتم إلغاء العجلتين ووضع (P_3)

14

ثم يتم تحميل جميع خطوط التأثير المعطاه، ويتم التصميم بعد ذلك، فبعد تجميع العزوم والقص من DL و LL يجب الحصول على التالى :

$Q_{max} = ✓$

$M_{Max +ve} = ✓$

$M_{Max -ve} = ✓$

غالباً يكون العزم الأكبر هو العزم الموجب لذلك يتم التصميم (T-sec)

نحسب العرض الفعال لشفه الضغط

$B \rightarrow b_{xG} + 16\, t_s$

$B \rightarrow$ Spacing of X.G.

ثم نحسب بعد N.A التقريبى (X)

$$X = 0.44 \sqrt{\frac{M_{+ve}}{B}}$$

• إذا كان $X < t_s$

$$\therefore d = k_1' \sqrt{\frac{M_{+ve}}{B}}$$

(k_1' ← T-sec)

• إذا كان $x > t_s$

نحسب العرض المكافىء (لقطاع مستطيل)

$$\therefore B_e = b_{xG} + (B - b_{xG}) * \frac{t_s}{x}\left(2 - \frac{t_s}{x}\right)$$

$$\therefore d = k_1' \sqrt{\frac{M_{+ve}}{B_e}}$$

(k_1' ← T-sec)

$$\therefore h = d + d' = ✓ \not< h_{xG}$$

(d' = 80 mm) (h_{xG} : $\frac{span}{10} + 0.15$)

في الامتحان لو مفيش وقت ممكن نبتدى تصميم XG من هذه المرحلة

$$\therefore d = h_{xG} - d' = ✓$$

$$\therefore A_{s+ve} = \frac{M_{+ve}}{k_2' \times d} = ✓ \quad (✓ \varnothing 18)$$

(k_2' ← T-sec)

$$A_{s-ve} = \frac{M_{-ve}}{k_2' \times d} = ✓ \quad (✓ \varnothing 12)$$

(k_2' ← T-sec)

$$A_{sh} = 0.08\, A_{s+ve} = ✓$$

ثم نقوم بعمل check على القص فى الكمرة

<u>check of shear:</u>

$Q_{max} = \checkmark$

$q = \frac{Q_{max}}{b_{xG} * d_{xG}} = \checkmark$

$\overset{0.7}{q_c} < q < \overset{2.1}{q_2}$

غالباً تقع قيمه q بين القيمتين q_c , q_2

$\therefore q_{st} = q - \frac{q_c}{2}$

ثم نفرض الكانات $2\phi10$

$\therefore q_{st} = \frac{\overset{2}{n} \overset{79}{A_{st}} \overset{140}{f_s}}{b_{xG} \times s}$

ونحسب (S)

وتقرب S للأصغر (مضاعفات 25 مم)

$75 < S < 200$ mm

Use 2br. St. $\phi 10$ @ S

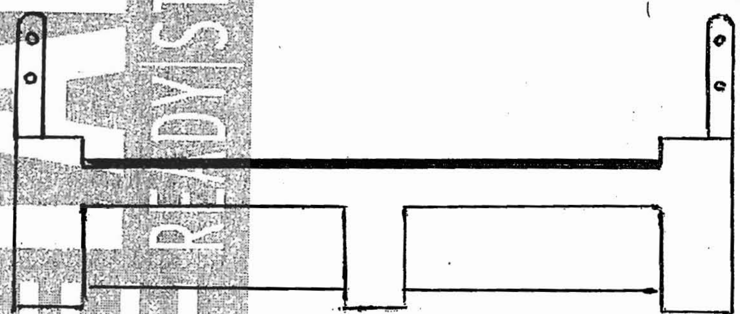
أما بالنسبة لحديد الانكماش ، يؤخذ $2\phi10$ على مسافات لاتزيد عن 300 مم

Design of Main girder

طريقه السؤال فى الامتحان :

The slab and girder bridge shown in figure (1), is simply supported with span L = 20 m, and with clear road width = 7m. The bridge consists of 3 Main Girders. The spacing of X.G. = 5.50 m. The breadth of M.G. = 0.50 m.

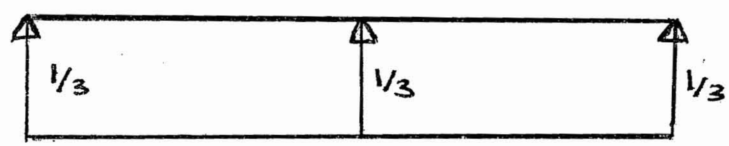
It is required to give full statical calculation and design for an Intermediate M.G.



Calculate B.M. at 4 points in MID-span and draw moment of resistance diagram.

Use both bent-up bars & stirrups for shear Rft.

Draw half Long. sec. & Cross sec.



I.L. RB

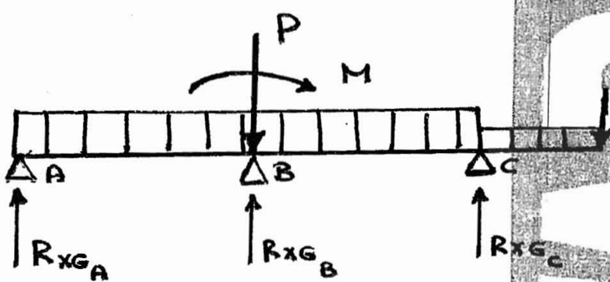
يجب استخراج جميع البيانات من رأس السؤال و إيجاد الأحمال على .X.G (انظر شرح .X.G)

- إذا كان المطلوب تصميم M.G داخلية فيجب أخذ RxG الداخلى ، و إذا كان المطلوب تصميم M.G. خارجية فيجب أخذ RxG الخارجى .

- عند تماثل الأحمال ، تكون جميع ردود أفعال .X.G متساوية .

$$R_{XG} = \frac{\Sigma Loads}{no.\ of\ MG^s}$$

- أما عندما تكون الأحمال غير متماثلة ، فيجب حساب مجموع الأحمال (P) ، و العزم حول مركز الركائز (M) و إيجاد ردود الأفعال على $M.G^s$



- عند ما يكون مطلوب تصميم .M.G طرفية
  نأخذ الأكبر من R_A أو R_C

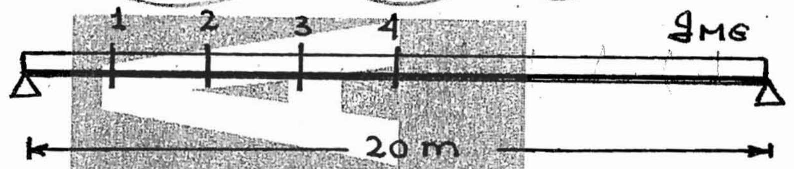
- عندما يكون مطلوب تصميم .M.G داخلية
  فنأخذ R_B

لاحظ فى حالة عدد ركائز (MG) فردى ، و المطلوب تصميم M.G داخليه ، لا داعى لحساب M
لأن : $R_{XG_B} = \frac{P}{3}$

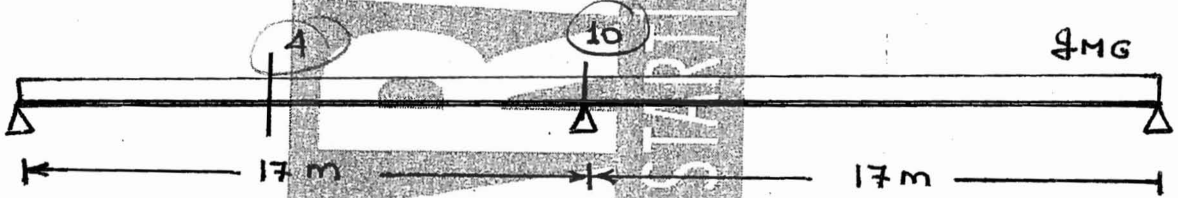
$$\therefore g_{MG} = (h_{MG} - t_s) * b_{MG} * \gamma_{RC} + \frac{R_{XG}}{b}$$

لابد من قراءة رأس السؤال جيداً لتحديد النظام الإنشائى للـ M.G. كمايلى

- Simply supported bridge with span (L) = 20 m , (4 points in MiD-span)



- Two spans continous M.G. , each span = 17 m , (point 4 and point 10 only)



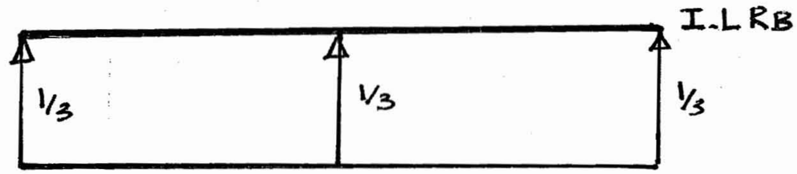
- One span M.G with one overhanging end.

أى حالة بخلاف الحالة الأولى والثانيـة ، سيعطى القطاع الطولى للـ M.G. مرسوم

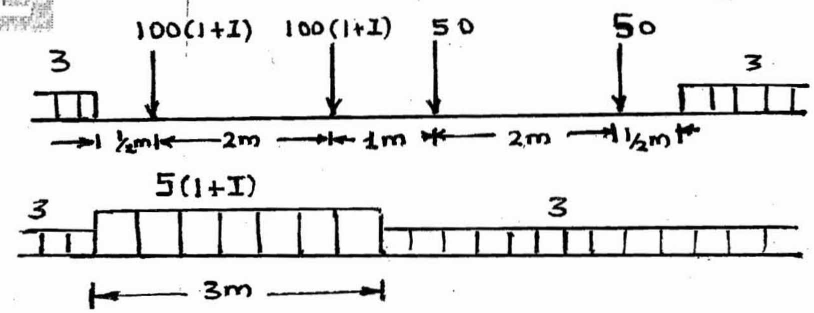
Live Load on M.G.

يجب حساب رد فعل .X.G على M.G موضوع الدراسة لذلك يجب وضع أحمال الكوبرى على (I.L R) وحساب نصيب .M.G من أحمال الكوبرى.

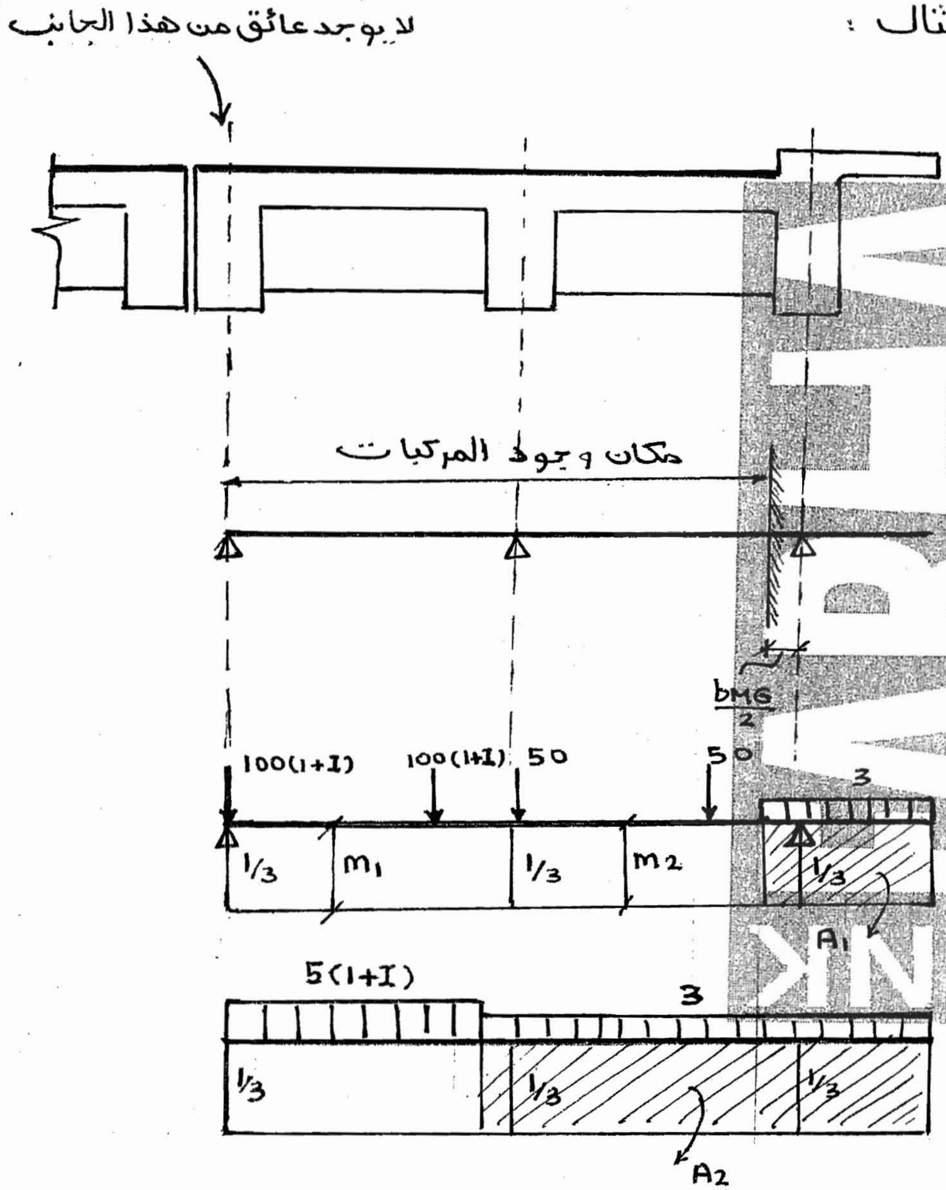
إذا كان لل .X.G أطراف كابولية فيجب مد خط التأثير على استقامته.



يجب إتباع نفس قواعد تحميل ال XG عند حساب ردود الأفعال على .M.G



مثال :



ثم نحسب قيم ردود الأفعال

$$W = 2*100*(1+I)*m_1 + 2*50*m_2$$

$$q_1 = 3*(A_1 + \dots)$$

← مجموع المساحات الواقعة تحت الحمل 3

$$q_2 = 5(1+I)*3m_1 + 3*(A_2 + \dots)$$

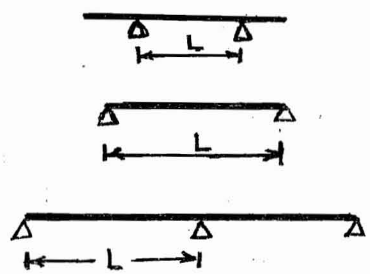
← المساحه الواقعه تحت الحمل 5

← مجموع المساحات الواقعة تحت الحمل 3

حيث (I)

$$I = 0.4 - 0.008(L)$$

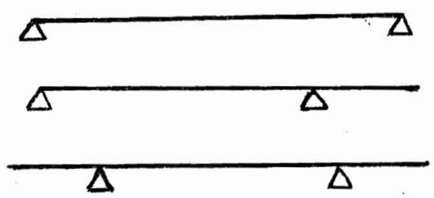
Span of Bridge



Span o
Spacing of MG

ثم نبدأ بتحميل القطاعات المطلوبة فى العزم و القص حسب النظام الإنشائى لل M.G.

• كمرة محددة :



ثم استنتاج خطوط التأثير

• كمرة غير محددة :

تكون معطاه فى الامتحان

نحسب العزوم عند القطاعات المطلوبة؛ ثم يتم التصميم عند القطاع الاكبر سواء موجب أو سالب

فى الامتحان :

Rec. Sec.	$f_c = 10.5$, $f_s = 200$	$k_1 = 0.712$	$k_2 = 170.6$
T sec.	$f_c = 7$, $f_s = 200$	$k_1 = 0.968$	$k_2 = 177$

21

تصميم القطاع :

- إذا كان العزم الأكبر على M.G موجب نصمم T-sec
- إذا كان العزم الأكبر على M.G. سالب نصمم Rec.

If T- Sec.

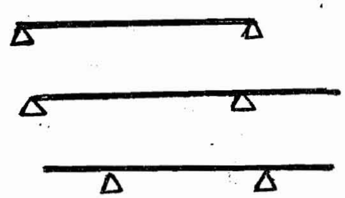
$B \rightarrow b_{MG} + 16\, t_s$

$B \rightarrow$ spacing of M.G.

$B \rightarrow b_{MG} + \frac{L'}{5}$

where $L' = \text{span}$

$L' = 0.7\ \text{span}$



$$X = 0.44 \sqrt{\frac{M_{+ve}}{B}}$$

→ If $x < t_s$

$$\therefore d = k_1' \sqrt{\frac{M_{+ve}}{B}}$$

→ If $x > t_s$

$$\therefore B_e = b_{MG} + (B - b_{MG}) * \frac{t_s}{x}\left(2 - \frac{t_s}{x}\right)$$

$$\therefore d = k_1' \sqrt{\frac{M_{+ve}}{B_e}}$$

$$\therefore h_{MG} = d + d' \;(100\text{mm}) = \checkmark \;\not< \frac{\text{Span}}{10}$$

$$\therefore d = h_{MG} - d'$$

$$A_{s_{+ve}} = \frac{M_{+ve}}{k_2' \times d} = \checkmark \;\; \varnothing 32$$

$$A_{s_{-ve}} = \frac{M_{-ve}}{k_2' \times d} = \checkmark \;\; \varnothing 32$$

$$A_{sh} = 0.08\ A_{s_{+ve}}$$

If Rec. Sec.

$$\therefore d = k_1 \sqrt{\frac{M_{-ve}}{b_{MG}}}$$

$$\therefore h_{MG} = d + d' \;(100) = \checkmark \;\not< \frac{\text{Span}}{10}$$

من أقصى قص Q_A or Q_B

$$\therefore q = \frac{Q_{max}}{b_{MG} \times d_{MG}}$$

$$\overset{0.7}{q_c} < q < \overset{2.1}{q_2}$$

مطلوب في السؤال تحمل القص بـ (خرسانه + كانات + حديد مكـ

نفرض الثلاث عناصر

1- Concrete :

$$\frac{q_c}{2} = \frac{0.7}{2} = 0.35 \ N/mm^2$$

2- Stirrups :

Try 4 br. St Ø10 @ 200 mm

$$\therefore q_{st} = \frac{n A_{st} f_s}{b_{MG} \times s}$$

$$q_{st} = \frac{4 \times 79 \times 140}{b_{MG} \times 200} = ✓ \ N/mm^2$$

$$\therefore d = h_{MG} - \overset{100mm}{d'} = ✓$$

$$\therefore A_{s-ve} = \frac{M_{-ve}}{k_2 \times d} = ✓ \quad Ø32$$

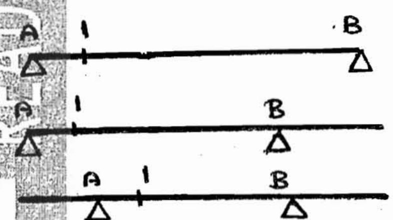
$$A_{s+ve} = \frac{M_{+ve}}{k_2 \times d} = ✓ \quad Ø32$$

$$A_{sh} = 0.08 \ A_s = ✓$$

Use 2Ø12 @ 300 mm (Shrinkage steel)

Check of shear:

• إذا كانت المسألة محددة



يتم حساب القص عند أقصى قطاع (Q_A)

ثم نحسب القص عند قطاع مجاور (Q_1)

3- bent-up bars

يتم فرض أقل حديد مكسح

$2\phi 32$ @ $d \rightarrow h_{MG} - d'$

$$q_b = \frac{n\ A_{st}\ f_s}{b_{MG} \times \frac{S_b}{d}} (\sin\alpha + \cos\alpha) = \checkmark$$

(n = 2, A_{st} = 804, f_s = 200, α = 60)

ثم نحسب q_t

$$\therefore q_t = \frac{q_c}{2} + q_{st} + q_b$$

If $q < q_t$ (OK)

$q > q_t \longrightarrow$ NOT OK

$$q_{st} = q - \frac{q_c}{2} - q_b$$

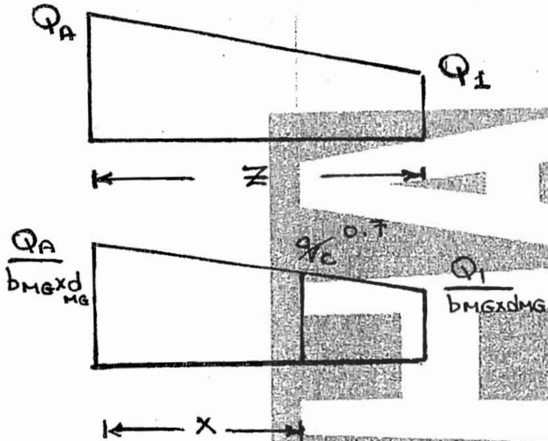
$$\therefore q_{st} = \frac{2 * 79 * 140}{b_{MG} \times S}$$

✓ ?

ثم نوجد (S)

ثم يتم حساب المسافة اللازمة للحديد المكسح (X).

حيث Z المسافة بين القطاعين.



ثم نحسب المسافة (X) بالنسبة والتناسب

ثم نحسب عدد التكسيحات

$$n_b = \frac{X}{S_b\ d} = \checkmark$$

ب • إذا كانت الكمرة غير محددة

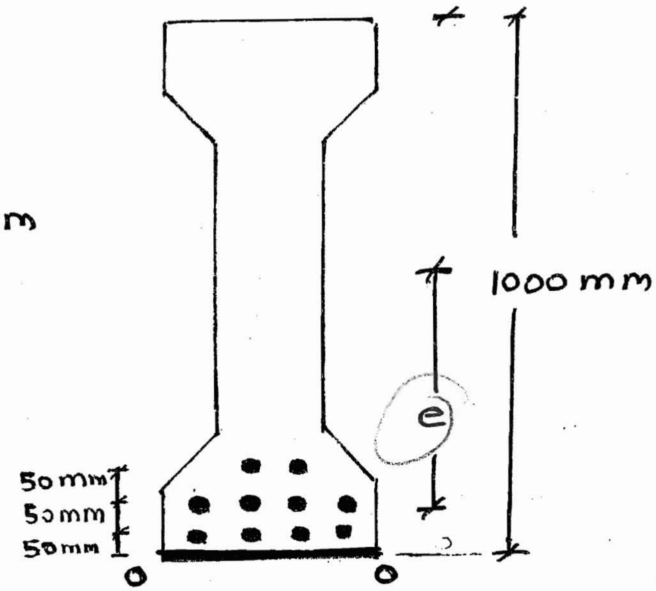
تتم نفس الخطوات لكن بدون حساب X ، فيتم فرض عدد التكسيحات (للتسهيل).

prestressed concrete

ذاكر ملزمة الشرح جيداً بالاضافة لورقة أسئلة (True or False)

يمكن أن تكون e مجهولة كالتالى :

$P = P_{/cable} \times$ no. of cables = ✓



Calculating C.G. of Cables : $\Sigma M @ o\text{-}o$

$$x = \frac{4*P*50 + 4*P*100 + 2*P*150}{10P} = 90 \text{ mm}$$

$$e = \frac{h}{2} - x = 500 - 90 = 410 \text{ mm}$$

e : هى المسافة من مركز القطاع إلى مركز الكابلا ..

Alexandria University
Faculty of Engineering
4 th Year Civil Engineering
Reinforced Concrete Bridges

End of Term Exam
Time Allowed 3 hours
Date Jan., 2005

- Notes, Data books, Codes and Tables are **NOT allowed** in the examination room
- Show all calculation steps clearly in detail.
- Assume ANY missing data you might need.

I- Problem 1 (10% of total mark)

For the **STIFF** cross girder supported on 3 Main girders (of **UNEQUAL** inertias) and loaded with an **Eccentric Concentrated** load of 1000 kN, as shown in Fig 1 . Calculate the **reaction** at each support for the shown load **only** (neglect the own weight).

II- Problem 2 (70% of total mark)

The **SLAB and GIRDER** bridge, shown in **Fig. 2,** is simply supported with span L= 22 m. and with clear road width = 7.0m. The bridge consists of 4 **Main girders** spaced at 2.50m, while the cross girders are spaced at 5.50 m. The breadth of the main girder = 0.5 m, the breadth of X.G, b_{xg} =0.25m.

1- It is required to give full statical calculations and design for the:

a) slabs

b) Cross Girder (**Do not** draw the X- Girder, Only the design is required)

c) An intermediate main girder. Use **BOTH stirrups and BENT UP bars** arrangement. (**DO NOT use stirrups alone**).

2- Give complete working drawings for :

i) Slabs.

ii) **Only one Half** Longitudinal section and a **transverse** cross-section of the designed **Main** girder showing all reinforcement details and dimensions (scale 1:25). Draw clearly the **maximum max. bending moment diagram and moment of resistance** (BM values at 4 points are required in half span).

III- Problem 3 (20% of total mark)

For the Pre-stressed concrete beam with the section shown in Fig. 3 , with 2 **different** cables at separate positions and the following data:

- Cable 1:

  Initial Prestressing force = 2000 kN, Final Prestressing force after losses= 1600 kN,
  Eccentricity of cable 1 = 0.90m (from CL)

- Cable 2 :

  Initial Prestressing force = 1000 kN, Final Prestressing force after losses = 800 kN,
  Eccentricity of cable 2 = 0.60m (from CL)

- Applied working **positive** bending moments are: DL= 1200 kN.m, L.L = 1800 kN.m

Concrete strength f_{cui} = 35N/mm^2 , f_{cu} = 45 N/mm^2

Area = 600 *10^3 mm^2 , Section Moment of Inertia I = 25 * 10^{10} mm^4

- Draw the stresses in the section and check against the allowable limits:

  At time of transfer

  In the lifetime (t = ∞).

Data for problem 2

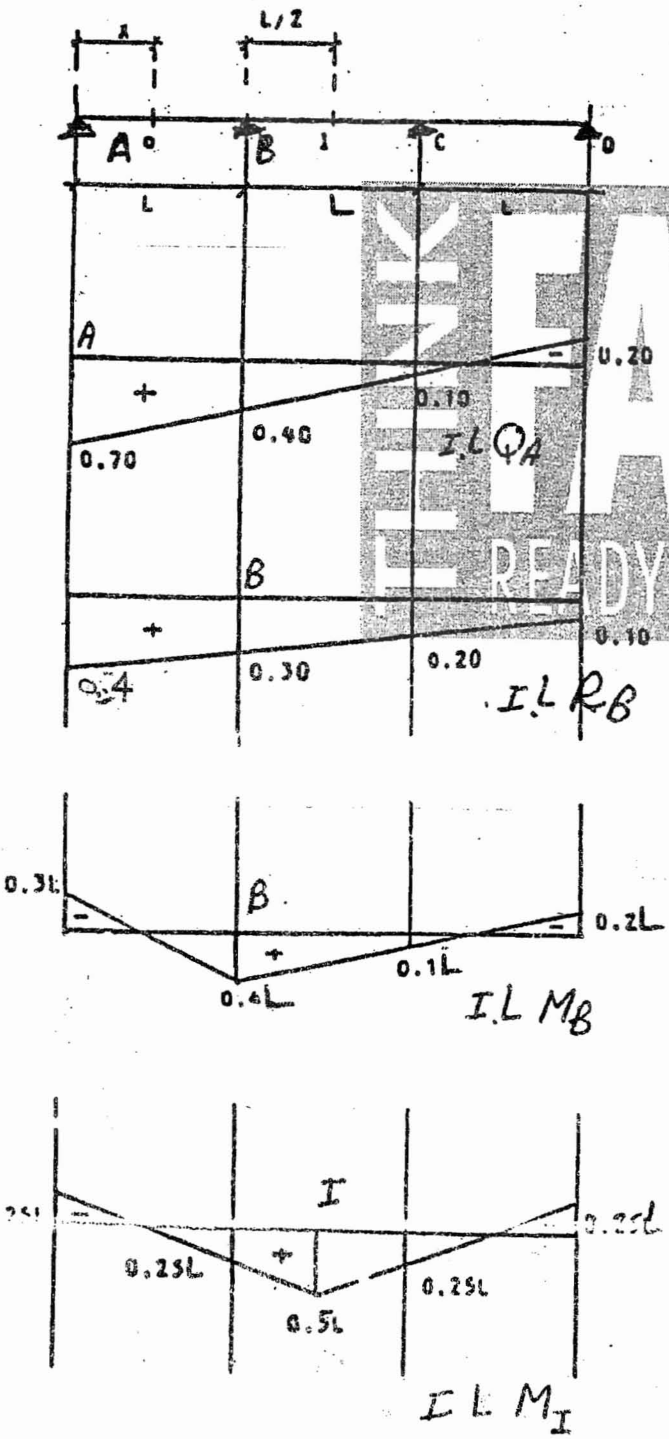
For f_{cu} = 30 N/mm² and for st 360/520 f_s = 200 N/mm²

f_c = 10.5 N/mm² for beams and slabs deeper than 200mm, k_1 = 0.711 k_2 = 170.6

f_c = 7.0 N/mm² , k_1 = 0.968 k_2 = 177

Area of steel bars (mm²)

Diameter mm	8	10	13	16	19	22	25	28	32
Area of one bar, mm²	50	79	132	201	284	380	491	616	804



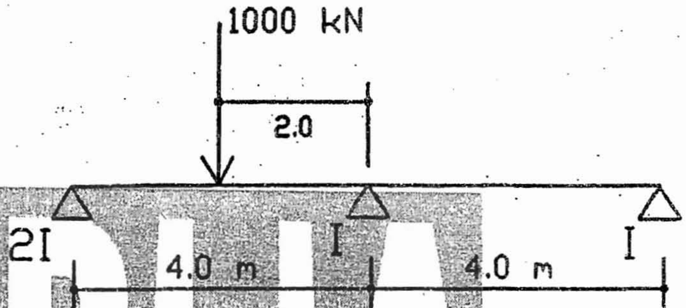


Fig. 1

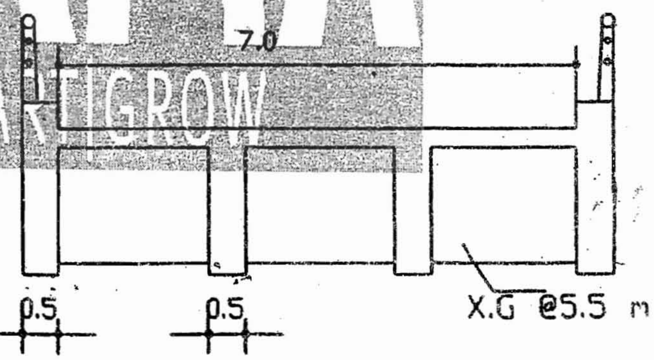


Fig. 2

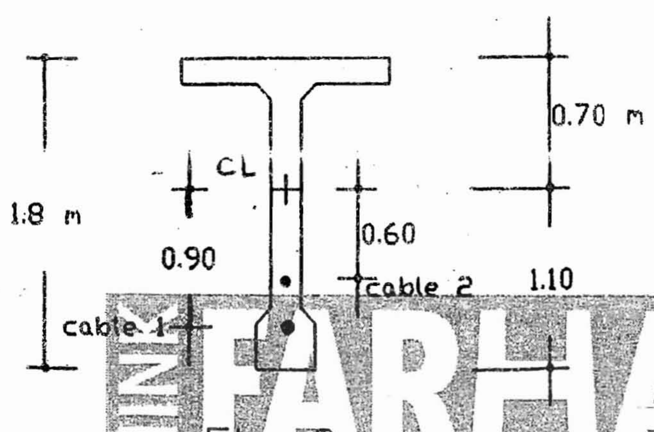


Fig. 3

Problem 2

Design of slab:

$a = 2.5$ m

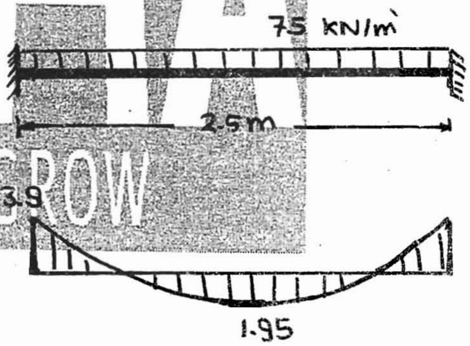
$b = 5.5$ m

$\therefore r = \frac{5.5 \times 0.76}{2.5 \times 0.76} = 2.2$ → one way in DL, one way in LL

Dead load:

$\therefore t_s = \frac{2.5}{15} = 0.1667 \rightarrow 0.18$ m

$\therefore g = t_s * \gamma_{RC} + Cov. = 0.18 * 25 + 3 = 7.5$ kN/m^2



Live load:

$S_1 = 0.2 + 2C + t = 0.2 + 2*0.15 + 0.18 = 0.68$ m

$S_2 = 0.6 + 2C + t = 0.6 + 2*0.15 + 0.18 = 1.08$ m

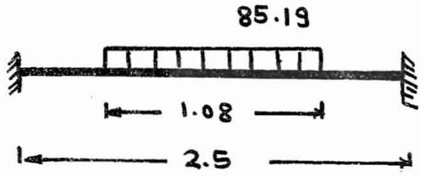
$a < 3$m (case of one wheel only)

$S_{1f} = S_1 + \frac{As'}{As} * a' = 0.68 + 0.5(0.76 * 2.5) = 1.63$ m $\not> 1.5$ m

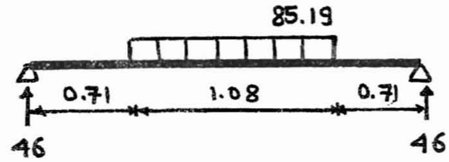
$S_{2f} = S_2 = 1.08$ m

$I = 0.4 - 0.008\,a = 0.4 - 0.008 * 2.5 = 0.38$

$$P = \frac{100(1+I)}{S_{1f} \times S_{2f}} = \frac{100 \times 1.38}{1.5 \times 1.08} = 85.19 \ kN/m^2$$



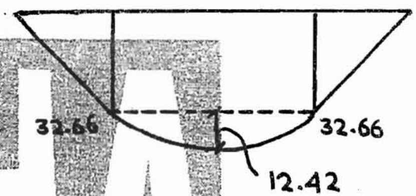
$$\text{Area of BMD} = \frac{1}{2} * 0.71 * 32.66 * 2 + 1.08 * 32.66 + \frac{2}{3} * 12.42 * 1.08$$



$$\text{Area of BMD} = 67.40 \ kN.m^2$$

$$M_f = \frac{67.40}{2.5} = 26.96 \ kN.m$$

$$M_{+ve} = (12.42 + 32.66) - \frac{26.96}{2} = 31.6 \ kN.m$$



Design

$$M_{T+ve} = 1.95 + 31.6 = 33.55 \ kN.m$$

$$M_{T-ve} = 3.9 + 26.96 = 30.86 \ kN.m$$

أكمل الحل ←

..em 2

Design of XG

$$h_{MG} = \frac{Span}{10} = \frac{22}{10} = 2.2\ m$$

$$h_{XG} = 2.2 - 0.2 = 2m$$

$b_{XG} = 0.25\ m \longrightarrow$ Given

$b = 5.5\ m\ ,\ a = 2.5\ m$

$$g_{XG} = (0.18 * 25 + 3) * 5.5 + (2 - 0.18) * 0.25 * 25 = 52.63\ kN/m'$$

(ts = 0.18, b = 5.5, ts = 0.18)

$$P_{HR} = 2 * 5.5 = 11\ kN/m'$$

$$R_{XG} = \frac{52.63 \times 3 \times 2.5 + 2 \times 11}{4} = 104.18\ kN$$

$M_{add} = 3.90 * 5.5 = 21.45\ kN.m \rightsquigarrow$ من حل البلاطه

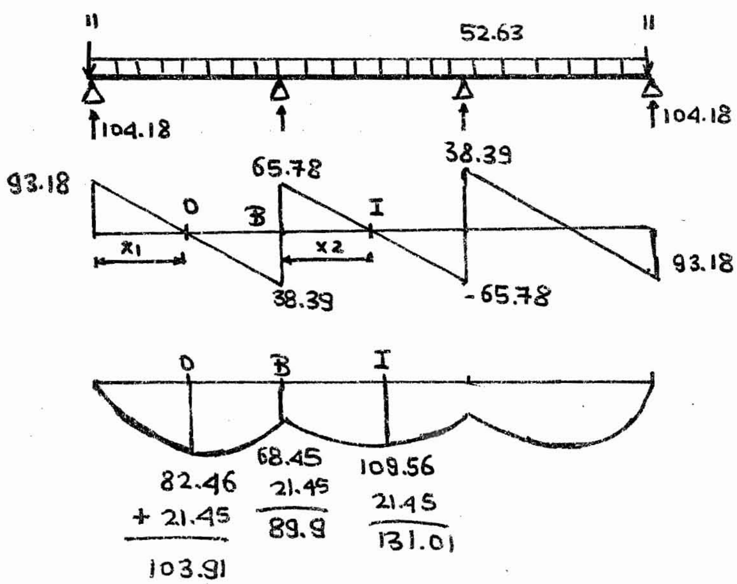
$$x_1 = \frac{93.18}{93.18 + 38.39} \times 2.5 = 1.77\ m$$

$$x_2 = 1.25\ m$$

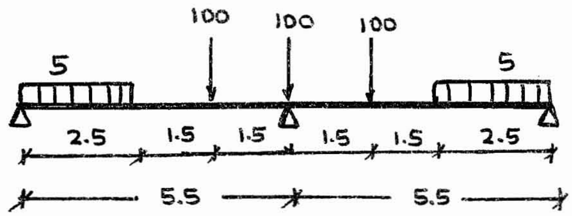
$M_O = 103.91\ kN.m$

$M_B = 89.9\ kN.m$

$M_I = 131.01\ kN.m$



Live load



$I = 0.4 - 0.008\,L = 0.34$

2x5.5 (2b) → 7.5 (L x G)

$\therefore\ R_1 = [100 + 2 \times 100 \times \frac{4}{5.5}] = 245.45$ kN

$R_2 = \frac{R_1}{2} = 122.73$

$P_1 = [5 * 2.5 * \frac{1.25}{5.5} \times 2] = 5.68$ kN/m'

$P_2 = \frac{3}{5} * P_1 = 0.6 * 5.68 = 3.4$ kN/m'

$P_3 = 3 * 5.5 = 16.5$ kN/m'

$R_1 * (1+I) = 328.9$ kN

$P_1 * (1+I) = 7.61$ kN/m'

خلي بالك : يتم تحميل المنحنيات المعطاه فقط .

$Q_{A+ve} = 2 \times 328.9 * 0.49 + 7.61 * 3 * 0.49 + 122.73 * 2 * 0.13 + 3.4 * 3 * 0.13 + 16.5 * 0.25 * 0.69 = 369.59$ kN.m

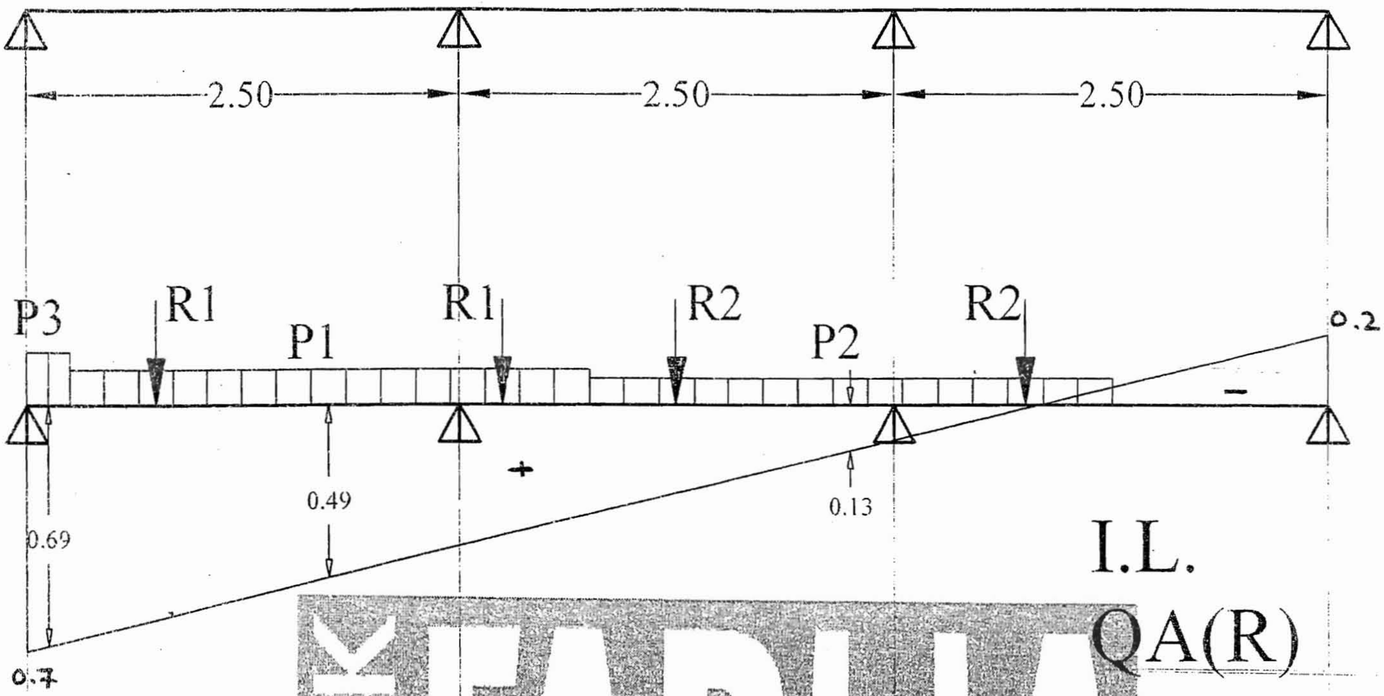
$M_{B-ve} = -16.5 * [1.07 * 0.38 + 1.67 * 0.25] = -13.59$ kN.m

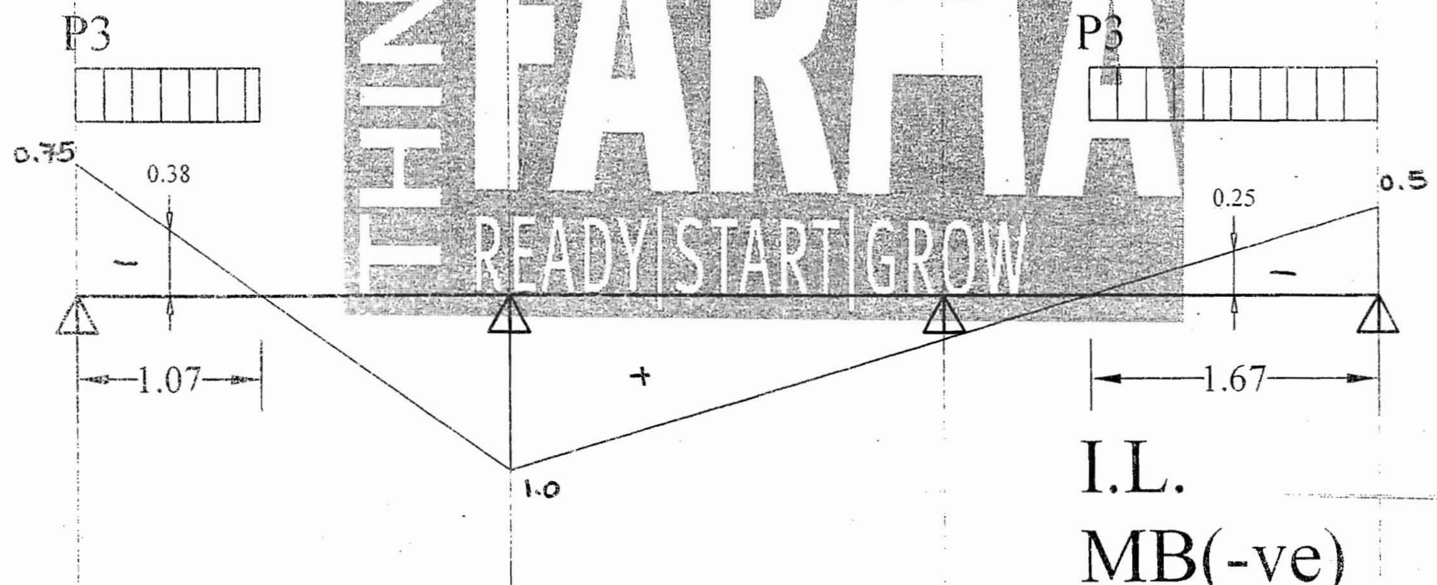
$M_{I+ve} = 2 * 328.9 * 0.75 + 7.61 * 3 * 0.75 + 122.73 * 2 * 0.25 + 3.4 * 3 * 0.25 = 574.38$ kN.m

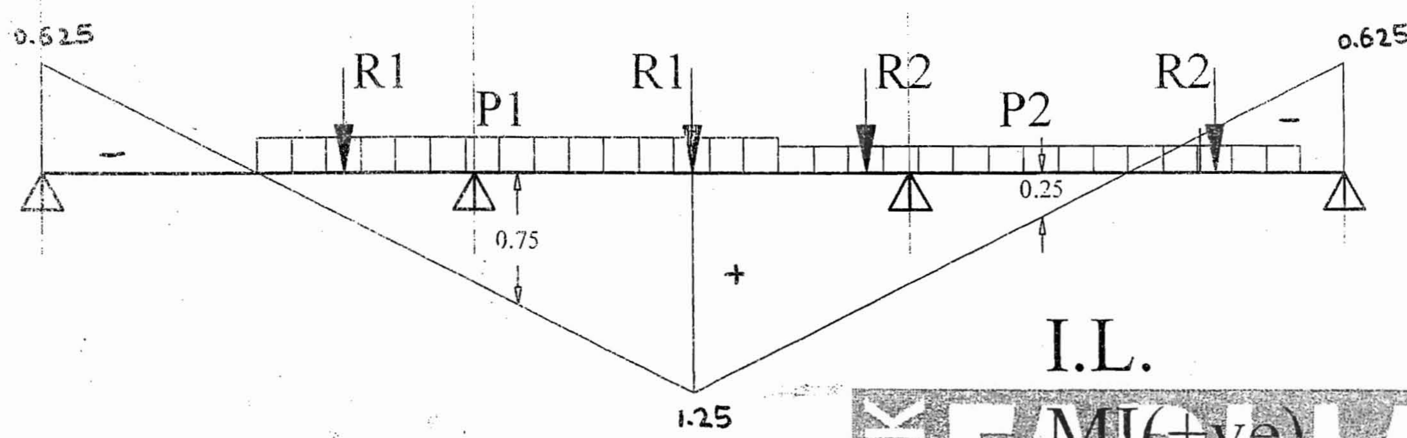
$Q_{A_T} = 93.18 + 369.59 = 462.77$ kN → ✓ Max shear

$M_B = 89.9 - 13.59 = 76.31$ kN.m يهمل

$M_I = 131.01 + 574.38 = 705.4$ kN.m ✓ Max Moment


2.50
2.50
2.50
P3
R1
P1
R1
R2
P2
R2
0.2
0.69
0.49
0.13
0.7
I.L.
QA(R)


P3
P3
0.75
0.38
0.25
0.5
1.07
1.67
1.0
I.L.
MB(-ve)


0.625
R1
P1
R1
R2
P2
R2
0.625
0.75
0.25
1.25
I.L.
MI(+ve)

Design

$f_{cu} = 30 \ N/mm^2$

$f_c = 10.5$ for T-section $f_c = 7 \ N/mm^2$

$k_1^* = 0.968$ $k_2^* = 177$

B = الأصغر → $250 + 16 * 180 = 3130$ / → 5500 mm

$\therefore x = 0.44 \sqrt{\frac{M_{max}}{B}} = 0.44 \sqrt{\frac{705.4 \times 10^6}{3130}} = 209 \ mm > t_s$

$\therefore B_e = 250 + (3130 - 250) * (\frac{180}{209})(2 - \frac{180}{209}) = 3074 mm$

$\therefore d = k_1^* \sqrt{\frac{M_{max}}{B_e}} = 0.968 \sqrt{\frac{705.4 \times 10^6}{3074}} = 463 \ mm$

$\therefore d = 2000 - 80 = 1920 \ mm$

$A_{s+ve} = \frac{705.4 \times 10^6}{177 \times 1920} = 2075 \ mm^2$

6 Ø 22

$A_s' = 0.2 \ A_s^{+ve} = 415 \ mm^2$

2 Ø 18

Design for shear

$q = \frac{462.77 \times 10^3}{250 \times 1920} = 0.96 > q_c \ \& < q_2$

$q_{st} = 0.96 - \frac{q_c}{2} = 0.96 - 0.35 = 0.61 \ N/mm^2$

$q_{st} = \frac{n . A_{st} . f_s}{b . s}$ $\therefore 0.61 = \frac{2 \times 79 \times 140}{250 \times S}$

$\therefore S = 145 \ mm \rightarrow 125 \ mm$ use 2br. st Ø 10 @ 125 mm

$A_{sh} = 0.08 \ A_s = 166 \ mm^2$ use 2 Ø 10 @ 300 mm

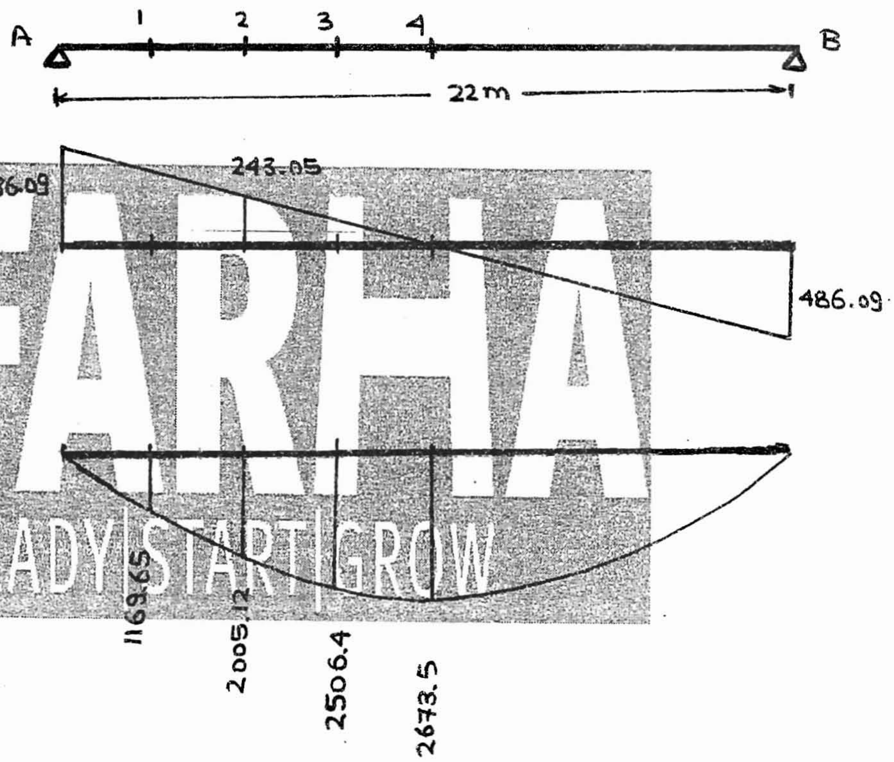
٥٨

Design of Main Girder

Dead load

$$g = \frac{R \times G}{b} + \text{own wt.}$$

$$g = \frac{104.18}{5.5} + (2.2 - 0.18) * 0.5 * 25 = 44.19 \ kN/m$$

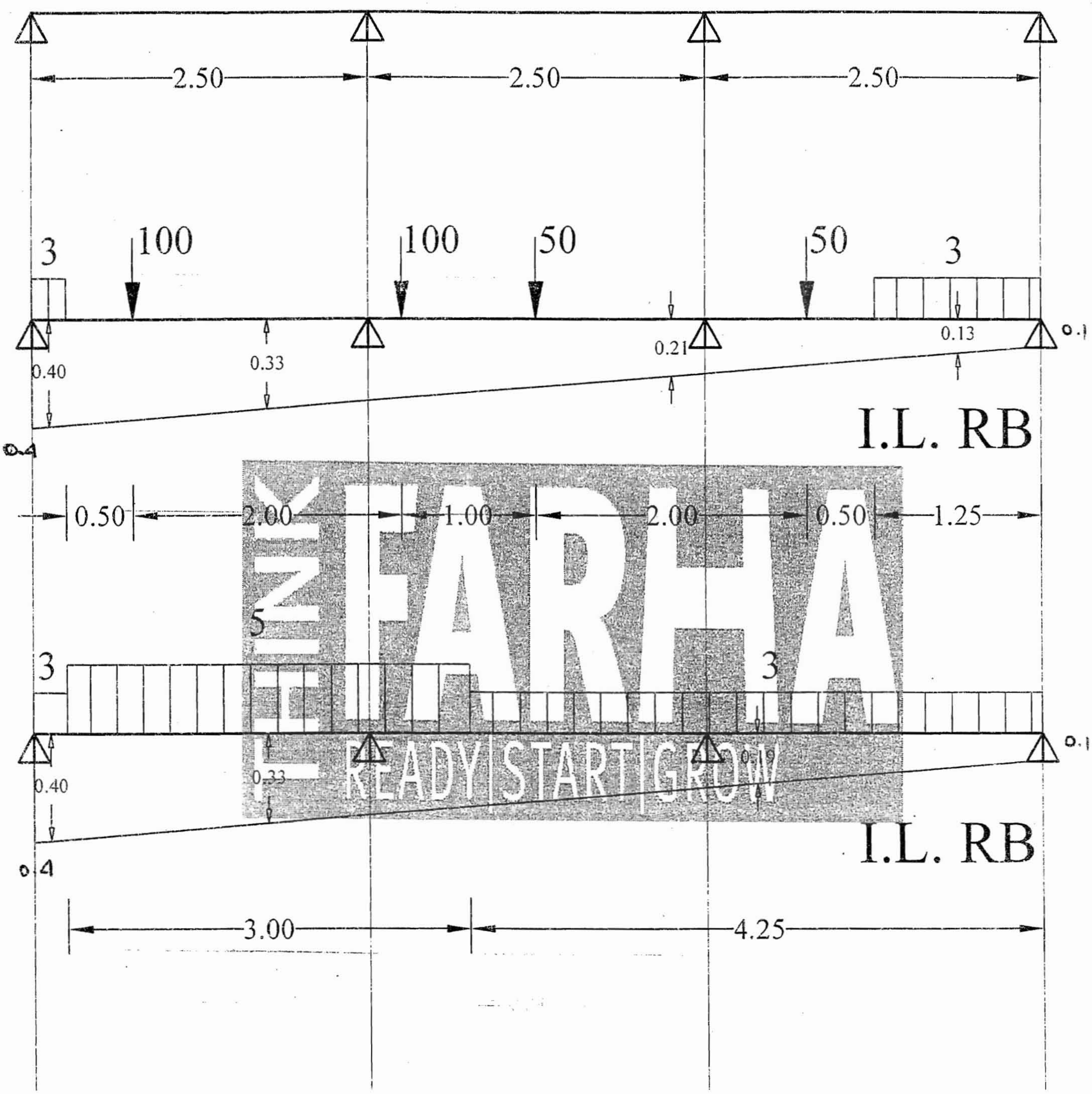


Live load

لاحظ فى رأس السؤال طلب كمرة متوسطه ..

نستخدم خط التأثير المعطى لرد الفعل عند B

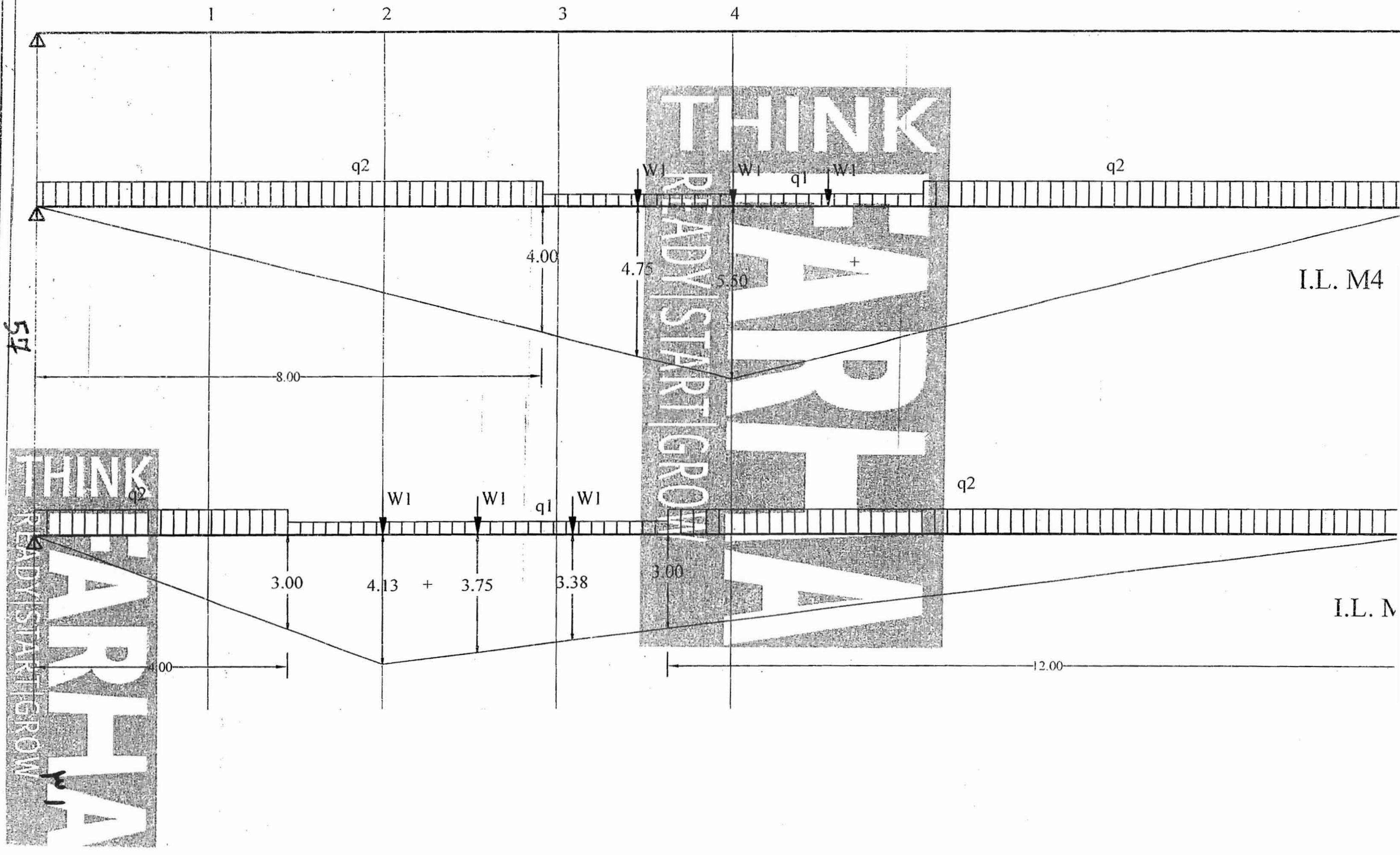
$$\therefore I = 0.4 - 0.008 \times 22 = 0.224$$



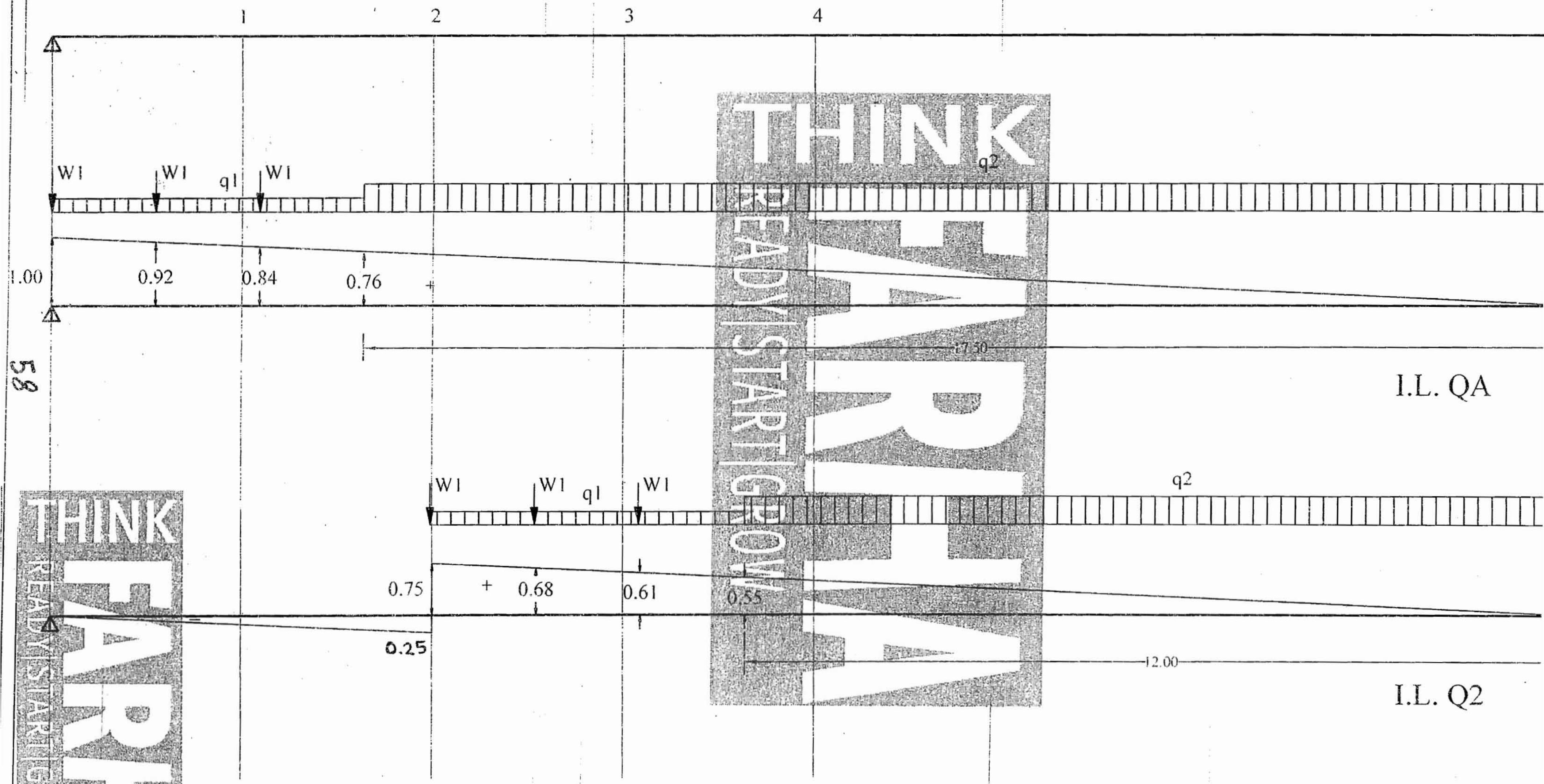
$w_1 = 2*100*0.33*1.224 + 2*50*0.21 = 101.78$ kN

$q_1 = 3(0.25*0.4 + 1.25*0.13) = 0.765$ kN/m

$q_2 = 5*3*0.33*1.224 + 3(0.25*0.4 + 4.25*0.19) = 8.714$ kN/m



1
2
3
4
q2
W1
q1
4.00
4.75
5.50
+
8.00
I.L. M4
3.00
4.13
3.75
3.38
12.00
I.L. M
57


1
2
3
4
W1
W1
q1
W1
q2
1.00
0.92
0.84
0.76
17.50
I.L. QA
W1
W1
q1
W1
q2
0.75
0.68
0.61
0.55
0.25
12.00
I.L. Q2

$$M_4 = \overset{w_1}{101.78}\,(5.5 + 2*4.75) + \overset{q_1}{0.765}*4.75*6 + \overset{q_2}{8.714}*0.5*8*4*2$$

$$\therefore\ M_4 = 1827.3\ \text{kN.m}$$

$$M_2 = 101.78\,(4.13 + 3.75 + 3.38) + 0.765\left[\frac{3+4.13}{2}\times 4.5 + \frac{3+4.13}{2}\times 1.5\right] + 8.714\left[0.5\times 12\times 3 + 0.5\times 4\times 3\right]$$

$$M_2 = 1371.5\ \text{KN.m}$$

$$Q_A = 101.78\,(1.0 + 0.92 + 0.84) + 0.765\left[\frac{1+0.76}{2}\times 4.5\right] + 8.714\left[0.5*17.5*0.76\right]$$

$$Q_A = 341.89\ \text{KN}$$

$$Q_2 = 101.78\,(0.75 + 0.68 + 0.61) + 0.765\left[\frac{0.75+0.55}{2}\times 4.5\right] + 8.714\left[0.5*12*0.55\right]$$

$$Q_2 = 238.6\ \text{kN.m}$$

$M_1 < M_3$ وتبقى وقت فى الامتحان احسب

Point	Q_{DL}	Q_{LL}	Q_{max}	Point	M_{DL}	M_{LL}	M_{Max}
A	486.09	341.89	827.98	A	0	0	0
1	—	—	—	1	1169.65	✓	✓
2	243.05	238.6	481.65	2	2005.12	1371.5	3376.6
3	—	—	—	3	2506.4	✓	✓
4	—	—	—	4	2673.5	1827.3	4500.8

Design

$M_{Max} = 4500.8$ kN.m

Design as T- section:

$\therefore B$ (الأصغر) →
- $500 + 16 * 180 = 3380$ mm
- $a = 2500$ mm ✓
- $500 + \frac{22000}{5} = 4900$ m

$\therefore X = 0.44 \sqrt{\frac{4500.8 \times 10^6}{2500}} = 590$ mm $> t_s$

$\therefore B_e = 500 + (2500 - 500) * \frac{180}{590} (2 - \frac{180}{590}) = 1534$ mm

$\therefore d = k_1 * \sqrt{\frac{M}{B_e}} = 0.968 \sqrt{\frac{4500.8 \times 10^6}{1534}} = 1658$ mm

$\therefore$ take $h = 2200$ mm

$\therefore d_{act} = 2200 - 100 = 2100$ mm

$\therefore A_s = \frac{4500.8 \times 10^6}{177 \times 2100} = 12108$ mm^2 16Ø32

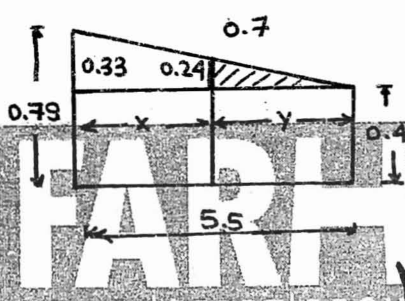
$A_s' = 0.2 A_s = 2421$ mm^2 5Ø25

$A_{sh} = 0.08 A_s = 968$ mm^2 use 2Ø12@300 mm

Design for shear

$Q_A \Rightarrow q_A = \frac{827.98 \times 10^3}{500 \times 2100} = 0.788$ N/mm^2 $\quad 0.7 < q < 2.1$ (OK)

$Q_2 \Rightarrow q_2 = \frac{481.65 \times 10^3}{500 \times 2100} = 0.458$ N/mm^2



$\therefore \frac{0.33}{5.5} = \frac{0.24}{y}$ $\quad \therefore y = 4$

$\therefore X = 1.5$ m

$q = q_{c/2} + q_{st} + q_{bu}$

$\therefore q_{st} + q_{bu} = 0.79 - 0.35 = 0.44\ N/mm^2$

نفرض bent-up

$S: d/2 \rightsquigarrow d$

$S: \frac{2100}{2} \rightsquigarrow 2100 \quad (1050 \nrightarrow 2100)$

1500 mm

$\therefore q_{bu} = \frac{2 * 804 * 200}{500 \times 1500} (\sin 60 + \cos 60) = 0.586\ N/mm^2$

(2 = سيخين ، 804 = $A_{\phi 32}$ ، 200 = f_s ، 500 = b ، 1500 = s)

$\therefore q_{st} = 0.44 - 0.586 = (-)$ مش محتاج Stirrups يبقى نحط min.

use 4 br. stirrups ϕ 10 @ 200 mm

(4 br.) علشان العرض اكبر من 400

حساب عدد التكسيحات

$X = 1.5\ m$

$S = 1.5\ m$

$n = \frac{X}{S} = 1$ تكسيحه واحدة

المفروض نرجع نعمل check من تاني لأن القانون يختلف في حاله تكسيحه واحده وتستبدل s ب d

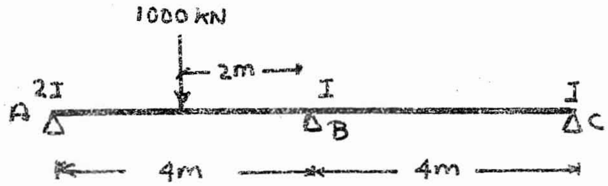
أو ممكن نعمل تكسيحتين في المسافه $\underline{\underline{X}}$ ونقلل $\underline{\underline{S}}$

اسم عادى ← كمل

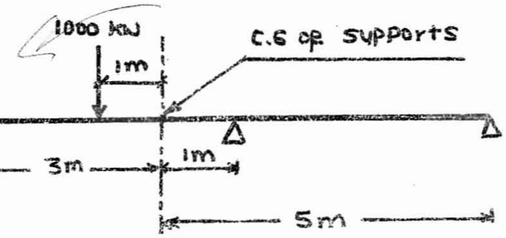
Jan 2005

problem 1

(Variable Inertia)



Calculation of C.G



$\Sigma M_A = 0$

$\therefore 2I * 0 + I * 4 + I * 8 = 4I * X$

$\therefore X = \frac{12I}{4I} = 3m$

$\therefore e = 1m$

$\therefore M = P.e = 1000 \text{ kN.m}$

$\therefore \Sigma I r^2 = 2I * 3^2 + I * 1^2 + I * 5^2 = 44 I$

$\therefore R = \frac{P}{\Sigma I} * nI \pm \frac{M}{\Sigma I r^2} nIr$

$\therefore R_A = \frac{1000}{4I} * 2I + \frac{1000}{44I} * 2I * 3 = 636.36 \text{ kN}$

$R_B = \frac{1000}{4I} * I - \frac{1000}{44I} * I * 1 = 227.27 \text{ kN}$

$R_C = \frac{1000}{4I} * I - \frac{1000}{44I} * I * 5 = 136.36 \text{ kN}$

check $R_A + R_B + R_C = 1000 \text{ kN}$ ok

Just mention (True or False)

1- Pretensioning and post-tensioning are related to the time of concrete casting (True). فعلا الشد يكون قبل أو بعد الصب

2- Anchorages are needed at the beam ends for pretensioned beams (False). دى بتعتمد على الاحتكاك

3- Circular concrete tanks can be either post-tensioned or pretensioned (False) يكون من النوع الشد اللاحق فقط

4- Prestressed concrete is related to the time of the applied load on a member (False) مالوش علاقة بالحمل

5- There are losses in prestressing in externally bonded pre-tensioned cables (True) أكيد كل الانواع فيها فواقد

6- Prestressing cables are always located in the lower side of section (False) لو عندى عزم سالب حنحط الكابل فوق

7- Prestressing can reduce deflection (True) دى من مميزات الخرسانة سابقة الاجهاد أصلا.

8- Post-tensioning forces are applied before casting of concrete. (False) لانها بتكون بعد الصب مش قبله

9- Unbonded cables are used in Pretensioning. (False) دى بيعتمد على الاحتكاك .. يبقى لازم يكون السيخ يعض فى الخرسانة.

10- Prestressing can produce upward camber (true) ده معناه ان الكمره ممكن تتقوس لاعلى وده بيحصل فى مرحله نقل الاحمال لان الكمره مش عليها الاحمال كلها .

11- Losses in post-tensioning are higher than in Pretensioning. (True) فعلا فواقد الشد اللاحق اكبر علشان الاحتكاك و انزلاق الوصله بتاعه الاسياخ

Solved Exams

R. Concrete Bridges

Alexandria University
Faculty of Engineering
4 th Year Civil Engineering
Reinforced Concrete Bridges

End of Term Exam
Time Allowed **3 hours**
Date Jan., 2011

- Notes, Data books, Codes and Tables are **NOT allowed** in the examination room
- Assume **ANY** missing data you might need.

Problem 1 (80% of total mark)

The **SLAB and GIRDER** bridge, shown in **Fig. 1,** the main girders are simply supported with cantilever. The main span L= 22 m and the cantilever length is 5.5 m. The clear road width = 7.0m. The bridge consists of 4 **Main girders** spaced at 2.50 m, while the **cross girders** are spaced at 5.5 m. The breadth of the main girder = 0.5 m, the breadth of X.G, b_{xg} = 0.25m.

1- It is required to give full calculations and design for the:

a) Slabs,

b) An **intermediate** main girder. Use **BOTH** stirrups and BENT UP bars arrangement. (DONOT **use stirrups alone).**

2- Give complete working drawings for :

a) Slabs, two cross sections, (scale 1:25), **Use BENT UP bars arrangement**

b) Longitudinal section of the beam and the **cantilever** and **a transverse** cross-section of the designed **Main** girder showing all reinforcement details and dimensions (scale 1:50). Draw clearly the **maximum max. bending moment diagram and moment of resistance** (BM values at the shown 5 points are required).

Problem 2 (20% of total mark)

A- Which is of the following statements **False** and which is **True**.

1- Pre-tensioned cables are externally unbounded cables.
2- Post-tensioning forces are applied after casting the concrete.
3- Anchorages are needed at the beam ends for pretensioned beams.
4- Pre-tensioning and post-tensioning are related to the time of concrete casting.
5- Prestressing cables are always located in the lower side of the section.
6- Prestressing can produce upward camber.
7- Time dependent losses are high at transfer.
8- There are friction losses in post-tensioned cables.

B- For the Pre-stressed concrete beam with the section shown in Fig. 2 , with **2 different** cables at separate positions and the following data:

- **Cable 1**: Initial Prestressing force = 2500 kN, Final Prestressing force after losses= 2000 kN,
  Eccentricity of cable 1 = 0.90m (from CL)
- **Cable 2** : Initial Prestressing force = 1250 kN, Final Prestressing force after losses = 1000 kN,
  Eccentricity of cable 2 = 0.60m (from CL)
- Applied working **positive** bending moments are: DL= 1500 kN.m, L.L = 3000 kN.m

Concrete strength f_{cui} = 35N/mm^2 , f_{cu} = 40 N/mm^2

Area = 610 *10^3 mm^2 , Section Moment of Inertia I = 26 * 10^{10} mm^4

- **Draw** the stresses in the section at time of transfer and in the lifetime.

Data

For $f_{cu} = 30$ N/mm^2 and for st 360/520 $f_s = 200$ N/mm^2

$f_c = 10.5$ N/mm^2 for beams and slabs deeper than 200mm, $k_1 = 0.711$ $k_2 = 170.6$

$f_c = 7.0$ N/mm^2 for T section design $k_1 = 0.968$ $k_2 = 177$

Area of steel bars (mm^2)

Diameter mm	8	10	13	16	19	22	25	28	32
Area of one bar, mm^2	50	79	132	201	284	380	491	616	804

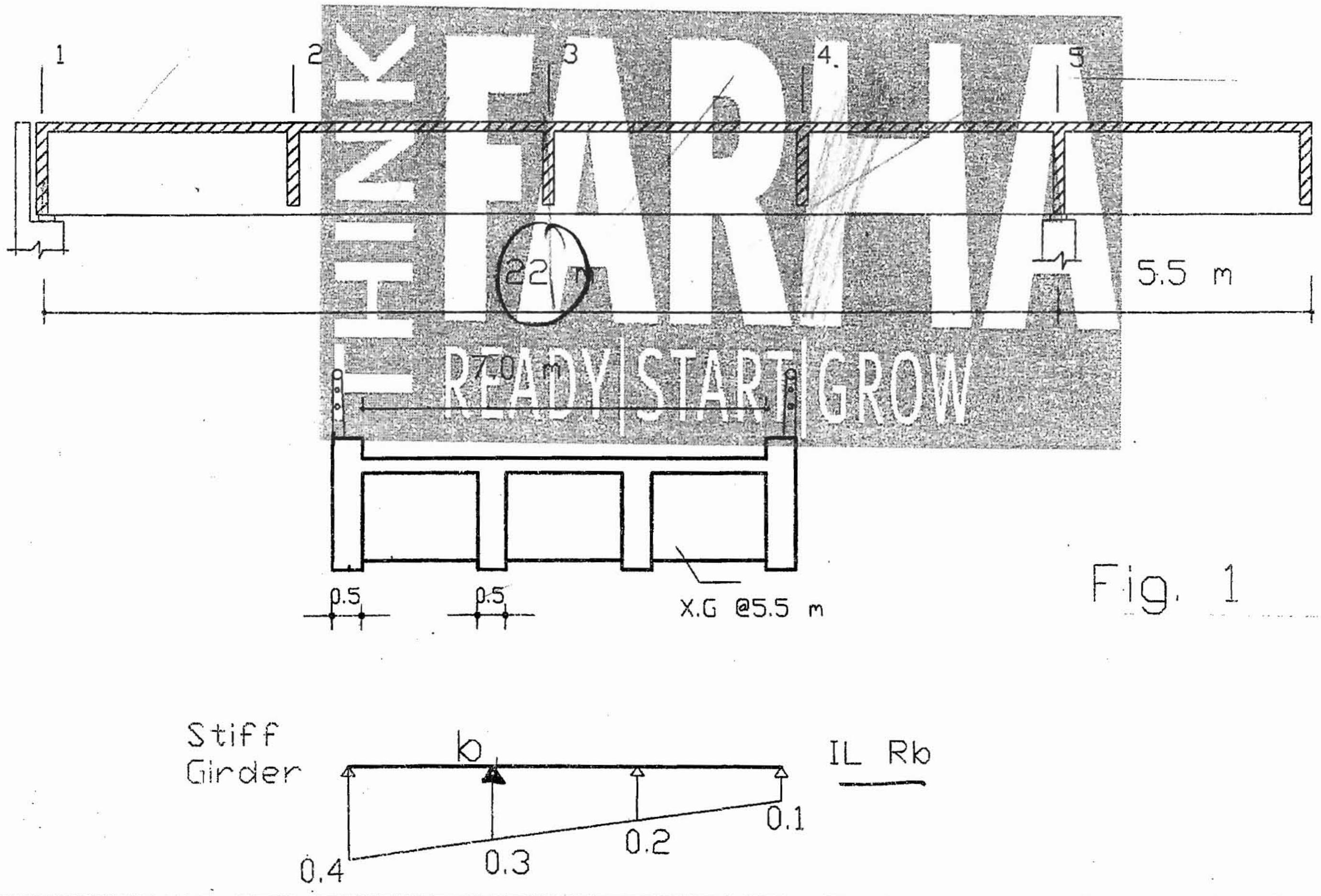


Fig. 1

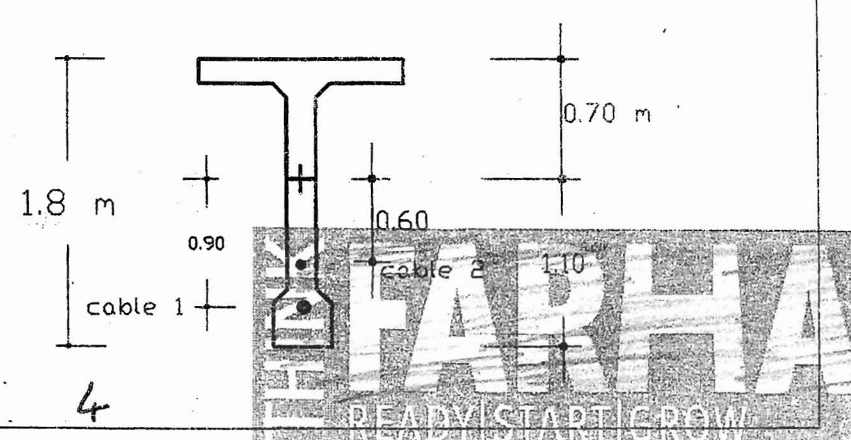


Fig. 2

January 2011

Problem 1 (80%)

A) Design of slabs:

Spacing of M.G = 2.50 m

Spacing of X.G. = 5.50 m

$$r = \frac{5.5 \times 0.76}{2.5 \times 0.76} = 2.2$$ → one way in D.L. / → one way in L.L.

Dead load:

$$t_s = \frac{a}{15} = \frac{2.5}{15} = 0.1667 \longrightarrow 0.18 \text{ m}$$

$$\therefore g = t_s * \gamma_{Rc} + \text{Cover}$$

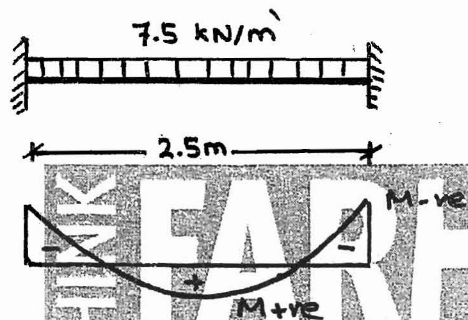
$$= 0.18 * 25 + 3 = 7.5 \quad \text{kN/m}^2$$

For 1m width strip:

$$M_{-ve} = \frac{g a^2}{12} = \frac{7.5 * 2.5^2}{12}$$

$$M_{-ve} = -3.9 \quad \text{kN.m}$$

$$M_{+ve} = \frac{g a^2}{24} = 1.95 \quad \text{kN.m}$$



Live Load :

For a standard truck :

$S_1 = 0.2 + 2C + t = 0.2 + 2 * 0.15 + 0.18 = 0.68\ m$

$S_2 = 0.6 + 2C + t = 0.6 + 2 * 0.15 + 0.18 = 1.08\ m$

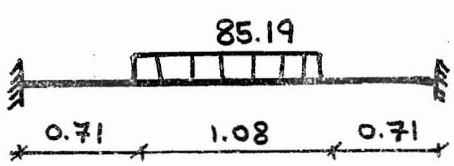
$a < 3m$ Case of one wheel only

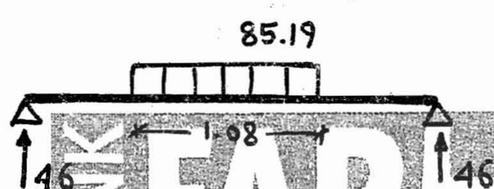
S_{1f} →
- $S_1 + \frac{A_s'}{A_s} * a' = 0.68 + 0.5\,(0.76 * 2.5) = 1.63\ m$
- $S_1 + 2m = 0.68 + 2 = 2.68\ m$
- $1.5\ m$ (spacing of wheels) الأصغر
- $b = 5.50\ m$

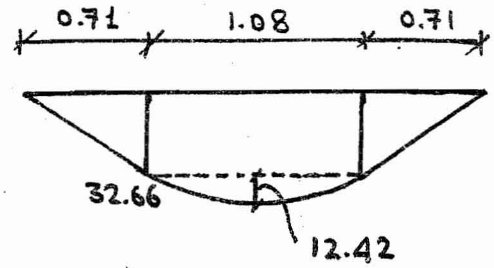
$S_{2f} = S_2 = 1.08\ m$

$I = 0.4 - 0.008\,(a) = 0.38$ (a = 2.5)

$\therefore P = \frac{100 \times (1 + I)}{S_{1f} \times S_{2f}} = \frac{100 \times 1.38}{1.5 \times 1.08} = 85.19\ kN/m^2$







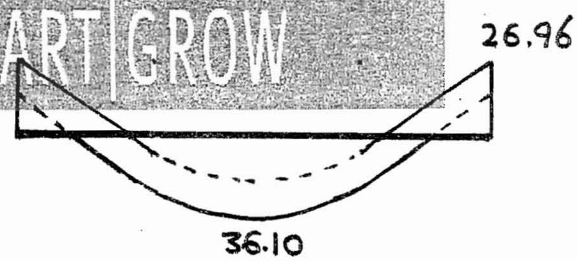
$$\text{Area of B.M.D} = 1.08 * 32.66 + 0.5 * 0.71 * 32.66 * 2 + \frac{2}{3} * 1.08 * 12.42$$

$$\text{Area of B.M.D} = 67.40 \ \text{kN.m}^2$$

$$\therefore M_p = \frac{\text{Area of B.M.D}}{a} = \frac{67.40}{2.50} = 26.96 \ \text{kN.m}$$

$$M_{+ve} = M_o - \frac{M_p}{2}$$

$$M_{+ve} = (32.66 + 12.42) - \frac{26.96}{2} = 31.60 \ \text{kN.m}$$



Design:

$$M_{+ve} = M_{DL_{+ve}} + M_{LL_{+ve}} = 1.95 + 36.1 = 33.55 \ \text{kN.m}$$

$$M_{-ve} = M_{DL_{-ve}} + M_{LL_{-ve}} = 3.90 + 26.96 = 30.86 \ \text{kN.m}$$

for $f_{cu} = 30 \ N/mm^2 \longrightarrow f_c = 10.5 \ N/mm^2$

$f_y = 3600 \ N/mm^2 \longrightarrow f_s = 200 \ N/mm^2$

$\therefore (k_1 = 0.711 \ , \ k_2 = 170.6)$ Given

$$\therefore d = k_1 \sqrt{\frac{M}{b}} = 0.711 \sqrt{\frac{33.55 \times 10^6}{1000}} = 130.2 \ mm$$

$$\therefore t = d + d' = 130.2 + 30 = 160.2 \longrightarrow 180 \ mm$$

$$\therefore d = 180 - 30 = 150 \ mm$$

$$\therefore As = \frac{M}{k_2 \times d} = \frac{33.55 \times 10^6}{170.6 \times 150} = 1311 \ mm^2$$

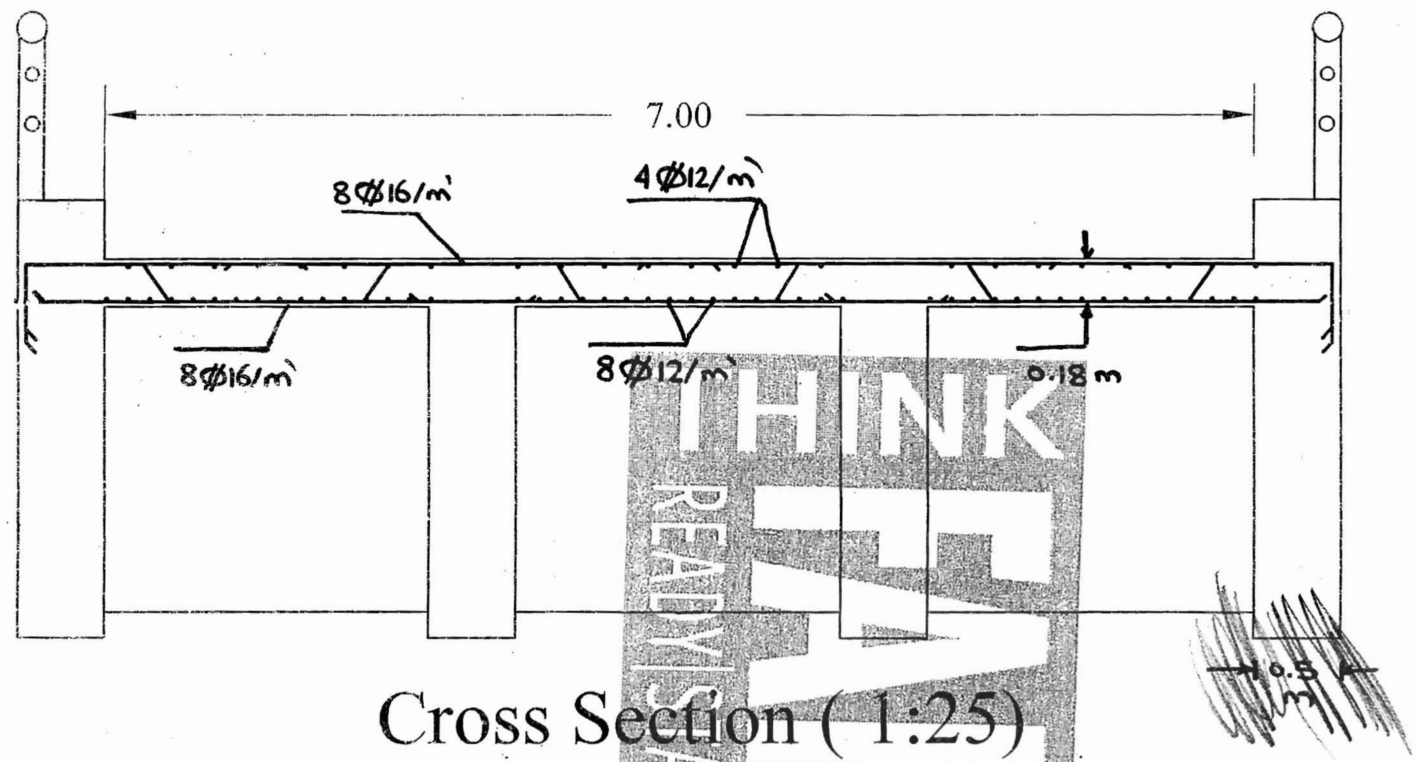
Use $As = 8 \phi 16 / m'$

$As' = 0.5 \ As$

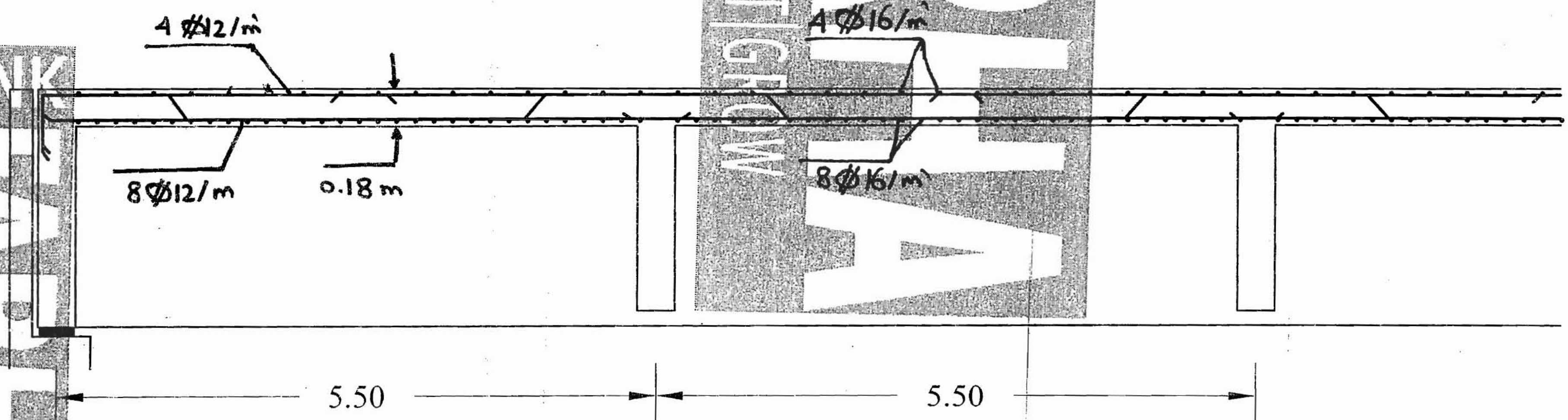
Use $As' = 8 \phi 12 / m'$

Drawing :

Two Sections (1:25)



Cross Section (1:25)



Long. Section (1:25)

B) Design of an intermediate M.G.

Assume

$$h_{MG} = \frac{Span}{10} = \frac{22}{10} = 2.20 \text{ m}$$

$$h_{xG} = h_{MG} - 0.20 = 2.20 - 0.20 = 2.00 \text{ m}$$

$$b_{xG} = 0.25 \text{ m}$$

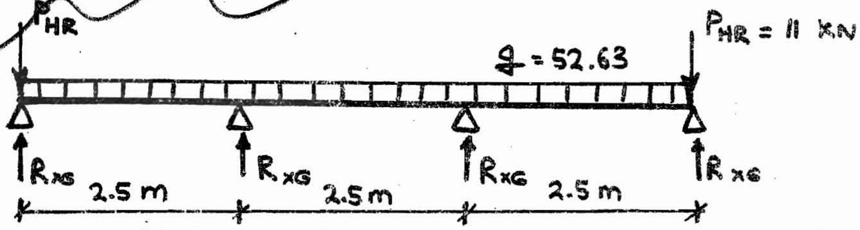
Dead load of X.G.

$$g = (h_{xG} - t_s) * b_{xG} * \gamma_{Rc} + (t_s * \gamma_{Rc} + cover) * b$$

$$g = (2 - 0.18) * 0.25 * 25 + (0.18 * 25 + 3) * 5.50$$

$$g = 52.63 \text{ kN/m'}$$

$$P_{HR} = 2 * 5.50 = 11 \text{ kN}$$



$$R_{xG} = \frac{52.63 * (3 * 2.5) + 2 * (11)}{4} = 104.18 \text{ kN}$$

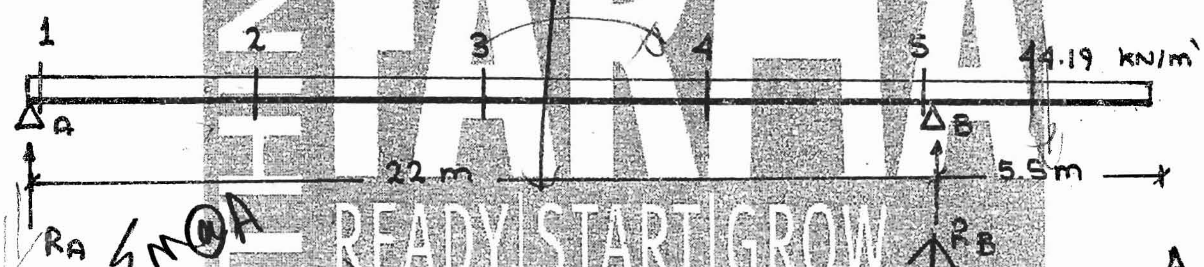
Dead load of M.G.

$$g_{MG} = \text{own wt.} + \frac{R \times G}{b}$$

$$g_{MG} = (h_{MG} - t_s) * b_{MG} * \gamma_{RC} + \frac{R \times G}{b}$$

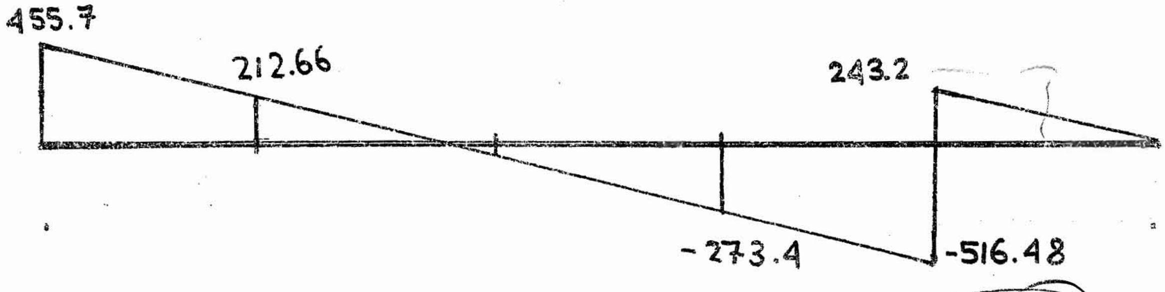
$$g_{MG} = (2.2 - 0.18) * 0.5 * 25 + \frac{104.18}{5.5}$$

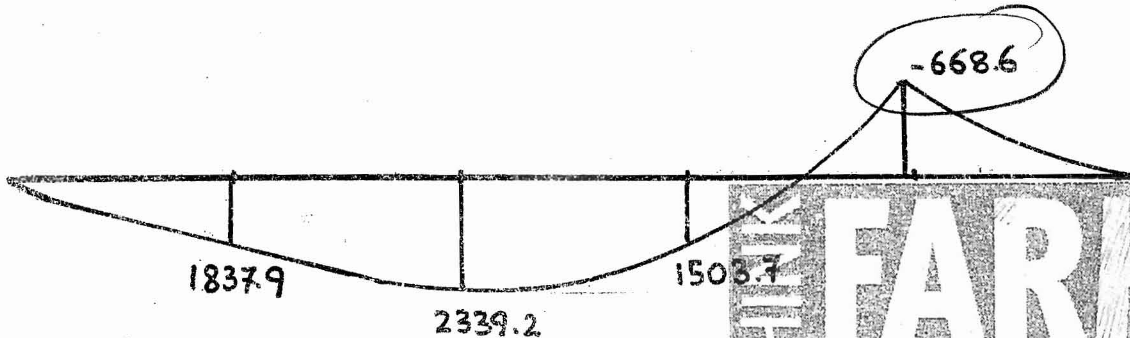
$$g_{MG} = 44.19 \text{ kN/m}'$$



$$R_B = \frac{44.19 * 27.5^2/2}{22} = 759.5 \text{ kN}$$

$$R_A = 44.19 * 27.5 - 759.5 = 455.7 \text{ kN}$$





Live Load of M.G.

Design of an intermediate M.G. (Infl. line for RB)

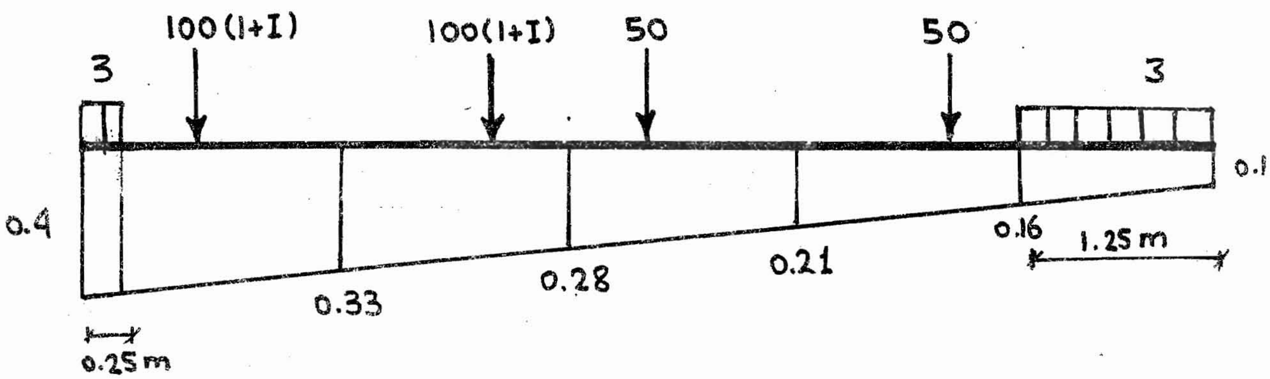
$I = 0.4 - 0.008\ L$

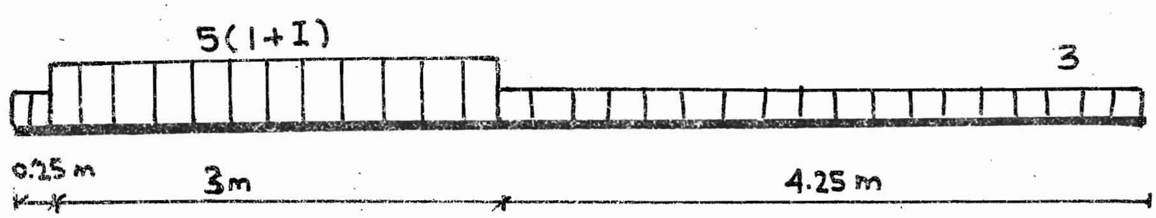
for interior span

$I = 0.4 - 0.008(22) = 0.224$

for cantilever part

$I = 0.4 - 0.008(5.5) = 0.356$





For interior span :

$$W = 2*100*1.224*0.33 + 2*50*0.21 = 101.78 \text{ kN}$$

$$q_1 = 3(0.4*0.25 + 1.25*\frac{0.1+0.16}{2}) = 0.787 \text{ kN/m}'$$

$$q_2 = 5(1.224)*3*0.33 + 3(0.4*0.25 + 4.25*\frac{0.1+0.28}{2})$$

$$q_2 = 8.78 \text{ kN/m}'$$

For cantilever part:

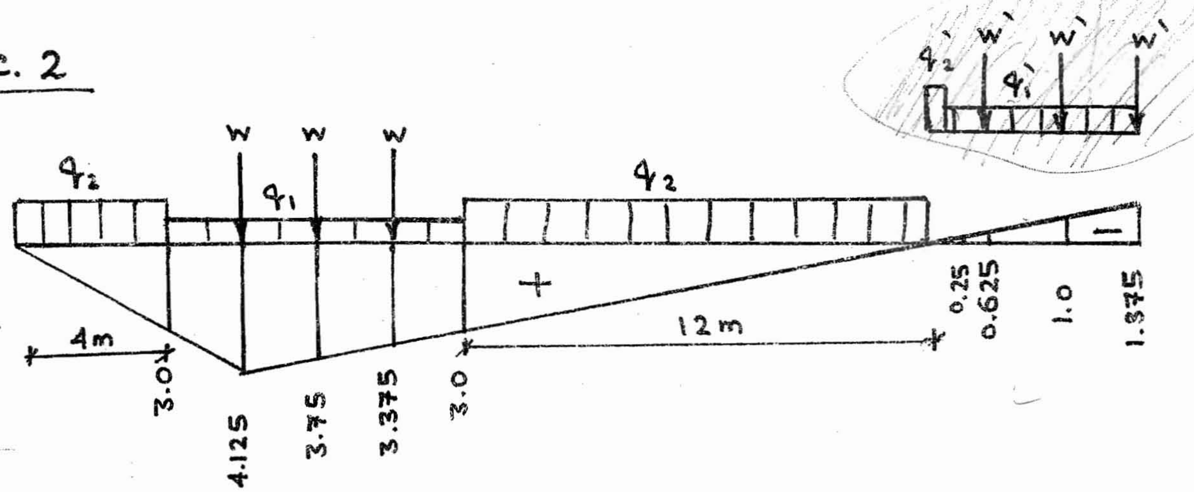
$$W' = 2*100*1.356*0.33 + 2*50*0.21 = 110.5 \text{ kN}$$

$$q_1' = 0.787 \text{ kN/m}'$$

$$q_2' = 5(1.356)*3*0.33 + 3(0.4*0.25 + 4.25*\frac{0.1+0.28}{2})$$

$$q_2' = 9.43 \text{ kN/m}'$$

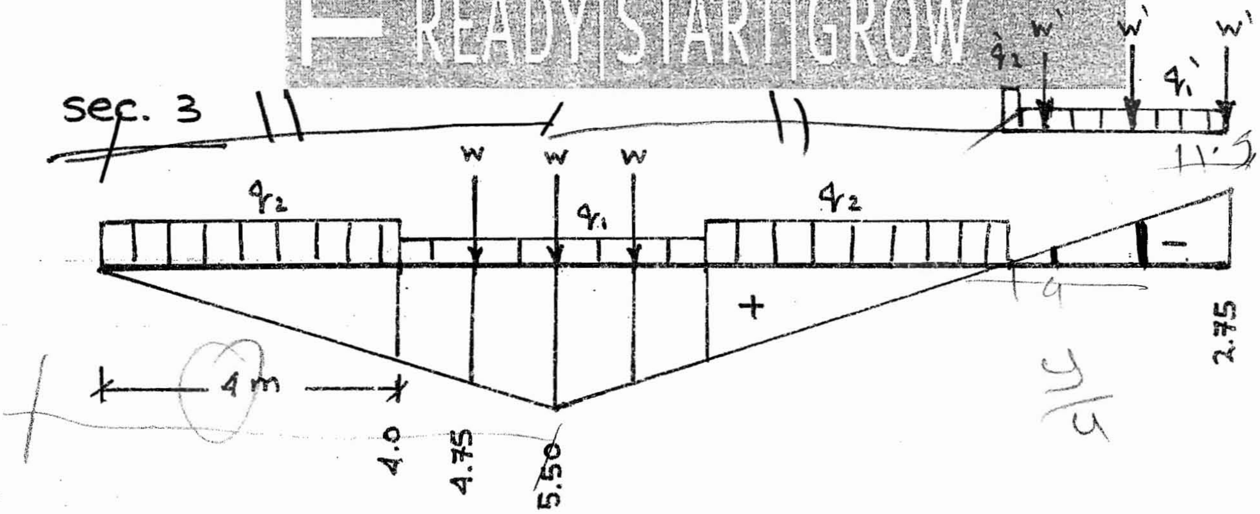
sec. 2



$$M_{LL_{2+ve}} = W(4.125 + 3.75 + 3.375) + q_1\left(\frac{3+3.75}{2} * 1.5\right) + q_1\left(\frac{4.125+3}{2} * 4.5\right) + q_2(0.5 * 4 * 3) + q_2(0.5 * 12 * 3) = 1372.3 \text{ kN.m}$$

$$M_{LL_{2-ve}} = W'(1.375 + 1.0 + 0.625) + q_1'\left(\frac{1.375+0.25}{2} * 4.5\right) + q_2'(0.5 * 0.25 * 1) = -335.56 \text{ kN.m}$$

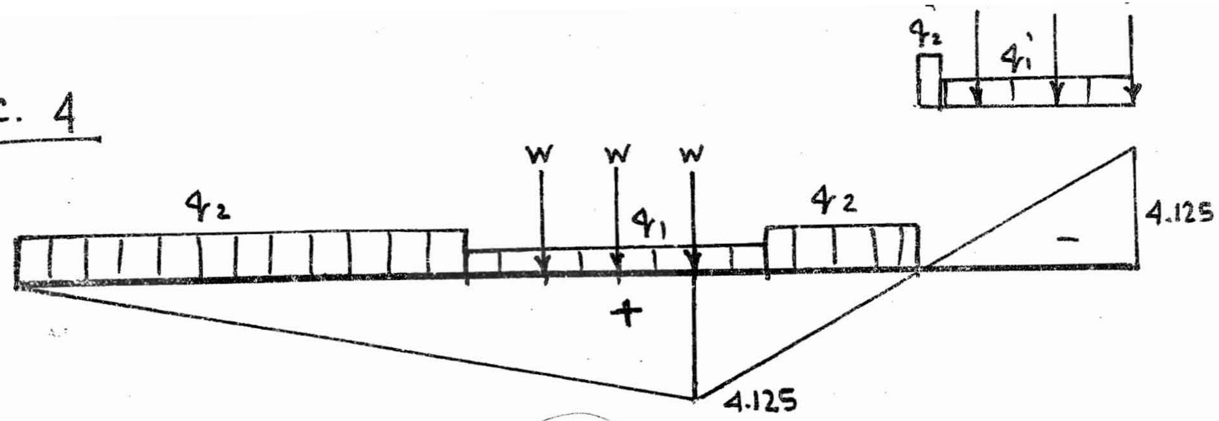
sec. 3



$$M_{LL_{3+ve}} = W(5.5 + 2 * 4.75) + q_1(4.75 * 6) + q_2(0.5 * 4 * 4) * 2 = 1689.6 \text{ kN.m}$$

$$M_{LL_{3-ve}} = M_{LL_{-ve_2}} * 2 = -671.11 \text{ kN.m}$$

Sec. 4



$M_{LL_{4+ve}} = M_{LL_{2+ve}} = 1372.3$ kN.m

$M_{LL_{4-ve}} = M_{LL-ve_2} * 3 = -1006.67$ kN.m

Sec. 5

$M_{LL_{5+ve}} =$ zero

$M_{LL_{5-ve}} = M_{LL_{2-ve}} * 4 = -1342.22$ kN.m

Sec.	M_{DL}	M_{LL} +ve	M_{LL} -ve	M_{Max}	M_{Min}	
2	1837.9	1372.3	-335.56	3210.2	1502.3	
3	2339.2	1689.6	-671.11	4028.8	1668.1	Max +ve
4	1503.7	1372.3	-1006.67	2876	497.03	
5	-668.6	0	-1342.22	-668.6	-2010.8	Max -ve

Design for moment:

For +ve Moment (T- Sec)

$$B \rightarrow \begin{cases} b_{MG} + 16\,t_s = 500 + 16 * 180 = 3380 \text{ mm} \\ \text{spacing of M.G.} = 2500 \text{ mm} \\ b_{MG} + \frac{L'}{5} = 500 + \frac{22000}{5} = 4900 \text{ mm} \end{cases}$$

Use $B = 2500$ mm

$$\therefore\ x = 0.44\sqrt{\frac{M_{+ve}}{B}} = 0.44\sqrt{\frac{4028.8 \times 10^6}{2500}} = 558.6 \text{ mm}$$

$$B_e = b_{MG} + (B - b_{MG}) * \frac{t_s}{x}\left(2 - \frac{t_s}{x}\right)$$

$$B_e = 500 + (2500 - 500) * \frac{180}{558.6}\left(2 - \frac{180}{558.6}\right)$$

$$B_e = 1581.3 \text{ mm}$$

$$\therefore\ d = k_1' \sqrt{\frac{M_{+ve}}{B_e}} = 0.968\sqrt{\frac{4028.8 \times 10^6}{1581.3}} = 1545 \text{ mm}$$

$$\therefore\ h_{MG} = 1545 + 100 = 1645 \text{ mm} \longrightarrow 2200 \text{ mm}$$

$$\therefore\ d_{act} = 2200 - 100 = 2100 \text{ mm}$$

$$As_{+ve} = \frac{M_{+ve}}{k_2' \times d} = \frac{4028.8 \times 10^6}{177 \times 2100} = 10839 \text{ mm}^2$$

Use 14 Ø 32

For -ve moment (Rec. sec.)

$$As_{-ve} = \frac{M_{-ve}}{k_2 \times d} = \frac{2010.8 \times 10^6}{170.6 \times 2100} = 5612.7 \ mm^2$$

7Ø32

$$As' = 0.2 \ As_{+ve} = 0.2 * 10839 = 2167.8 \ mm^2$$

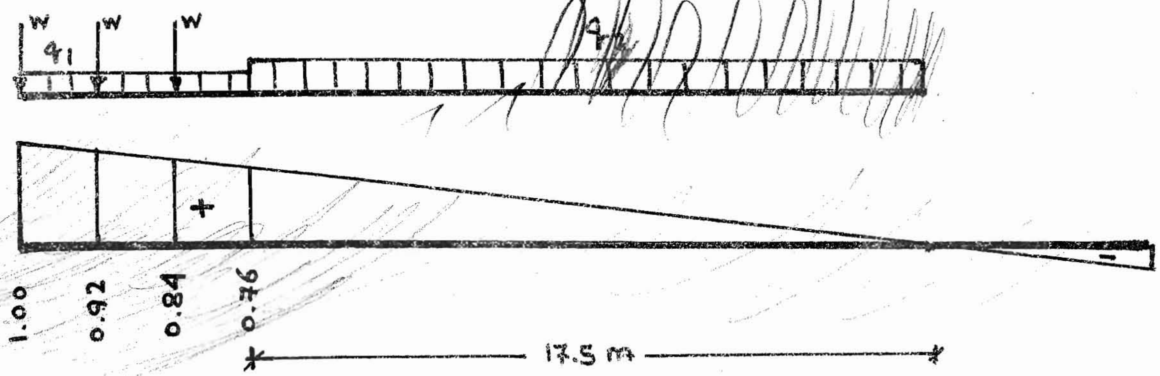
4Ø28

$$A_{sh} = 0.08 \ As = 867.12 \ mm^2$$

Use 2Ø12 mm @ 300 mm (Shrinkage steel)

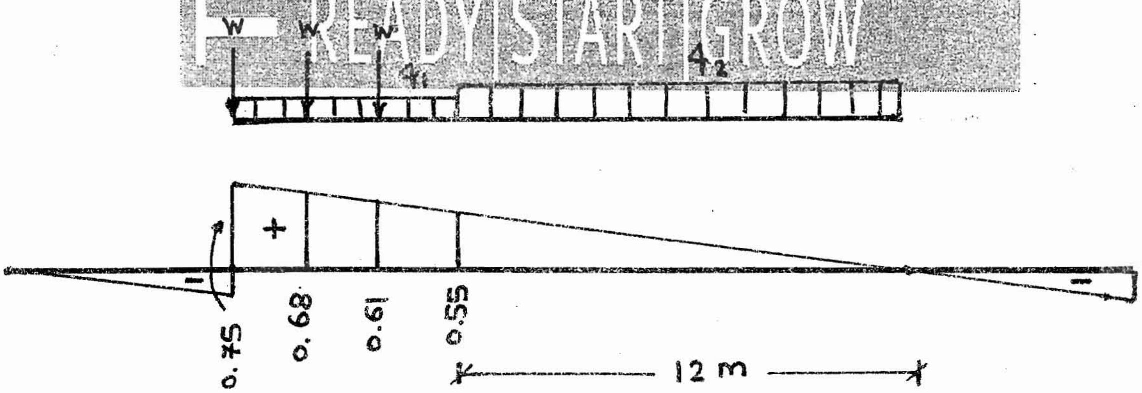
Loading for shear :

Sec. 1



$$Q_1 = w\,(1 + 0.92 + 0.84) + q_1\left(\frac{1 + 0.76}{2}\right) * 4.5 + q_2\,(0.5 * 17.5 * 0.76) = 342.42 \text{ kN}$$

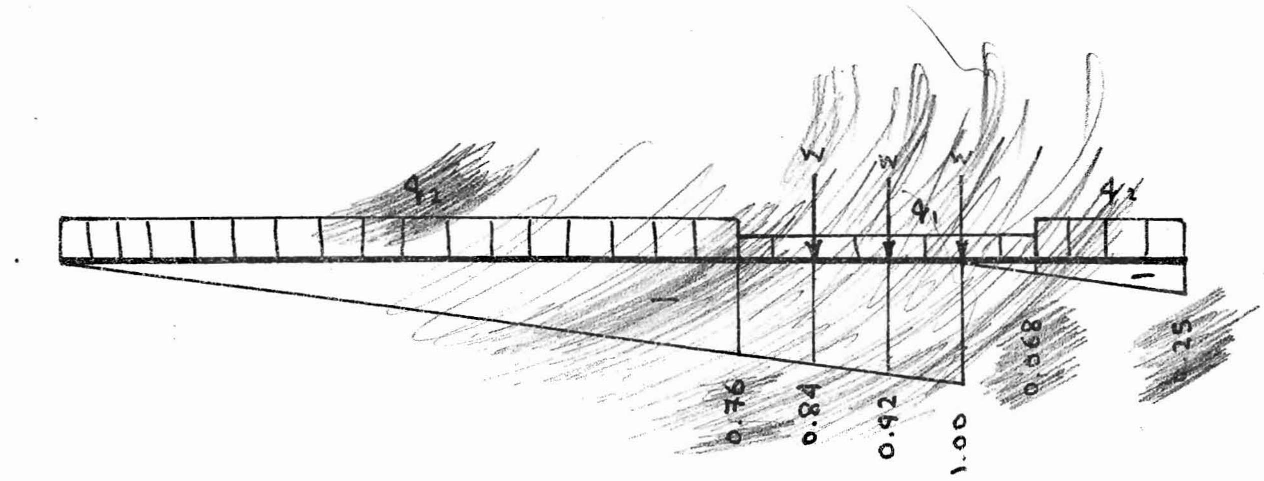
Sec. 2



$$Q_2 = w\,(0.75 + 0.68 + 0.61) + q_1\left(\frac{0.75 + 0.55}{2}\right) * 4.5 + q_2\,(0.5 * 12 * 0.55) = 238.91 \text{ kN}$$

THINK FARHA
READY|START|GROW

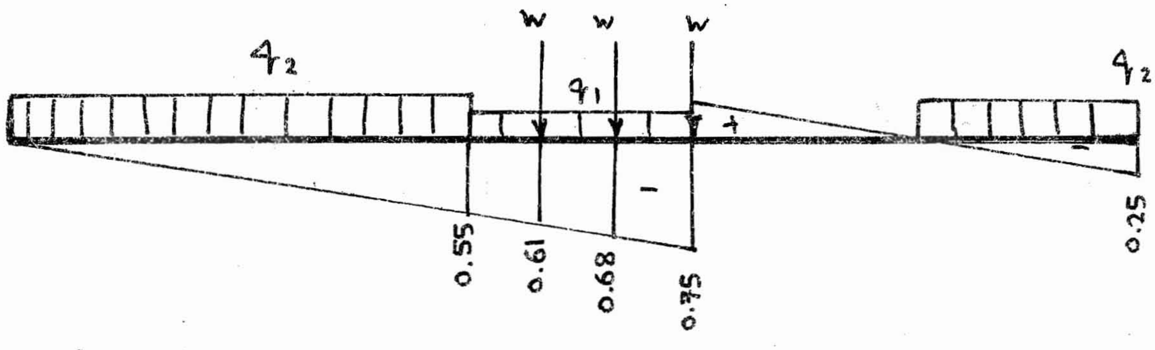
Sec. 5_L



$$Q_{5_L} = -Q_1 + q_1(0.5 * -0.068 * 1.5) + q_2\left(\frac{-0.068 - 0.25}{2} \times 4\right)$$

$$Q_{5_L} = -342.42 - 5.62 = -348 \text{ kN}$$

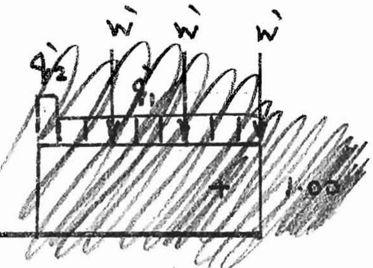
Sec. 4



$$Q_4 = -Q_2 + q_2(0.5 * -0.25 * 5.5)$$

$$Q_4 = -238.91 - 6.04 = -244.95 \text{ kN}$$

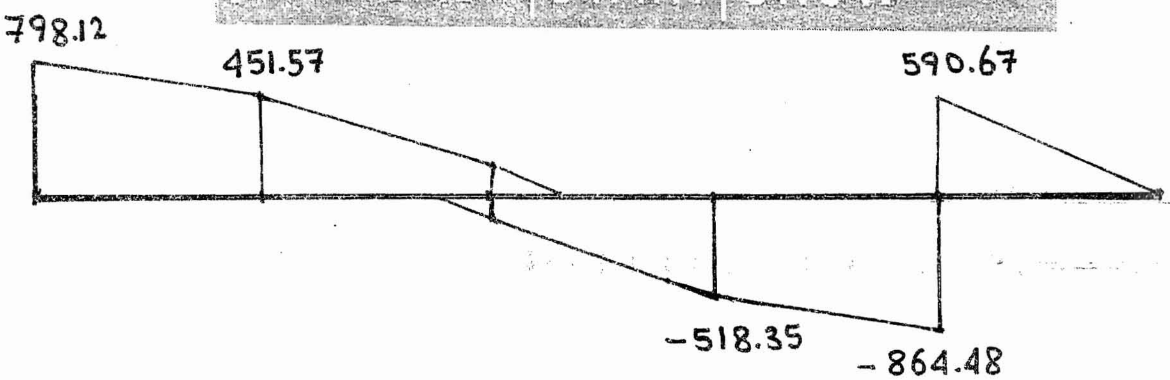
Sec. 5_R



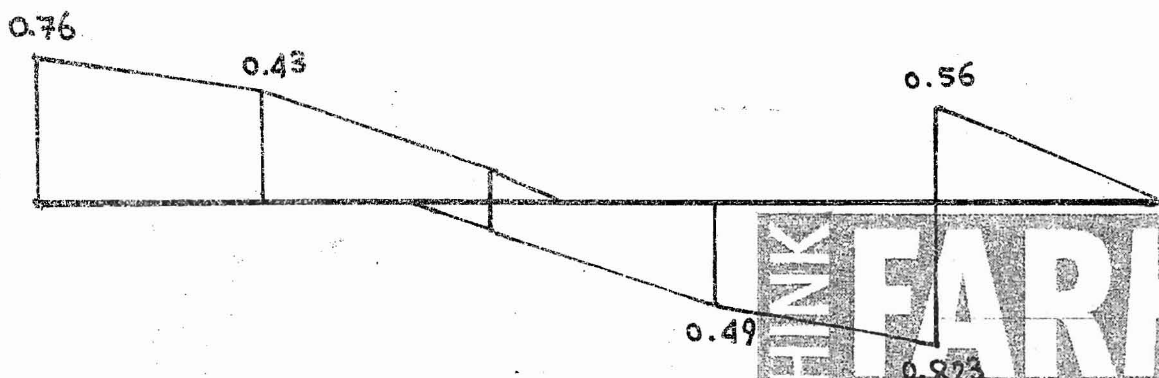
~~$Q_{5_R} = w'(1+1+1) + q_1'(1 * 4.5) + q_2'(1 * 1)$~~

$Q_{5_R} = 347.47$ kN

MAXIMUM S.F.D



Shear Stress Diagram:



Check of shear stress:

$$q = \frac{Q \times 10^3}{b_{MG} \times d_{MG}} = \frac{Q \times 10^3}{500 \times 2100} = \checkmark \quad N/mm^2$$

Section at B_{Left}

assume shear Rft (Minimum)

Concrete : $\frac{q_c}{2} = \frac{0.7}{2} = 0.35 \; N/mm^2$

Stirrups : 4 br. st. ϕ 10 @ 200 mm

$$q_{st} = \frac{4 \times 79 \times 140}{500 \times 200} = 0.44 \; N/mm^2$$

bent_up bars : 2 ϕ 32 @ ~~d~~ 2100 mm

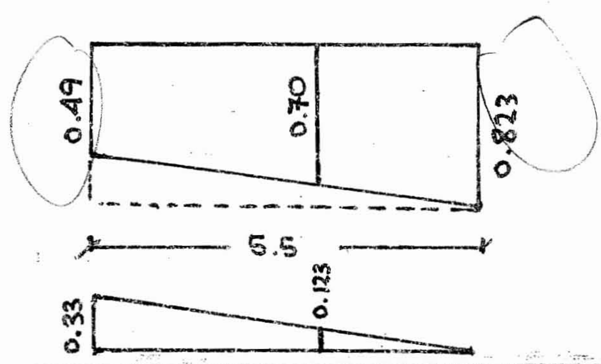
$$q_b = \frac{n \times A_b \times f_s}{b \times S_b}$$

$$q_b = \frac{2 \times 804 \times 200}{500 \times 2100} = 0.31 \; N/mm^2$$

$$\therefore q_{total} = 0.35 + 0.44 + 0.31 = 1.1 \; N/mm^2 \not> q_{max}$$

ok

Calculating no. of bents



$$\frac{X}{0.123} = \frac{5.5}{0.33} \qquad \therefore X = 2.05 \; m$$

$$\therefore n_b = \frac{2.05}{~~d~~ \; 2.1} = 0.98 \longrightarrow 1$$

Take $S_b = 2.05$ m

Section at A_R

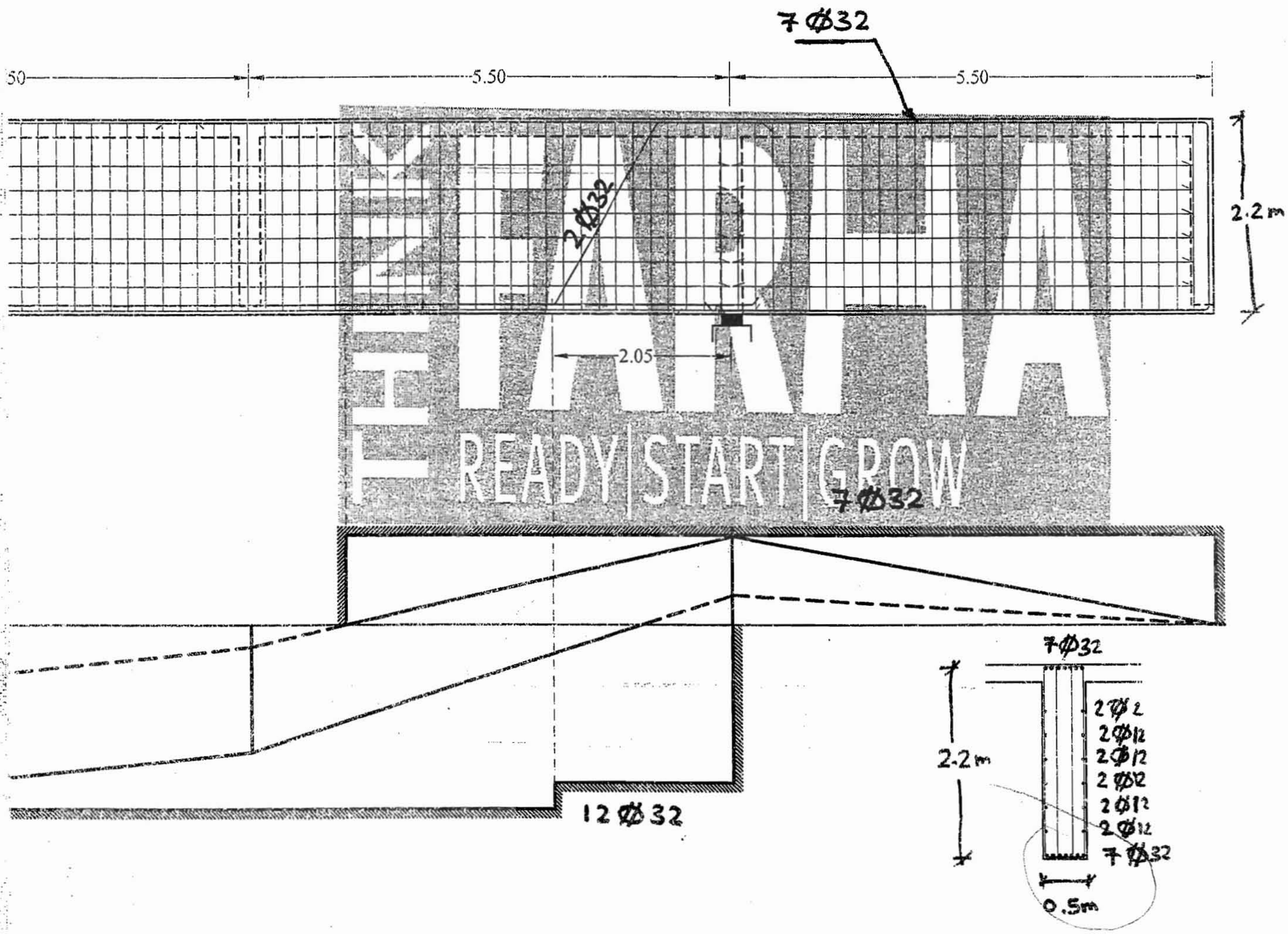
Use the same arrangment for B_L

section at B_R

Use concrete & stirrups only

$\therefore q_{total} = 0.35 + 0.44 = 0.79 \text{ N/mm}^2 > q_{B_R}$

ok.


7Ø32
50
5.50
5.50
2Ø32
2.2 m
2.05
7Ø32
12Ø32
7Ø32
2Ø2
2Ø12
2Ø12
2Ø12
2Ø12
2Ø12
7Ø32
2.2m
0.5m

problem 2 (20%)

A- which is of the following statements False and which is True :

1- False

2- True

3- False

4- True

5- False

6- True

7- False

8- True

B- check the stresses :

$I = 26 \times 10^{10}\ mm^4$

$y_1 = 1100\ mm \quad , \quad y_2 = 700\ mm$

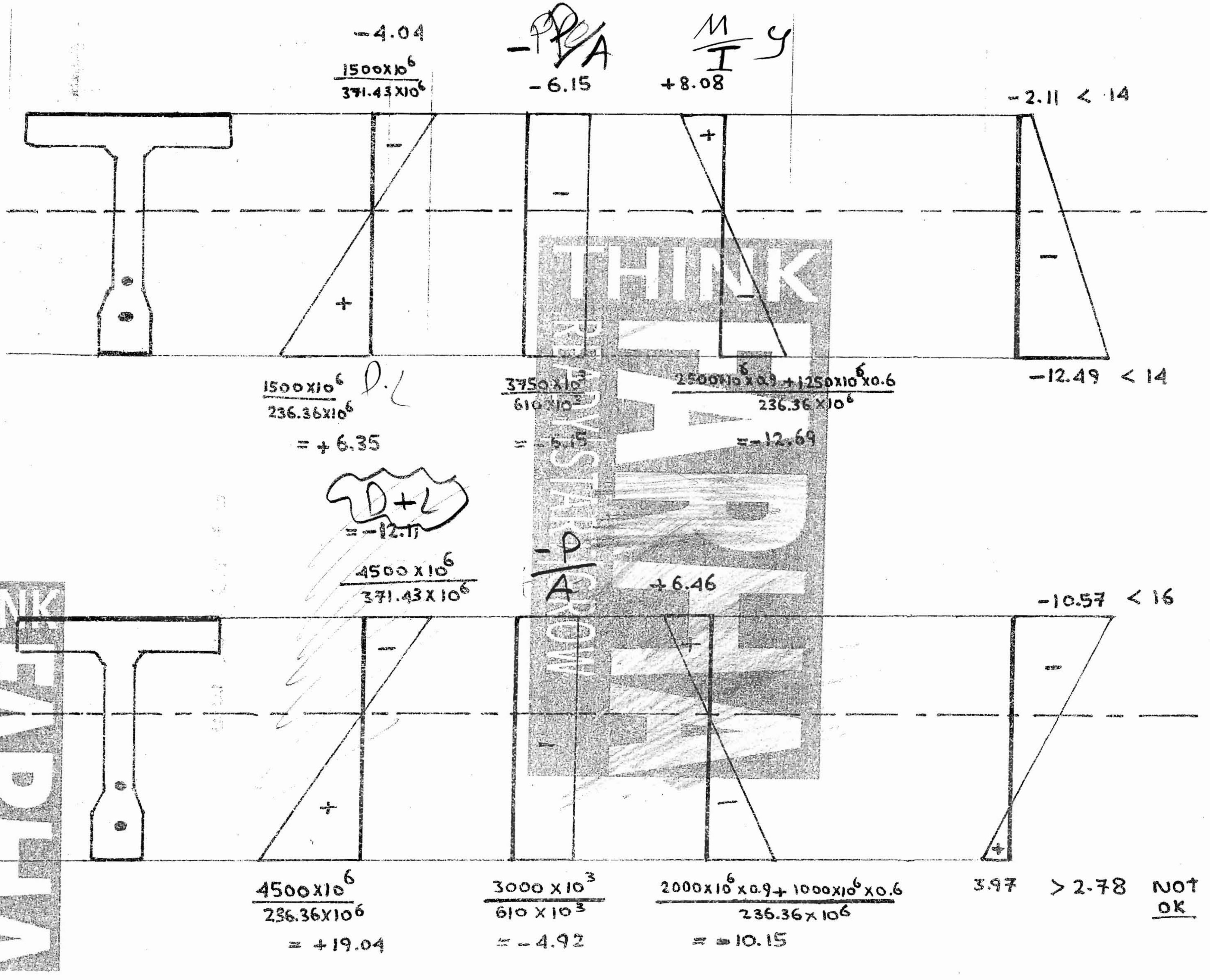
$Z_1 = \frac{I}{y_1} = 236.36 \times 10^6\ mm^3$

$Z_2 = \frac{I}{y_2} = 371.43 \times 10^6\ mm^3$

$A = 610 \times 10^3\ mm^2$

$M_{DL} = 1500\ kN.m$

$M_{LL} = 3000\ kN.m$


-4.04
1500X10^6 / 371.43X10^6
-P/A
-6.15
M/I y
+8.08
-2.11 < 14
1500X10^6 / 236.36X10^6
= +6.35
D.L
3750X10^3 / 610X10^3
2500X10^6 X0.9 + 1250X10^6 X0.6 / 236.36X10^6
=-12.69
-12.49 < 14
D+L
=-12.11
4500X10^6 / 371.43X10^6
-P/A
+6.46
-10.57 < 16
4500X10^6 / 236.36X10^6
= +19.04
3000X10^3 / 610X10^3
= -4.92
2000X10^6 X0.9 + 1000X10^6 X0.6 / 236.36X10^6
= 10.15
3.97 > 2.78 NOT OK

allowable Limits:

1. At Transfer:

$$f_{tt} = 0.22\sqrt{f_{cui}} = 0.22\sqrt{35} = 1.3 \ N/mm^2$$

$$f_{ct} = 0.45 \ f_{cui} = 0.45 * 35 = 14 \ N/mm^2$$

2. At. Life Time:

$$f_{tw} = 0.44\sqrt{f_{cu}} = 0.44\sqrt{40} = 2.78 \ N/mm^2$$

$$f_{cw} = 0.40 \ f_{cu} = 0.40 \times 40 = 16 \ N/mm^2$$

Alexandria University
Faculty of Engineering
4 th Year Civil Engineering
Reinforced Concrete Bridges

End of Term Exam
Time Allowed 3 hours
Date Jan., 2009

- Notes, Data books, Codes and Tables are <u>NOT allowed</u> in the examination room
- Show all calculation steps clearly in detail.
- Assume ANY missing data you might need.
- Use the Standard Truck

<u>I-Problem 1 (75%)</u>

The <u>SLAB and GIRDER</u> bridge, shown in Fig. 1, has Main Girders which are beams with *TWO Cantilevers*. The MG inetrior span, L= 16.0m., and each cantilever = 4.0 m. The clear road width of the bridge = 6.0m. The bridge consists of 3 **Main girders**. The **Cross Girders** are spaced at 4.0m. apart. The breadth of the Main Girder = 0.40m., the breadth of X.G, b_{xg} = 0.20m .

1- It is required to give full calculations and design for the:

a) **Slabs**

b) An intermediate main girder. Use <u>**BOTH** stirrups and **BENT UP** bars</u> arrangement.

2- Give complete working drawings for :

i) Slabs (two cross sections and plan), (appropriate scale).

ii) One **Half Longitudinal** section and **Transverse** cross-sections of the designed Main girder showing all reinforcement details and dimensions (scale 1:25). Draw clearly the **<u>maximum max. bending moment diagram and moment of resistance</u>** . BM values are required at 3 points (1, 2, & 3) as shown.

<u>II- Problem 2 (25%)</u>

A- Mention the main types of losses in presuress (Just Mention).

B- Which of the following statements is False and which is True (JUST write false or true)

1- Pretensioning and post-tensioning are related to the time of concrete casting

2- Anchorages are needed at the beam ends for pretensioned beams.

3- Circular Concrete Tanks can be either postioned or pretensioned

4- Prestressed concrete is related to the time of application of the applied load on a member

5- There are losses in externally bonded pre-tensioned cables

6-Prestressing cables are always located in the lower side of the section.

7- Prestressing can reduce deflection.

8. Post-tensioning forces are applied before casting the concrete.

9. Unbonded cables are used in pretension.

C- For the Pre-stressed concrete beam with the section shown in **Fig. 2**

Data:

- Initial Prestressing force = 2700 kN, Final Prestressing force after losses= 2200 kN, Eccentricity of cables = 0.80m (from CL)
- Applied working positive bending moments are: M DL= 1300 kN.m, M L.L = 2200 kN.m

Concrete strength f_{cui} = 40N/mm^2 , f_{cu} = 50 N/mm^2

Area = 600 * 10^3 mm^2 , Section Moment of Inertia I = 25 * 10^{10} mm^4

- Draw the stresses in the section and check against the allowable limits:
  1- At time of transfer
  2- In the lifetime (t =∞).

Data for problem 1

For $f_{cu} = 30\ N/mm^2$ and for st 360/520 $f_s = 200\ N/mm^2$

$f_c = 10.5\ N/mm^2$ for beams and slabs deeper than 200mm; $k_1 = 0.711$ $k_2 = 170.6$

$f_c = 7.0\ N/mm^2$, $k_1 = 0.968$, $k_2 = 177$

Area of steel bars (mm^2)

Diameter mm	8	10	13	16	19	22	25	28	32
Area of one bar, mm^2	50	79	132	201	284	380	491	616	804

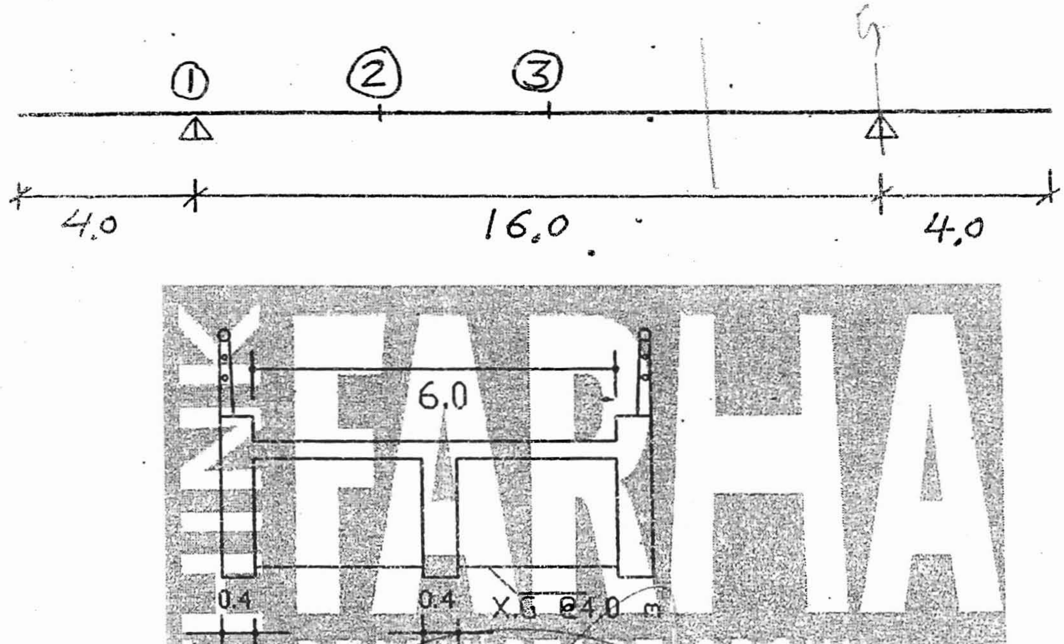
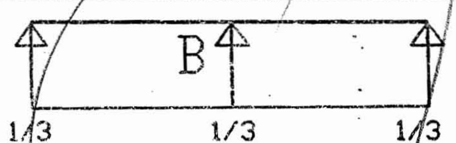


Fig. 1



I.L R_B [stiff Girder]

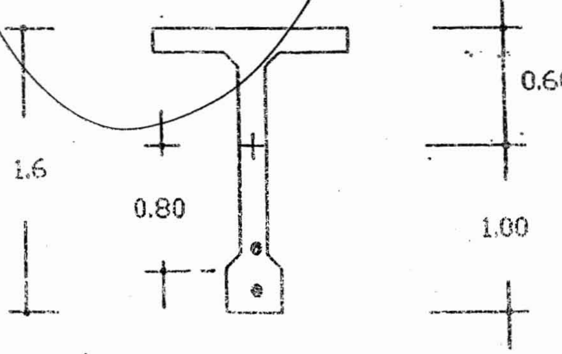


Fig. 2

January 2009

Design of slabs:

[redacted]

$\therefore r = \dfrac{4 \times 0.76}{3.2 \times 0.76} = 1.25$

$r = 1.25 \longrightarrow$ Two way slab in DL & LL

Dead load:

$t = \dfrac{a}{15} = \dfrac{3.2}{15} = 0.21 \rightarrow 0.22\ m$

$\therefore$ own wt $= 0.22 * 25 = 5.5\ kN/m^2$

covering $= 3\ kN/m^2$

$\therefore g =$ own wt + covering $= 5.5 + 3 = 8.5\ kN/m^2$

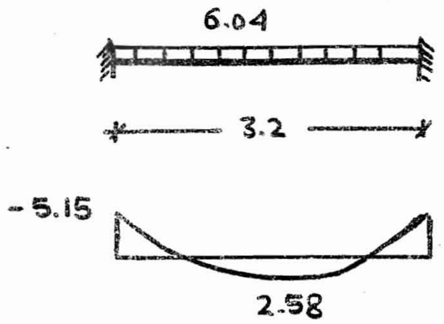
(Two way) نوع البلاطه

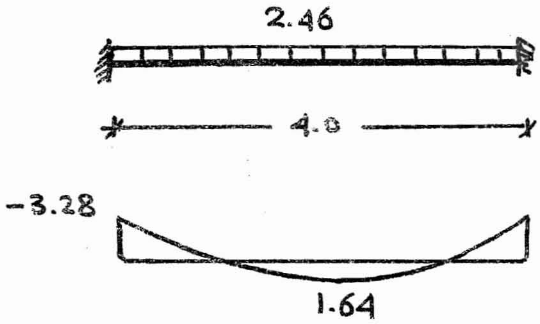
$\therefore \alpha = \dfrac{r^4}{1+r^4} = 0.71$

$\beta = \dfrac{1}{1+r^4} = 0.29$

$\therefore g_1 = \overset{\alpha}{0.71} * \overset{g}{8.5} = 6.04\ kN/m^2$

$g_2 = \overset{\beta}{0.29} * \overset{g}{8.5} = 2.46\ kN/m^2$





$M_{-ve} = \frac{-6.04 \times 3.2^2}{12} = -5.15$ kN.m/m'

$M_{+ve} = \frac{6.04 \times 3.2^2}{24} = 2.58$ kN.m/m'

$M_{-ve} = \frac{-2.46 \times 4^2}{12} = -3.28$ kN.m/m'

$M_{+ve} = \frac{2.46 \times 4^2}{24} = 1.64$ kN.m/m'

Live load:

→ case of one wheel:

$S_1 = 0.2 + 2C + T = 0.2 + 2 * 0.15 + 0.22 = 0.72$ m

$S_2 = 0.6 + 2C + T = 0.6 + 2 * 0.15 + 0.22 = 1.12$ m

→ Two way slab:

$\therefore S_{1F} = S_1 + 0.4\, a' \left(2 - \frac{a'}{b'}\right)$

$\therefore S_{1F} = 0.72 + 0.4\,(0.76 * 3.2)\left[2 - \frac{3.2 \times 0.76}{4 \times 0.76}\right]$

$S_{1F} = 1.887$ m $\ngtr 1.5$ m

$\ngtr b = 4$ m

Take $S_{1F} = 1.5$ m

$\therefore S_{2F} = S_2 + 0.4\, a'$

$S_{2F} = 1.12 + 0.4 * 0.76 = 2.1$ m $\ngtr 2$m

$\ngtr 3$m

$\ngtr a = 3.2$ m

Take $S_{2f} = 2\,m$

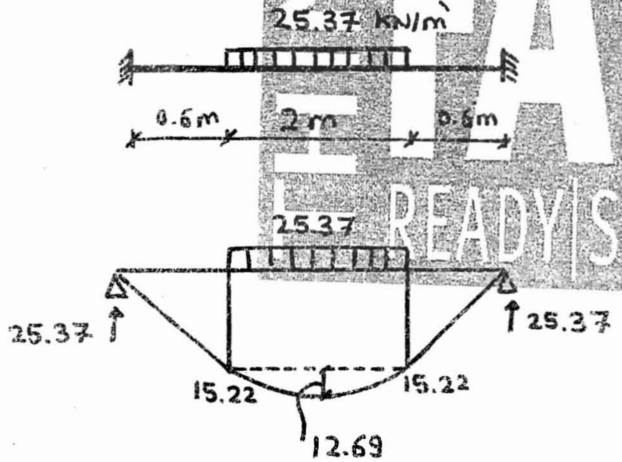
[redacted]

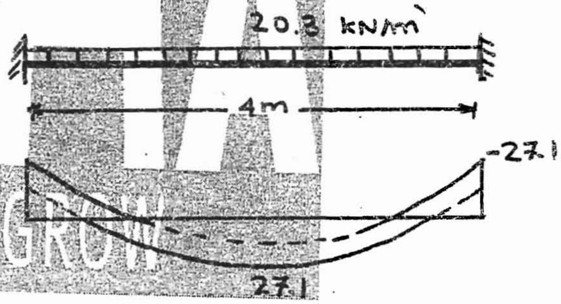
$$\therefore P = \frac{100 * (1+I)}{S_{1f} * S_{2f}}$$

$$\therefore P = \frac{100 * 1.37}{1.5 * 2} = 45.667 \quad kN/m^2$$

$$\therefore P_1 = 45.667 \times \frac{4}{3.2+4} = 25.37 \quad kN/m'$$

$$P_2 = 45.667 \times \frac{3.2}{3.2+4} = 20.29 \quad kN/m'$$



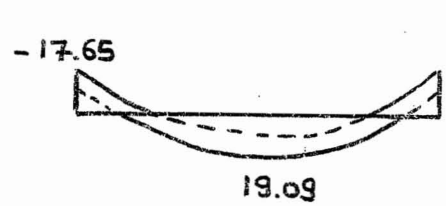


$$M_{+ve} = M_{-ve} = \frac{20.3 \times 4^2}{12}$$

$$M_{+ve} = M_{-ve} = 27.1\ kN.m$$

$$\text{Area of BMD} = 15.22 * 2 + 0.5 * 15.22 * 0.6 \times 2 + \frac{2}{3} \times 12.69 * 2 = 56.49\ kN.m^2$$

$$\therefore M_f = \frac{56.49}{3.2} = 17.65\ kN.m$$



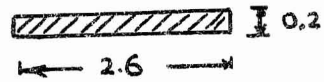
$$M_o = 15.22 + 12.69 = 27.91\ kN.m$$

$$\therefore M_{+ve} = 27.91 - \frac{17.65}{2} = 19.09\ kN.m$$

→ Case of two wheels

$S_{2f} = 2.1\,m$ ⟶ one wheel من حالة

∴ العجل يتداخل ويتم حلهم كعجله واحدة



$S_1 = 0.2 + 2C + t$

$S_{1f} = S_1 + 0.4\,a'(2 - a'/b')$

مثل حالة one wheel بالضبط

∴ $S_{1f} = 1.89 \ngtr 1.5\,m$ نأخذ نفس الأرقام

∴ $S_{1f} = \underline{1.5\ m}$

∴ $S_2 = 2.6 + 2C + t = 3.12\ m$

$S_{2f} = S_2 + 0.4\,a = 3.12 + 0.4 * 0.76 * 3.2 = 4.09\ m$

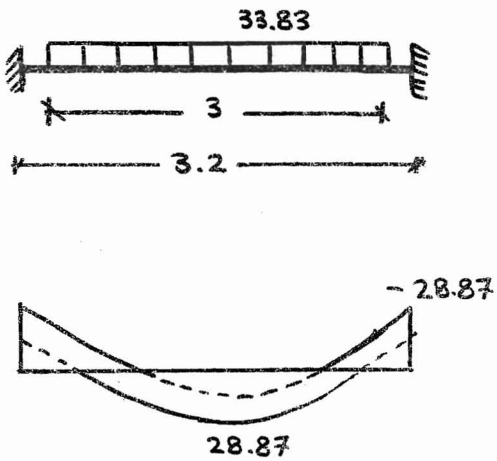
∴ Take $S_{2f} = \underline{3\ m}$ $\ngtr a = 3.2\,m$
$\ngtr 3\,m$

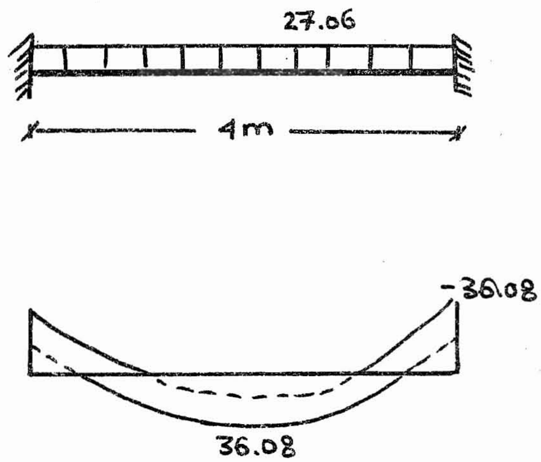
∴ $P = \dfrac{200\,(1 + I)}{S_{1f} \times S_{2f}}$

∴ $P = \dfrac{200 * 1.37}{1.5 \times 3} = 60.89\ kN/m^2$

∴ $P_1 = 60.89 * \dfrac{4}{3.2 + 4} = 33.83\ kN/m'$

$P_2 = 60.89 * \dfrac{3.2}{3.2 + 4} = 27.06\ kN/m'$





$M_{+ve} = M_{-ve} = \frac{33.83 \times 3.2^2}{12}$

$M_{+ve} = M_{-ve} = 28.87$ kN.m

$M_{+ve} = M_{-ve} = \frac{27.06 \times 4^2}{12} = 36.08$ kN.m

Total Moments

- Short Direction

$M_{+ve} = 2.58 + 28.87 = 31.45$ kN.m

$M_{-ve} = -5.15 - 28.87 = -34$ kN.m

- Long Direction

$M_{+ve} = 1.64 + 36.08 = 37.72$ kN.m

$M_{-ve} = -3.28 - 36.08 = -39.36$ kN.m

$\Longrightarrow M_{Max} = 39.36$ kN.m

Design :

$$d_{Min} = k_1 \sqrt{\frac{M_{max}}{b}} = 0.712 \sqrt{\frac{39.36 \times 10^6}{1000}} = 141.3 \text{ mm}$$

Take $T = d + 40 = 141.3 + 40 = 181.3 \rightarrow 200$ mm

$\therefore d_1 = 200 - 40 = 160$ mm

Short Direction :

$$As_{+ve} = \frac{31.45 \times 10^6}{170.6 \times 160} = 1152 \text{ mm}^2$$

$$As_{-ve} = \frac{34 \times 10^6}{170.6 \times 160} = 1245 \text{ mm}^2$$

Long Direction :

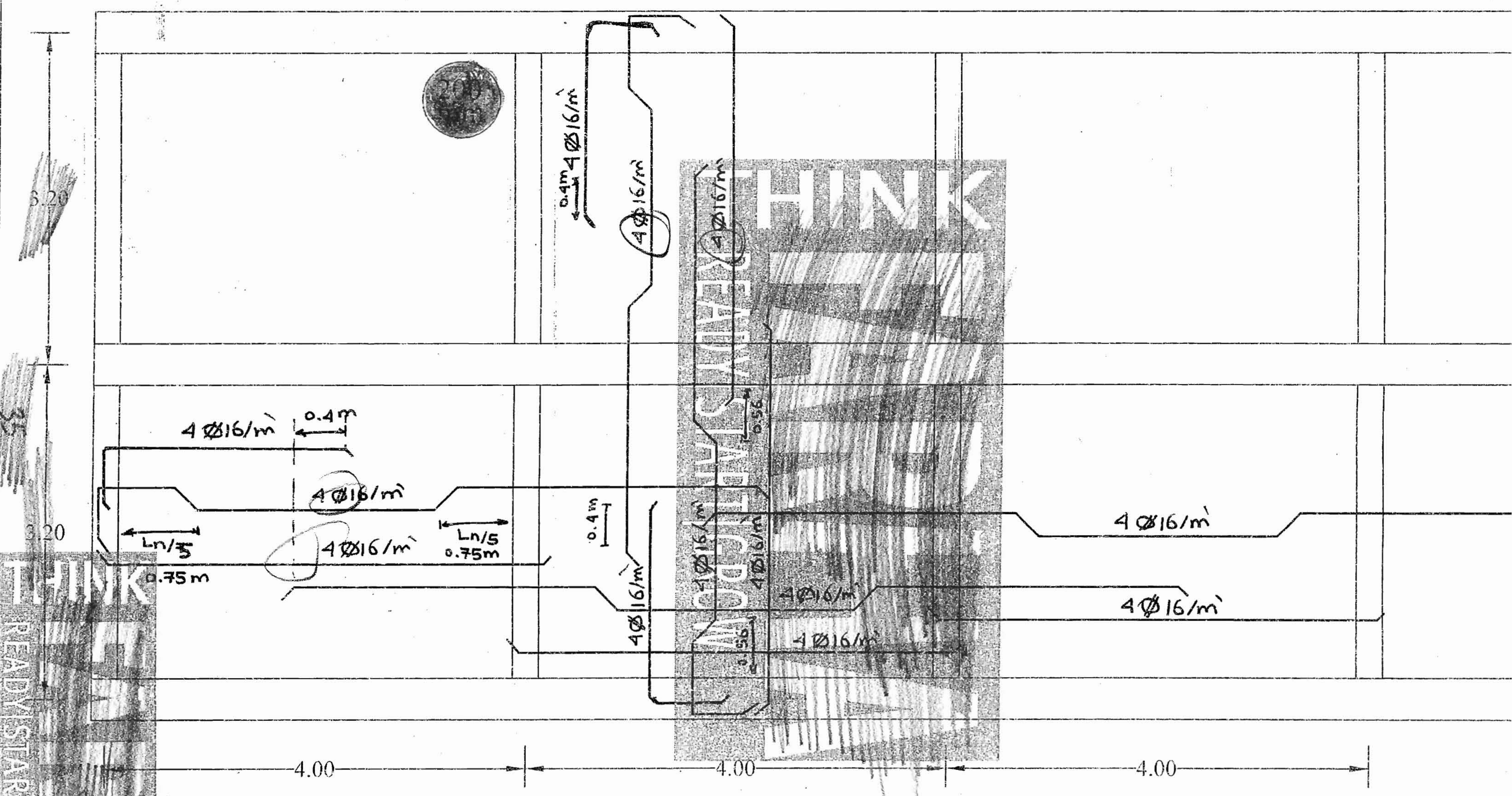
القطر المستخدم في Short Dir.

$$d_2 = 160 - 16 = 144 \text{ mm}$$

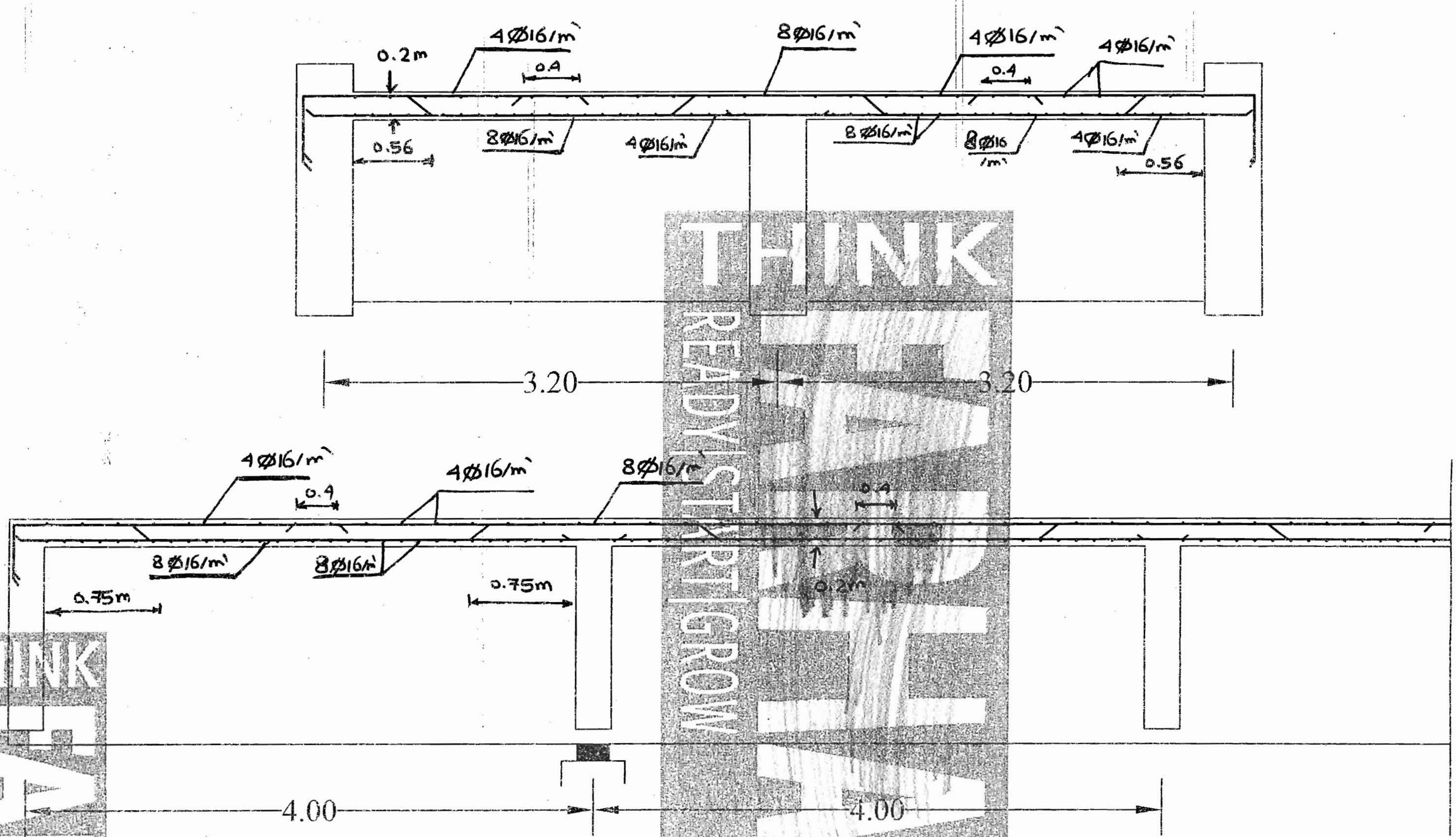
$$\therefore As_{+ve} = \frac{37.72 \times 10^6}{170.6 \times 144} = 1535 \text{ mm}^2$$

$$As_{-ve} = \frac{39.36 \times 10^6}{170.6 \times 144} = 1602 \text{ mm}^2$$

use **8Ø16** in Short & Long Directions



Plan (1:50)



Sections (1:25)

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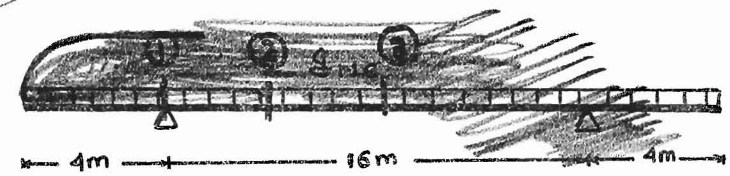
Design of Intermediate MG:

~~$h_{MG} = \frac{span}{10} = \frac{16}{10} = 1.6\ m$~~

$h_{XG} = h_{MG} - 0.2\ m$

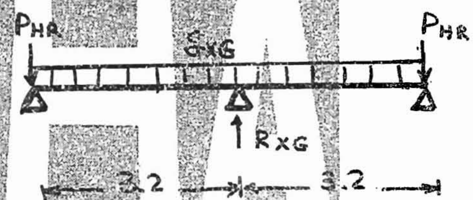


$h_{XG} = 1.5\ m$

Calculating R_{XG}

$g_{XG} = (0.2 * 25 + 3) * 4.0 + 0.2 * (1.5 - 0.2) * 25$

(t_s = 0.2, b = 0.2)



$\therefore g_{XG} = 38.5\ kN/m$

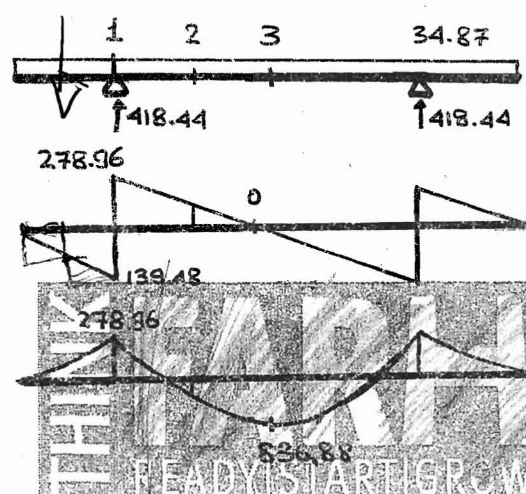
$P_{HR} = 2 * 4 = 8\ kN$

$\therefore R_{XG} = (38.5 * 3.2 * 2 + 8 * 2)/3 = 87.47\ kN$

$\therefore g_{MG} = \frac{R_{XG}}{b}$ + own wt. of MG

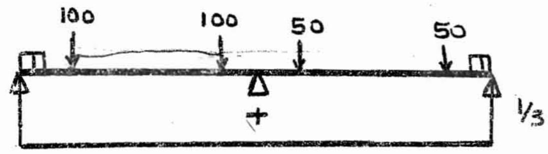
$\therefore g_{MG} = \frac{87.47}{4} + 0.4 * (1.5 - 0.2) * 25 = 34.87\ kN/m$

Point	M_{DL}	Q_{DL}
1	-278.96	-139.5 / 278.96
2	557.92	139.48
3	836.88	0



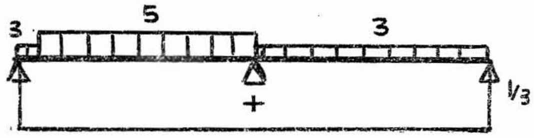
Live load

$I = 0.4 - 0.008 \times 16 = 0.272$



$w_1 = [200(1+I) + 100] \times \frac{1}{3}$

$w_1 = 118 \text{ kN}$



$q_1 = [3 * 0.2 * 2] * 1/3$

$q_1 = 0.4 \text{ kN/m}'$

$q_2 = [5 * 3 * (1+I) + 3 * 3.4] * \frac{1}{3}$

$q_2 = 9.75 \text{ kN/m}'$

المفروض لكل حالة تحميل I لكن علشان وقت الامتحان احنا حنستخدم

I المحسوبة على أساس أن الطول المحمل (L) 16m

$M_{1\,L.L-ve} = -118(4 + 2.5 + 1.0) - 0.4 * 2 * 4 = -888.2 \text{ kN.m}$

$M_{2\,L.L+ve} = 118(3 + 2.63 + 2.25) + 0.4\left(\frac{1.88+3}{2} * 1.5 + \frac{3+1.88}{2} * 4.5\right) + 9.75(0.5 * 1.88 * 2.5 + 0.5 * 1.88 * 7.5) = 1026.5 \text{ kN.m}$

$M_{2\,L.L-ve} = -118 * (3 + 1.88 + 0.75) - 0.4 * 1.5 * 4 - 9.75 (0.5 * 1 * 4) = -685.65 \text{ kN.m}$

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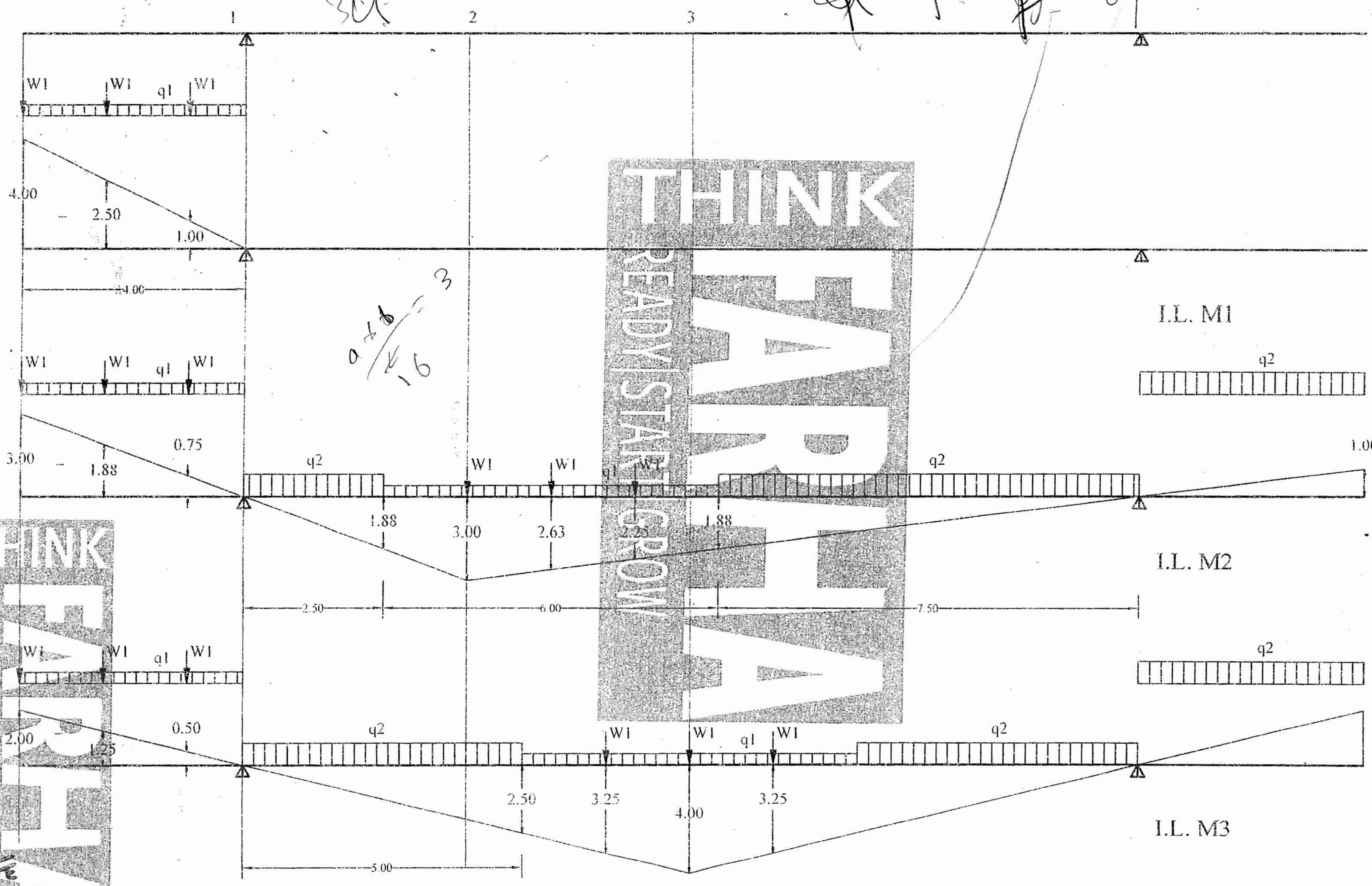
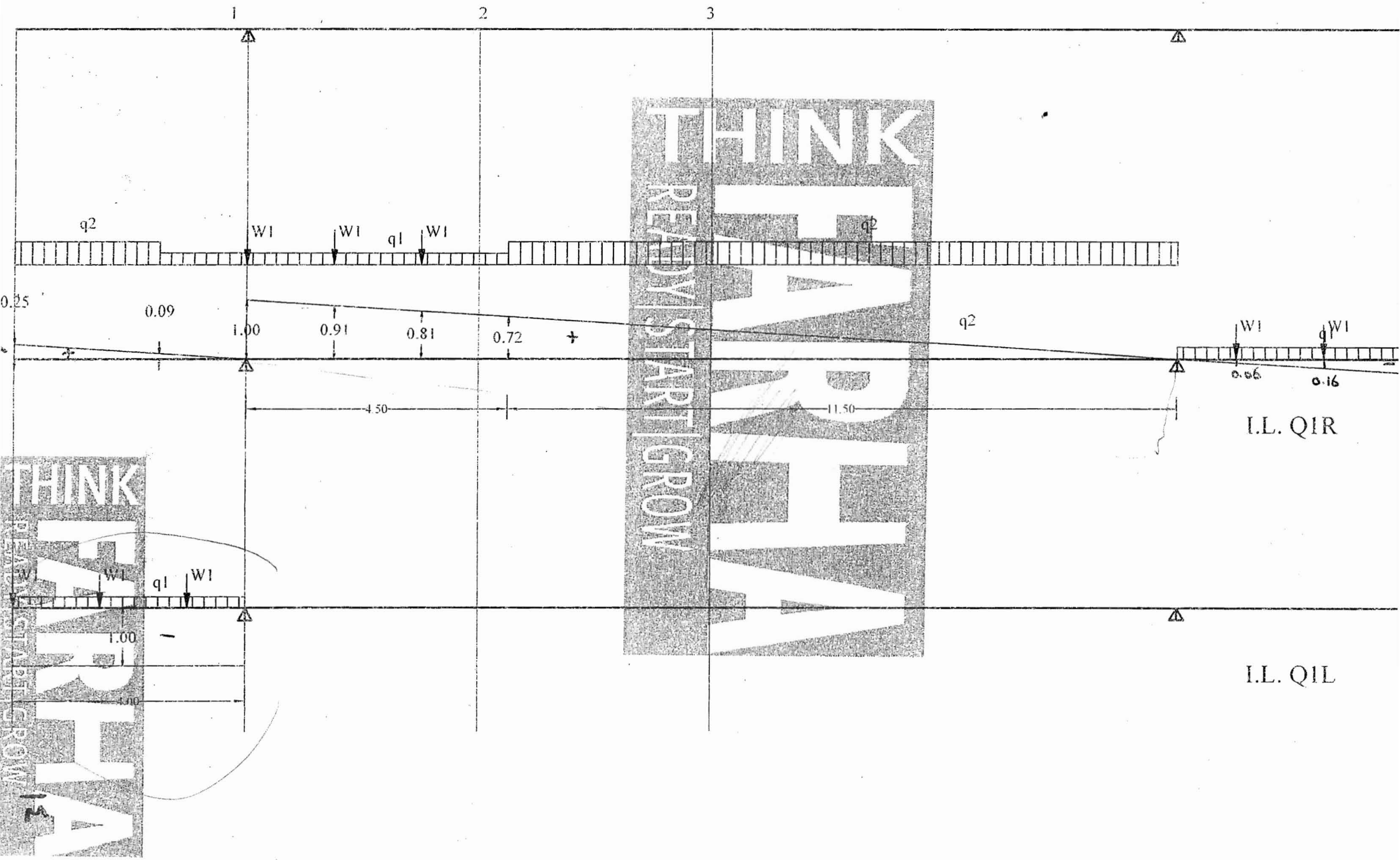

1
2
3
W1
q1
4.00
2.50
1.00
I.L. M1
q2
3.00
1.88
0.75
1.88
3.00
2.63
2.25
2.50
6.00
7.50
1.00
I.L. M2
2.00
1.25
0.50
2.50
3.25
4.00
3.25
5.00
I.L. M3



1
2
3
q2
W1
W1
q1
W1
q2
0.25
0.09
1.00
0.91
0.81
0.72
+
q2
W1
q1
W1
0.06
0.16
4.50
11.50
I.L. QIR
W1
W1
q1
W1
1.00
–
1.00
I.L. QIL

$$M_{L.L_{3+ve}} = 118\ (4 + 3.25*2) + 0.4\ (3.25*6) + 9.75\ (0.5*2.5*1.88*2) = 1368.67\ kN.m$$

$$M_{L.L_{3-ve}} = -118\ (2+1.25+0.5) - 0.4\ (1*4) - 9.75*(0.5*2*4) = -483\ kN.m$$

For shear

$$Q_{1_R L.L+ve} = 118\ (1.0 + 0.91 + 0.81) + 0.4\left[\frac{0.72+1}{2}*4.5 + 0.5*0.09*1.5\right] + 9.75\ \left(0.5*0.72*11.5 + \frac{0.09+0.25}{2}*2.5\right) = 366.87\ kN$$

$$Q_{1_R L.L-ve} = -118\ (0.25 + 0.16 + 0.06) - 0.4\ (0.5*0.25*4) = -55.48\ kN$$

$$Q_{1_L L.L+ve} = 0$$

$$Q_{1_L L.L-ve} = -118\ (1*3) - 0.4\ (1*4) = -355.6\ kN$$

Point	M_{DL}	M_{LL}		M_{Max}	M_{Min}
		+ve	-ve		
1	-278.96	0	-888.2	-278.96	-1167.16
2	557.92	1026.5	-685.65	1584.4	-127.73
3	836.88	1368.7	-483.1	2205.58	353.78

10

Design for moment

$M_{-ve} = -1167.16$ kN.M (Rec. Section)

$\therefore M_{+ve} = 2205.6$ kN.m (T- Section)

Design as T - section

B → $400 + 16 * 200 = 3600$

الأصغر → $400 + 0.7 * \frac{16000}{5} = 2640$ ✓

→ 3200 (spacing)

$X = 0.44 \sqrt{\frac{2205.6 \times 10^6}{2640}} = 402 > t_s$

$\therefore B_e = 400 + (2640 - 400) * (\frac{200}{402})(2 - \frac{200}{402}) = 2074$ mm

$\therefore d = k_1^* \sqrt{\frac{M}{B_e}} = 0.968 \sqrt{\frac{2205.6 \times 10^6}{2074}} = 1019$ mm

For -ve Moment

$d = k_1 \sqrt{\frac{M_{-ve}}{b}} = 0.712 \sqrt{\frac{1167.16 \times 10^6}{400}} = 1216$ mm

Take $h_{MG} = 1600$ mm $\boxed{d = 1500 \text{ mm}}$

$\therefore As_{+ve} = \frac{M_{+ve}}{k_2^* * d} = \frac{2205.6 \times 10^6}{177 \times 1500} = 8307 \text{ mm}^2$

12Ø32

$As_{-ve} = \frac{M_{-ve}}{k_2 * d} = \frac{1167.2 \times 10^6}{170.6 \times 1500} = 4561 \text{ mm}^2$

6Ø32

Design for Shear

Q MAX

Point	DL	L.L +ve	L.L -ve	MAX	Min
1_L	-139.5	0	-355.6	-139.5	-495.1
1_R	278.96	366.87	-55.48	645.83	223.48

for cantilever parts

we will use stirrups only →

$Q_{1L} = -495.1 \text{ KN}$

$q_{1L} = \frac{495.1 \times 1000}{400 \times 1500} = 0.825 \text{ N/mm}^2$ $\qquad q_c \overset{0.7}{<} q_{1L} < \overset{2.1}{q_2}$

$\therefore q_{st} = 0.825 - \frac{0.7}{2} = 0.475$

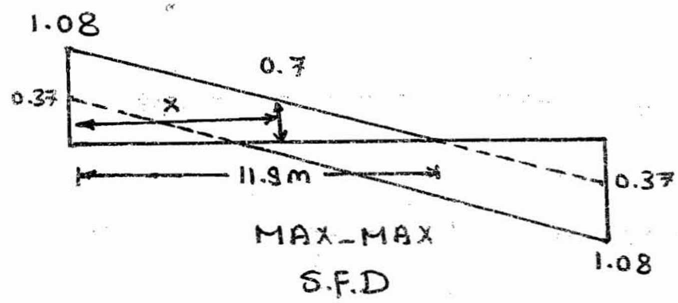
$\therefore 0.475 = \frac{4 \times 79 \times 140}{400 \times S} \qquad \therefore S = 233 \text{ mm}$

use 4 br. st. $\phi 10$ @ 200 mm

for Inner span

$q_{1R_{max}} = \frac{645.83 \times 10^3}{400 \times 1500} = 1.08$

$q_{1R_{Min}} = \frac{223.48 \times 10^3}{400 \times 1500} = 0.37$



$x = 4.2 \text{ m}$

$$q = q_{c/2} + q_{st} + q_{bu}$$

$$\therefore q_{st} + q_{bu} = 1.08 - 0.35 = 0.73 \ N/mm^2$$

For bent-up bars

$S = d/2 \rightarrow d$ (750 mm → 1500 mm)

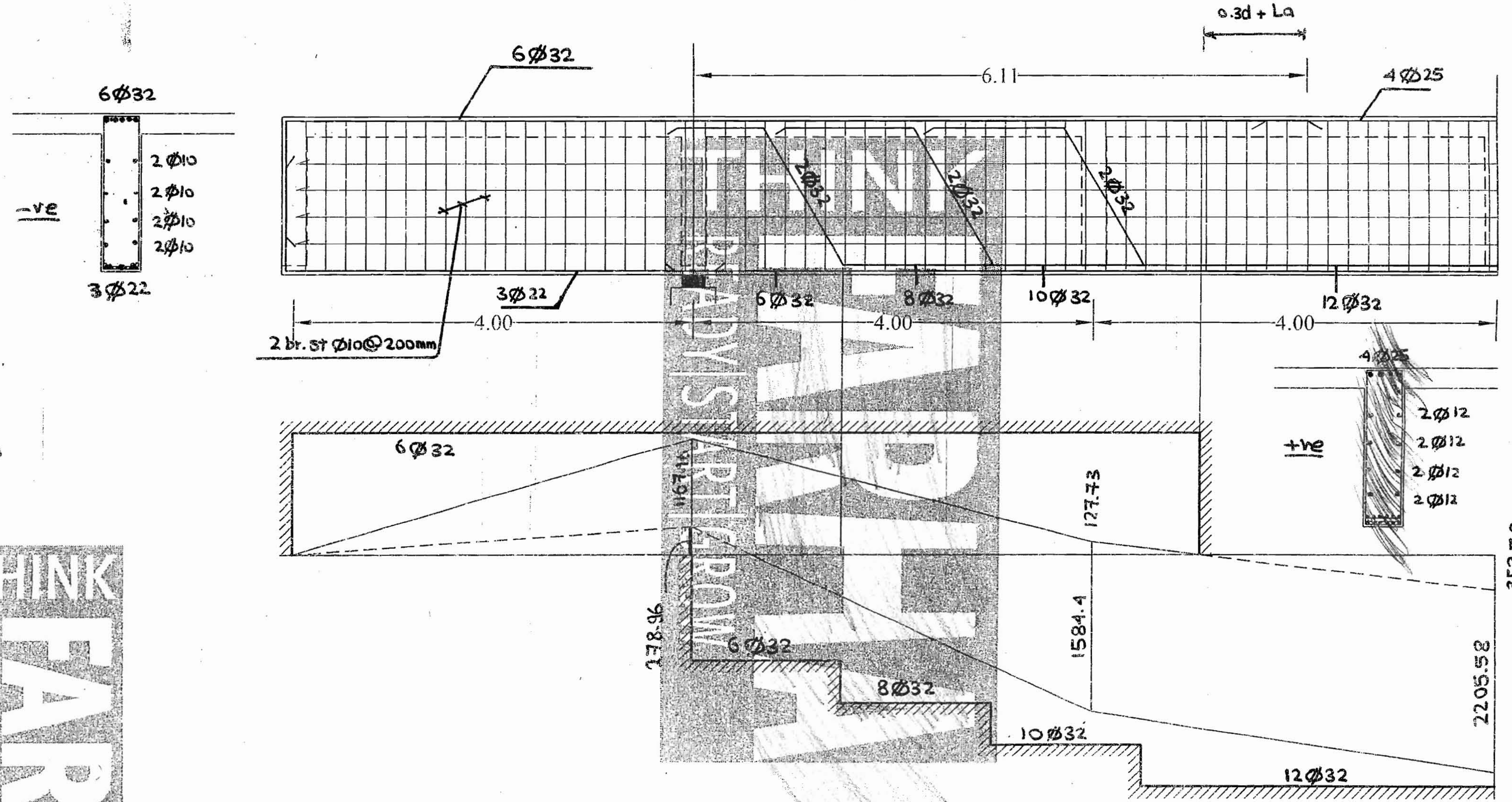
Try $S = 1500$ mm & (2Ø32)

$$\therefore q_{bu} = \frac{2 * 804 * 200}{400 \times 1500} (\sin 60 + \cos 60) = 0.732 \ N/mm^2$$

عدد الانكسيجات = 4.2/1.2 = 3

$\therefore q_{st} = 0.73 - 0.732 = \ominus$

Use Min. Stirrups 4 br. st. Ø10 @ 200 mm


6Ø32
2 Ø10
2 Ø10
2 Ø10
2 Ø10
-ve
3 Ø22
0.3d + La
6.11
6Ø32
4Ø25
2Ø32
2Ø32
2Ø32
3Ø22
6Ø32
8Ø32
10Ø32
12Ø32
2 br. st Ø10@200mm
4.00
4.00
4.00
4Ø25
2Ø12
2Ø12
2Ø12
2Ø12
+ve
6Ø32
1167.41
127.73
353.78
1584.4
2205.58
278.96
6Ø32
8Ø32
10Ø32
12Ø32

45

19