NOW

after mid-Term

1,50

Steel Structures

3rd Year Civil Eng.

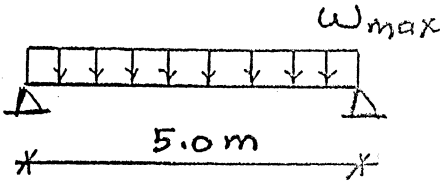
Design of Beams

Examples on Laterally unsupported Beams ($l_u \neq 0$)

With my best wishes

Example (1) "مسألة المحاضرة"

- **For the Shown Beam:-** (un supported)



- St (37)
- IPE 300
- $l_u = 5.0\,m$
- $C_b = 1.13$

- **Required:-**

Find the Max. Moment, Max. Shear and W_{max}.

Solution

ملاحظة هامة

من المفترض أن يتم عمل check للعزمة ما إذا كان القطاع Compact أو Non Compact ويتم ذلك على مرحلتين

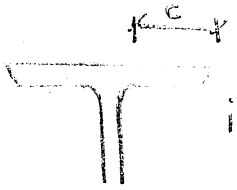
* **check of Compact or Non Compact For web:-**

Code P.9 if $\boxed{\frac{d_w}{t_w} \leq \frac{127}{\sqrt{F_y}}}$ → web is compact

$$\frac{d_w}{t_w} = \frac{24.8}{0.71} = 35 < \frac{127}{\sqrt{F_y}} = \frac{127}{\sqrt{2.4}} = 82$$

∴ web is Compact

* **check of compact or Non Compact For Flange:-**



Code P.11

if $\boxed{\frac{c}{t_f} \leq \frac{15.3}{\sqrt{F_y}}}$ → Flange is compact

$$\frac{c}{t_f} = \frac{b_f - t_w/2 - r}{t_f} = \frac{7.5 - 0.71/2 - 1.07}{1.07} = 5.7 < \frac{15.3}{\sqrt{F_y}} = 9.9$$

$\sqrt{2.4}$

∴ Flange is compact

وكذلك نجد أن جميع قطاعات الـ I-Section الموجودة في الجداول تكون Compact

For M max :-

$\frac{20bf}{\sqrt{Fy}} = 194\,cm$, $lu = 500\,cm$, $\frac{1380 Af}{d\,Fy} Cb = 348\,cm$ ③

$$Fltb_1 = \frac{800\,Af}{lu * d} Cb = \frac{800\,[15 * 1.07]}{500 * 30} * 1.13 = 0.967\ t/cm^2 < 0.58Fy = 1.4$$

Fltb2 $\quad r_t = \sqrt{\frac{Iy}{A}}$

$$A = 15 * 1.07 + (5 - 1.07) * 0.71 = 19.34\,cm^2$$

$$Iy = \frac{1.07\,(15)^3}{12} + \frac{(5-1.07)(0.71)^3}{12} = 301\,cm^4$$

هذا الجزء يمكن اهماله

$$r_t = \sqrt{\frac{301}{19.34}} = 3.94\,cm.$$

$$\frac{lu}{rt} = \frac{500}{3.94} = 126.4$$

$84\sqrt{\frac{Cb}{Fy}} = 57.6$ $\qquad$ ② $\qquad$ $188\sqrt{\frac{Cb}{Fy}} = 129$

$$\therefore Fltb_2 = \left[0.64 - \frac{(lu/rt)^2 Fy}{1.176 * 10^5 * Cb}\right] Fy$$

$$= \left[0.64 - \frac{(126.4)^2 * 2.4}{1.176 * 10^5 * 1.13}\right] * 2.4 = 0.838\ t/cm^2 < 0.58Fy.$$

$$\therefore Fltb = \sqrt{Fltb_1^2 + Fltb_2^2} \leq 0.58Fy$$

$$= \sqrt{(0.967)^2 + (0.838)^2} = 1.28\ t/cm^2 < 0.58Fy = 1.4$$

$$\boxed{Mmax = Fltb * Zx}$$

$$Mmax = 1.28 * 557 = 713.9\ t.cm$$

$$\boxed{Mmax = 7.139\ t.m}\ \checkmark$$

For Q_{max} :-

$$q_{all} = \frac{Q_{max}}{h * t_w} \rightarrow \boxed{Q_{max} = h * t_w * q_{all}}$$

$$Q_{max} = 0.84 * 30 * 0.71 = 17.9 \text{ ton}$$

$$\boxed{Q_{max} = 17.9 \text{ ton}}$$

For ω_{max} :-

$$M_{max} = \frac{\omega L^2}{8} \rightarrow 7.139 = \frac{\omega (5)^2}{8} \rightarrow \omega = 2.3 \text{ t/m'}$$

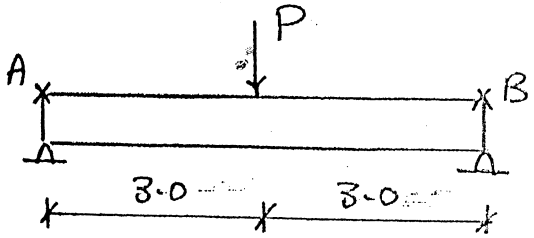
$$Q_{max} = \frac{\omega L}{2} \rightarrow 17.9 = \frac{\omega (5)}{2} \rightarrow \omega = 7.12 \text{ t/m'}$$

$$\boxed{\therefore \omega_{max} = 2.3 \text{ t/m'}}$$

Example ②

"فكروحلوه"

- For the given beam braced laterally at points A, B Find Max load "P" that can be carried by the beam if the beam is IPE 300
- st (37)
- neglect owt of Beam.



Solution

→ The Beam is laterally un supported ⇒ $l_u = 6.0m$

← يجب انه يتم حساب قيمة اقل "P" بحيث يكون

① Normal stresses "safe"

② shear stress "safe"

③ Deflection "safe"

① **Normal stresses :-**

$l_u = 6.0m$

$$\rightarrow \frac{20\,b_f}{\sqrt{F_y}} = \frac{20 * 15}{\sqrt{2.4}} = 193\,cm$$

$$\rightarrow \frac{1380\,A_f}{d\,F_y} C_b = \frac{1380 * 15 * 1.07}{30 * 2.4} * 1.35 = 415\,cm$$

∴ l_u اكبر من القيمتين ⇐ وبالتالى يتم حساب F_{ltb}

$$F_{ltb} = \sqrt{F_{ltb_1}^2 + F_{ltb_2}^2} \leq 0.58 F_y$$

$$f_{itb_1} = \frac{800}{l_u \cdot d / A_f} C_b = \frac{800}{600 * \frac{30}{15 * 1.07}} * 1.35 = 0.963 \quad < 0.58 F_y$$

ok

f_{itb_2} ⇒ depend on l_u/r_t (From table) ⇒ $r_t = 3.94$ cm

$$\therefore \frac{l_u}{r_t} = \frac{600}{3.94} = 152.28$$

$$84\sqrt{\frac{C_b}{F_y}} = 63 \quad (C_b^{1.35},\ F_y^{2.4}) \qquad 188\sqrt{\frac{C_b}{F_y}} = 141 \quad (C_b^{1.35},\ F_y^{2.4})$$

$$\therefore f_{itb_2} = \frac{12000}{(l_u/r_t)^2} * C_b = \frac{12000}{(152.2)^2} * 1.35 = 0.7 \ t/cm^2$$

$< 0.58 F_y$ ok

$$\therefore f_{itb} = \sqrt{0.963^2 + 0.7^2} = 1.19 \ t/cm^2 < 0.58 F_y$$

ok

∴ For the Max load "P" :-

$$M_x = \frac{PL}{4} = \frac{P * 6}{4} = 1.5P$$

$$f_b = \frac{M_x}{Z_x}$$

$$\therefore M_{x_{max}} = Z_x * f_{itb}$$

$$= 557 * 1.19 = 662.83 \ t.cm.$$

$$= 6.63 \ t.m.$$

$$\therefore 1.5P = 6.63$$

$$\therefore P_1 = 4.42 \ ton$$

(2) Max load For shear :—

$$q_{act} \not< q_{all}$$

$$q_{act} = \frac{Q}{h\, t_w} \qquad q_{all} = 0.35\, f_y$$

$$Q = P/2$$

$\Rightarrow$ Max load at $q_{act} = q_{all}$

$$\frac{P/2}{30 * 0.71} = 0.35 * 2.4$$

$$P_2 = 35.7 \text{ ton}$$

(3) Max load For deflection :—

$$\Delta = \frac{P L^3}{48 E I}$$

← نستخدم الحمل P الكلي في حساب الترخيم حيث أنه يعطى لـ L.L لوحده في السؤال.

$\Delta_{all} = \frac{Span}{300} = \frac{600}{300} = 2$ (ونفهم يعطى نوع التسقيب)

∴ at Max load

$$\Delta = \Delta_{all}$$

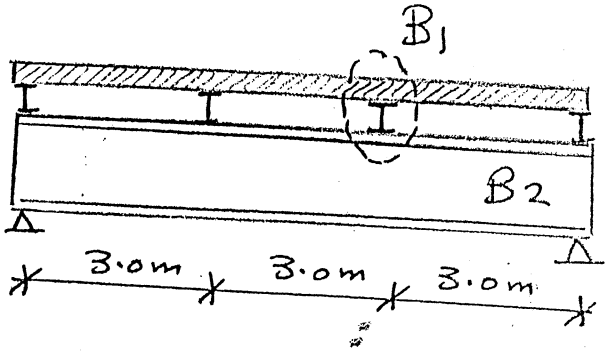
$$\frac{P * 600^3}{48 * 2.1 * 10^6 * 8356} = 2 \Rightarrow P = 7798.9 \text{ kg}$$

$$P_3 = 7.79 \text{ ton}$$

Maximum Safe load = Minimum of the 3 values

$$\therefore P_{max} = 4.42 \text{ ton}$$

Example (3)



- Given:-

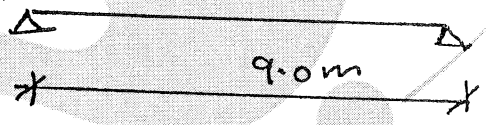
- wt of cover = 200 kg/m²
- L.L = 200 kg/m²
- Rc slab = 10cm.
- Spacing between Main beams B_2 = 6.0m
- st. (St) - neglect o.w. of steel beams

- Required:-

↳ Design B_2 as IPE section.

Solution

(1) span and structure system :-



(2) loads :-

↳ الكمرة "B_2" معرضة إلى أحمال مركزة ناتجة من ردود أفعال الكمرات "B_1"

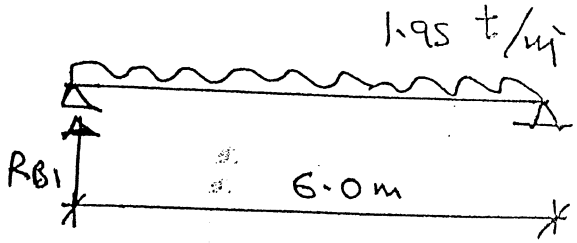
∴ loads on B_1

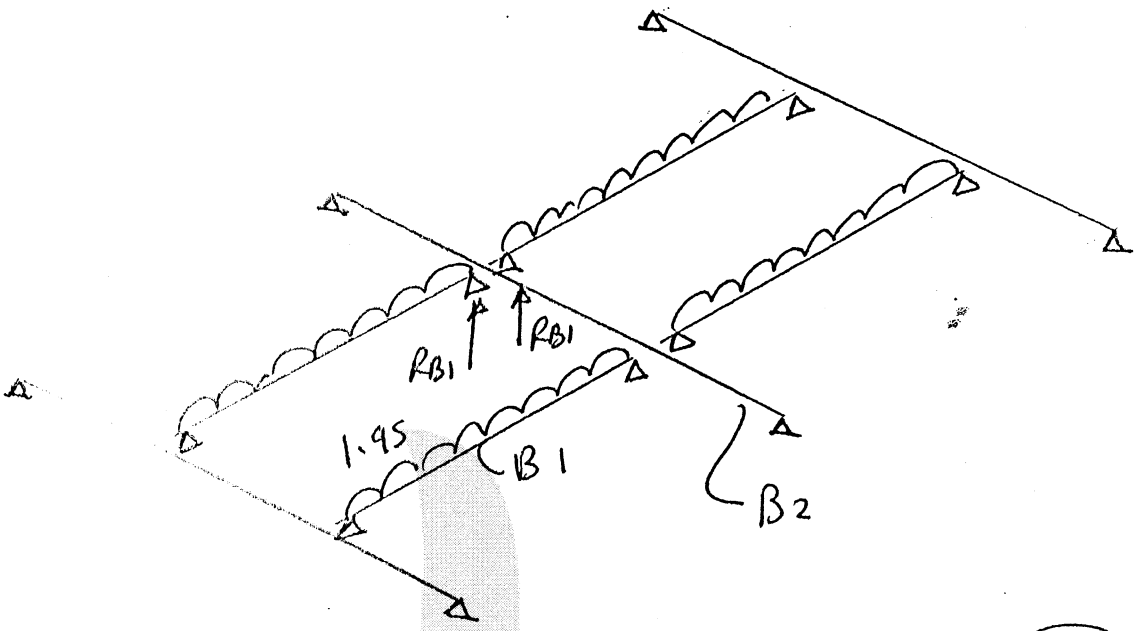
$$w_{B1} = (200 + 200 + 2500 * \frac{10}{100}) * 3$$

(200 = cov, 200 = LL, 2500 * 10/100 = Rc, 3 = S)

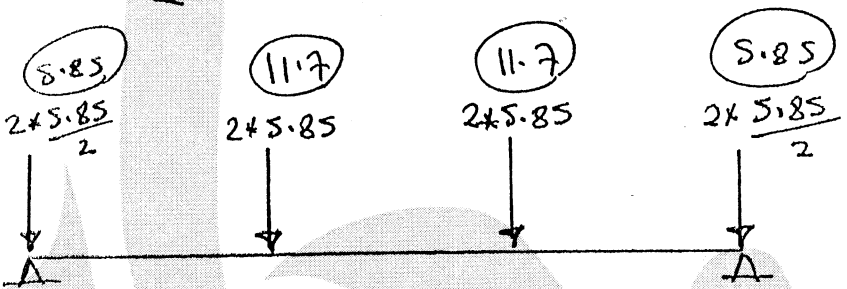
$$= 1950 \text{ kg/m}' = 1.95 \text{ t/m}'$$

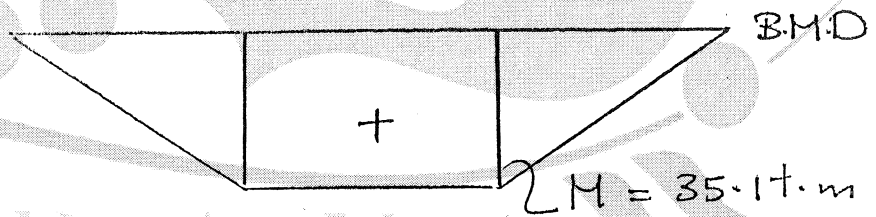
$$R_{B1} = \frac{1.95 * 6}{2} = 5.85 \text{ ton.}$$

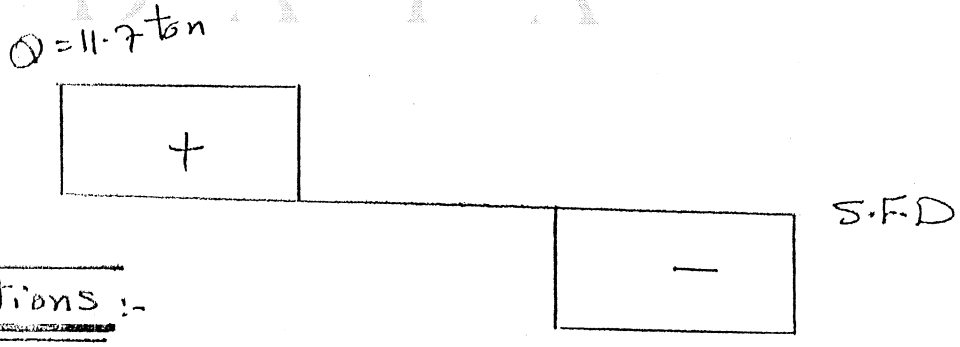




* For B2 :-







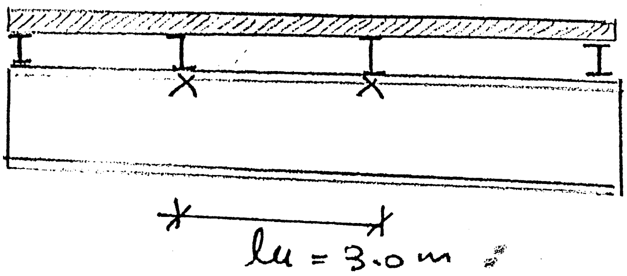
(3) Straining actions :-

$M_x = 35.1$ t.m

$Q_x = 11.7$ ton

(4) Suitable Section :-

كده تم فرض قطاع مناسب عن طريق فرض أن الإجهادات تسمح بـ .0.58 Fy



$$Z_{x\,req} = \frac{M_x}{F_{bx}} = \frac{35.1 * 100}{0.58 * 2.4} = 2521.55 \text{ cm}^3$$

F_{bx} = 0.58 Fy

∴ From tables Try IPE 600

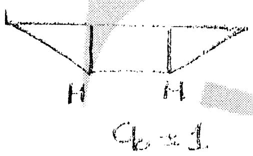
(5) Checks :-

(1) check of Normal stresses :-

$$l_u = 300 \text{ cm}.$$

$$\rightarrow \frac{20\, b_f}{\sqrt{F_y}} = \frac{20 * 22}{\sqrt{2.4}} = 284 \text{ cm}$$

(l_u)



$$\rightarrow \frac{1380\, A_f}{d\, F_y} C_b = \frac{1380 * 22 * 1.9}{60 * 2.4} * 1 = 400 \text{ cm}$$

لأنها محصورة بين القيمتين.

$$\therefore F_{bx} = 0.58\, F_y.$$

$$\therefore f_{act} = \frac{M_x}{Z_x} = \frac{35.1 * 100}{3070} = 1.14 < 0.58\, F_y \simeq 1.4$$

O.K

(2) check of shear :-

$$q_{act} = \frac{Q_{tot}}{h * t_w} = \frac{11.7}{60 * 1.2} = 0.16 \text{ t/cm}^2 < 0.35\, F_y = 0.84 \text{ t/cm}^2$$

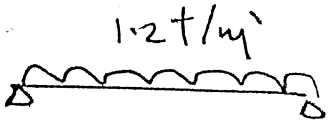
O.K

③ check of deflection :-

$$\Delta_{act_{LL}} \not< \frac{span}{300} = \frac{900}{300} = 3cm.$$

← في هذه الحالة الكمرة معرضة إلى حملين مركزين و لكن لا يوجد معادلة لحساب الترخيم الناتج عن حملين مركزين، لذلك يتم حساب الـ LL كحمل موزع على الكمرة حتى نستطيع حساب الترخيم.

$$\omega_{LL} = 200 \times S = 200 \times 6 = 1200 kg/m'$$

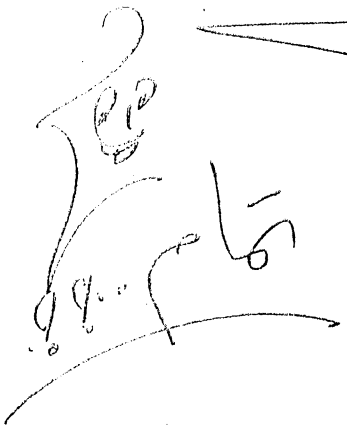


$$\therefore \Delta_{LL\,act} = \frac{5}{384} \frac{\omega_{LL}\, l^4}{E\, I_x}$$

$$= \frac{5}{384} \frac{\left(\frac{1200}{100}\right) * (900)^4}{2.1 \times 10^6 * 92080} = 0.53cm < 3cm$$

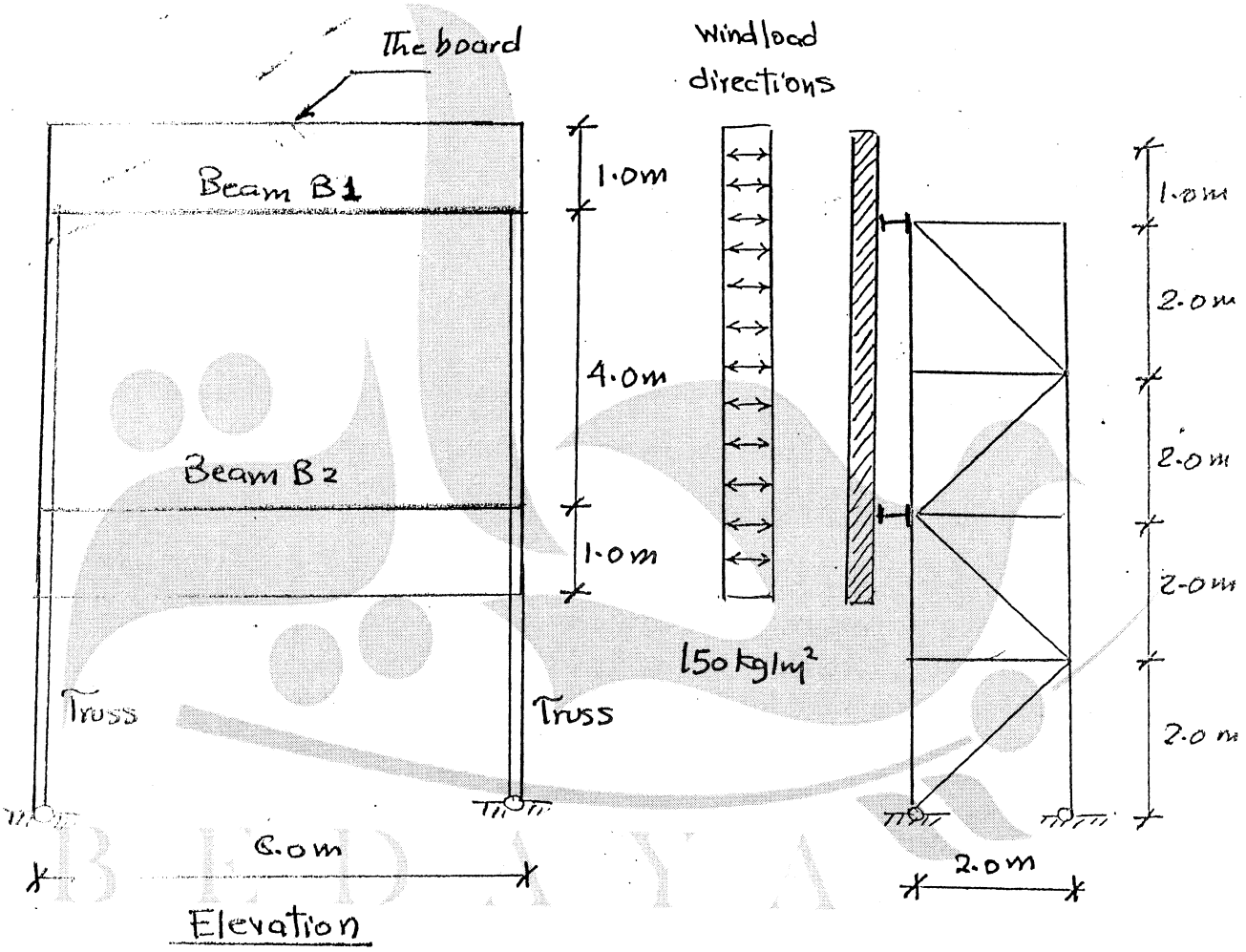
o.k

∴ Use IPE 600



Example ④ Final 2005

The Figure shows the Elevation and the Sideview of Steel Structure Carrying an advertising board of 2.0m * 6.0m. the Structure Consists of Two Beams Carrying the board and supported to Two Vertical Trusses Spaced at 6.0m as shown in the Figure.



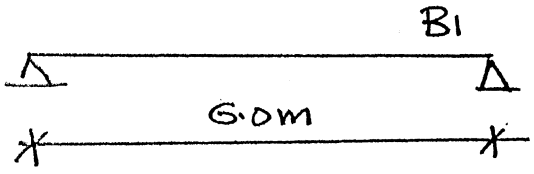
* Given:- - St (37)
  - Windload (Pressure + Suction) = 150 kg/m²
  - Neglect the Own Weight of the steel beams, the Trusses, and the board

* Required:-

check the Safty of the Beam "B1" as IPE 200 (Consider only the wind load). (12%)

Solution

1 Span & str. system:-



2 loading:-

$$\omega_{wind} = 150 * (3.0) = 450 \text{ kg/m}' = 0.45 \text{ t/m}'$$

3 Straining actions:-

$$M_x = \frac{0.45(6)^2}{8} = 2.028 \text{ t.m}$$

$$Q_x = \frac{0.45(6)}{2} = 1.35 \text{ ton}$$

4 checks:-

Normal

① check of stresses:-

From tables For IPE 200

$b_f = 10\text{cm}$, $t_f = 0.85\text{cm}$

$t_w = 0.56\text{cm}$, $Z_X = 194\text{cm}^3$

لفروض أنك حسبتها بمن !! ← $r_t = 2.63\text{cm}$.

$l_u = 6\text{m} = 600\text{cm}$

$$\frac{20 b_f}{\sqrt{f_y}} = \frac{20(10)}{\sqrt{2.4}} = 129\text{cm}$$

$$\frac{1380 A_f}{d f_y} C_b = \frac{1380(10)(0.85)}{(2.4)(20)}$$

$$= 276\text{cm}$$

$$\therefore \boxed{f_{act} = \frac{M_x}{Z_x} \not< f_{itb}}$$

$$f_{itb} = \sqrt{f_{itb_{①}}^2 + f_{itb_{②}}^2} = \checkmark \not< 0.58 f_y .$$

$$f_{itb_{①}} = \frac{800\ AF}{l_u * d} C_b = \frac{800 * 10 * 0.85}{600 * 20} * 1.13 = 0.64\ t/cm^2$$

$$\frac{l_u}{r_t} = \frac{600}{2.63} = 228.13$$

$$84\sqrt{\frac{C_b}{f_y}} = 84\sqrt{\frac{1.13}{2.4}} \qquad 188\sqrt{\frac{C_b}{f_y}} = 188\sqrt{\frac{1.13}{2.4}} = 129$$

$$f_{itb_{②}} = \frac{12000}{\left(l_u/r_t\right)^2} C_b = \frac{12000}{(228.13)^2} * 1.13 = 0.26\ t/cm^2$$

$$\therefore f_{itb} = \sqrt{0.64^2 + 0.26^2} = 0.69\ t/cm^2$$

$$f_{act} = \frac{M_x}{Z_x} = \frac{2.028 * 100}{194} = 1.04 > 0.69\ t/cm^2$$

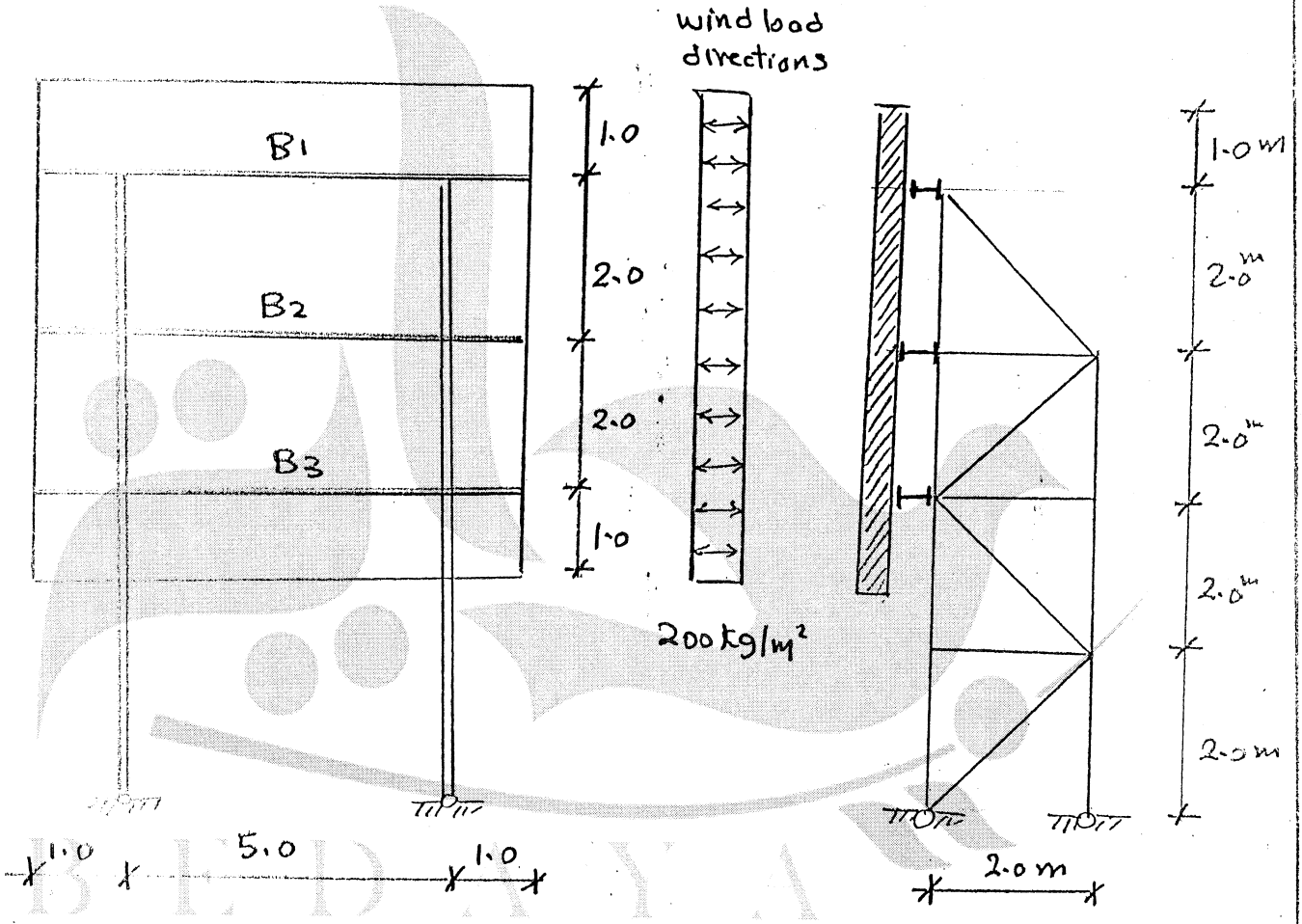
Not ok

$\therefore$ Section is not safe.

Example (5)

Sheet (5) مثل مسألة

The Figure shows the Eleration and the Side View of steel Structure Carrying an advirtising board of 2.0 m * 6.0 m the structure Consists of Three Beams Carrying the board and supported to Two Vertical Trusses Spaced at 5.0 m as shown in Figure.



*Given:- - st (37)

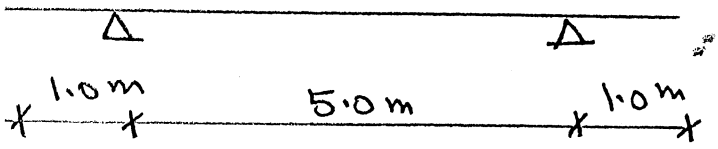
- wind load (pressure + Suction) = 200 kg/m²
- weight of board = 20 kg/m²

*Required:-

check the Safty of the Beam B1 as IPE 200

Solution

1 Span and Structure system:-



2 Loading:-

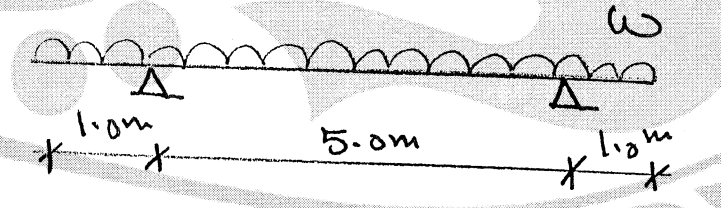
$w_x = 200 * 2 = 400 \text{ kg/m}' = 0.4 \text{ t/m}'$

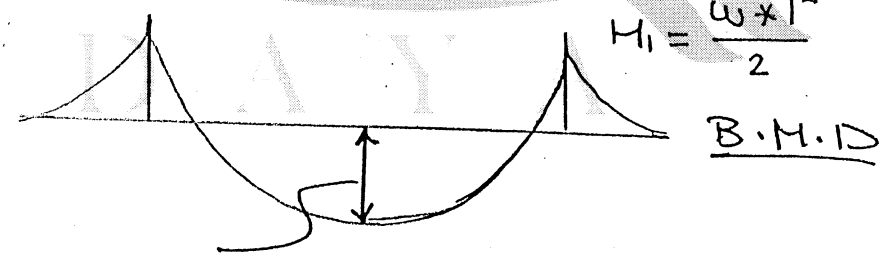
w_y = owt of Beam + owt of board

$= 22.4 + 20*2 = 62.4 \text{ kg/m}' = 0.0624 \text{ t/m}'$

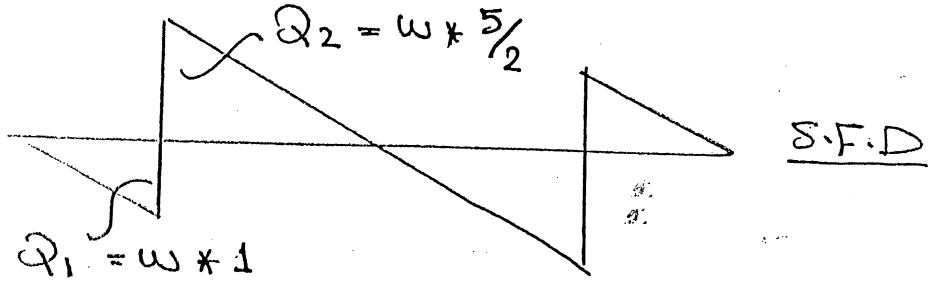
(22.4 from table)

3 Straining actions:-





$$M_2 = \frac{w*5^2}{8} - \frac{w*1^2}{2}$$



$$M_{x_1} = \frac{0.4 * 1^2}{2} = 0.2 \text{ t.m}$$

$$M_{x_2} = \frac{0.4 * 5^2}{8} - \frac{0.4 * 1^2}{2} = 1.05 \text{ t.m}$$

$$M_{y_1} = \frac{0.064 * 1^2}{2} = 0.0312 \text{ t.m}$$

$$M_{y_2} = \frac{0.0624 * 5^2}{8} - \frac{0.0624 * 1^2}{2} = 0.1638 \text{ t.m}$$

$$Q_{x_1} = 0.4 * 1 = \underline{\underline{0.4 \text{ ton}}}$$

$$Q_{x_2} = 0.4 * 5/2 = \underline{\underline{1 \text{ ton}}}$$

[4] Checks:-

① Check of Normal stresses:-

From tables:- For IPE

$b_f = 10 \text{ cm}$, $t_f = 0.85 \text{ cm}$, $t_w = 0.56 \text{ cm}$

$Z_x = 194 \text{ cm}$, $Z_y = 28.5 \text{ cm}$, $r_t = 2.63 \text{ cm}$.

$I_x = 28.5 \text{ cm}^3$

← مفروض أنه تم عمل هذا الـ check مرتين :

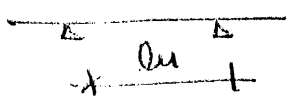
الأولى: باعتبار إتجاه wind → wind

وبالتالى تكون الكمرة Supported ($l_u = 0$)

الثانية: باعتبار إتجاه الـ wind ← wind

وبالتالى تكون الكمرة unsupported ($l_u \neq 0$)

← ولكن تم أخذ الحالة الأسوأ وهى أنه تكون ($l_u \neq 0$) وذلك لعمل الحالة الأولى ($l_u = 0$)



$l_u = 5.0m = 500cm$

$$\frac{M_x/Z_x}{F_{bcx}} + \frac{M_y/Z_y}{F_{bcy}} \leq 1.0$$

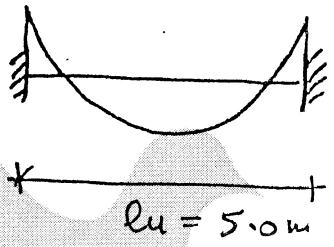
$l_u = 500cm$

$\frac{20*10}{\sqrt{2.4}} = 129.1$

$\frac{1380*10*0.85}{20*2.4} * 1.3 = 317.68$ (3)

خدبالك

From code Page 20



$F_{bcx} = F_{itb} = \sqrt{F_{itb_{①}}^2 + F_{itb_{③}}^2} \leq 0.58 F_y$

$F_{bcy} = 0.72 F_y$

$F_{itb_{①}} = \frac{800*10*0.85}{500*20} * 1.3 = 0.68 t/cm^2 < 0.58 F_y$

$\frac{l_y}{r_t} = \frac{500}{2.63} = 190$

$84\sqrt{\frac{1.3}{2.4}} = 61.82$

$188\sqrt{\frac{C_b}{F_y}} = 188\sqrt{\frac{1.3}{2.4}} = 138$ (3)

$F_{itb_{③}} = \frac{12000}{(190)^2} * 1.3 = 0.432 t/cm^2 < 0.58 F_y$

$F_{itb} = \sqrt{(0.68)^2 + (0.432)^2} = 0.81 t/cm^2 < 0.58 F_y$

$$\frac{\frac{1.05*100}{194}}{0.81} + \frac{\frac{0.1638*100}{28.5}}{0.72*2.4} = 0.98 < 1.0$$

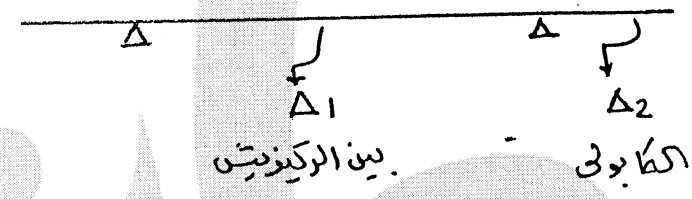
O.K

② Check of shear:-

$$q_{act} = \frac{Q_x}{h * t_w} = \frac{1}{20*0.56} = 0.09 \not> 0.35 f_y$$

O.K

③ Check of deflection:-



Δ_1 بين الركيزتين

Δ_2 للعرض الكابولي

$$\Delta_{1\,act} = \frac{5\,(0.4/100)*500^4}{384*2100*1943} = 0.8\,cm \not> \frac{500}{300} = 1.67\,cm$$

O.K

$$\Delta_{2\,act} = \frac{(0.4/100)*100^4}{8*2100*1943} = 0.012\,cm \not> \frac{100}{180} = 0.56\,cm$$

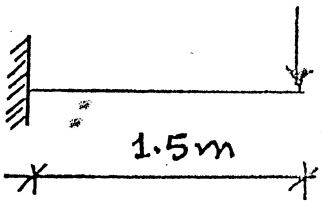
O.K

∴ Section is safe as IPE200

Example (6)

- **For the Shown Beam:-** (Unsupported)

  - St (37)
  - IPE 300



- **Required:-**

Find the Max Moment. (M_{max})

Solution

Page 1 الموجود في هذه المذكرة Example (1) ← هذه المسألة مثل

ولكن مع ملاحظة التالي:-

$l_u = 2.5\,L = 2.5 * 1.5 = 3.75m$ للكوابيل

طول الكابول

$C_b = 1.5$ (Code page 20)

$l_u = 375cm$

$\frac{20b_f}{f_y} = 194cm$

$\frac{1380\,A_f}{d\,f_y}\,C_b = 348$ (3)

إذا كانت النتيجة

∴ $\boxed{M_{max} = f_{itb} * Z_x}$

← ونكمل كما سبق ... إحسب f_{itb} وهات Z_x من الجدول

وعوض في المعادلة ... وهات M_{max}.

وشكراً ٢٠٠٧