Mechanical Engineering Department
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قسم الهندسة الميكانيكية
كلية الهندسة
جامعة بيشة

Solved Problem (2)

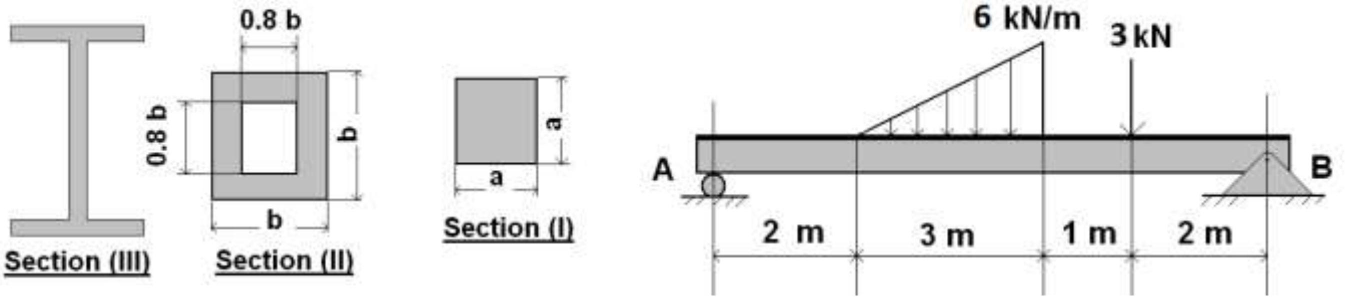

Figure (1)

For the shown steel loaded simply supported beam (Figure 1) get the following:

1. Beam reactions and bending moment diagram. Identify the value and the position of the maximum bending value in (N.mm).

2. Design the given steel loaded simply supported beam (Figure 2) on static flexural stress by getting the suitable cross-section among the following three cross-sections:
(a) Solid square section (I) , (b) Box square section (II) and (c) Standard I-beam section (III) in both x-x and y-y positions.

3. Get the factor of safety (n) for each standard cross-section.

4. If each 1 kg of the used structural steel (steel density 7.8 g/cm^3) beam costs **20 SAR**, calculate the cost of each designed cross-section beam and show **how much did you save in SAR** by selecting the lighter one?

(Use design factor (n_d) = 3 and material's yield strength =390 MPa)

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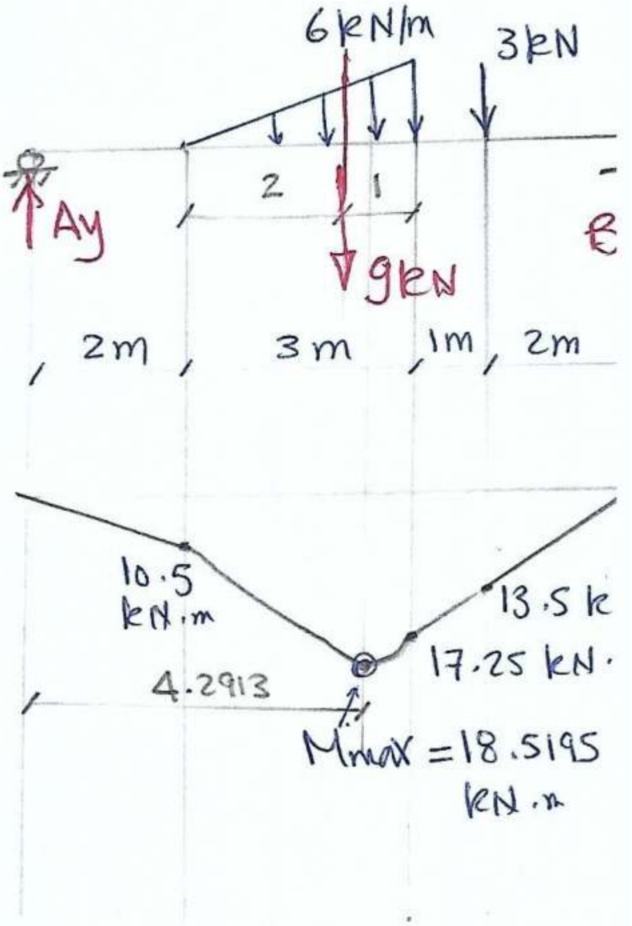
Problem (2)



$\sum M_A = 0$

$8By - 3*6 - 9*4 = 0$

$By = \frac{27}{4}\ kN \uparrow$

$\sum M_B = 0$

$8Ay - 9*4 - 3*2 = 0$

$Ay = \frac{21}{4}\ kN \uparrow$

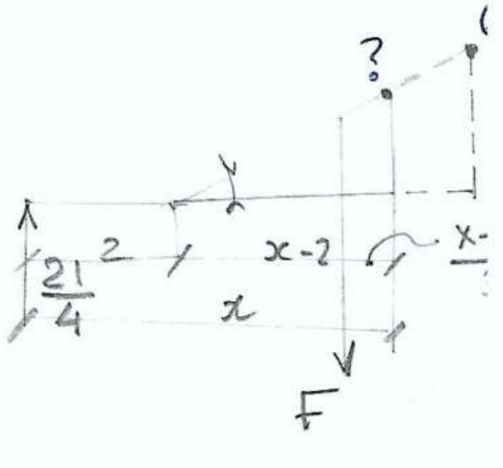
Check $\sum Fy = 0$

$\frac{27}{4} + \frac{21}{4} - 9 - 3 = 0$

o.K. ✓

B.M.D.

Get M(x) for $2 \leq x \leq 5$



$M(x) = \frac{21}{4}x - F\,\frac{(x-2)}{3}$

$F = \frac{1}{2}(x-2) * ?$

$\frac{?}{x-2} = \frac{6}{3} = 2 \Rightarrow ? = 2(x-2)$

$M(x) = \frac{21}{4}x - \frac{1}{3}(x-2)^3$ #

To get x at $M = M_{max}$

$$\frac{\partial M(x)}{\partial x} = 0$$

$$M(x) = \frac{21}{4}x - \frac{1}{3}(x-2)^3$$

$$M(x) = \frac{21}{4}x - \frac{1}{3}\left(x^3 - 6x^2 + 12x - 8\right)$$

$$\frac{\partial M(x)}{\partial x} = 0 = \frac{21}{4} - \frac{1}{3}\left(3x^2 - 12x + 12\right)$$

$$5.25 - x^2 + 4x - 4 = 0$$

$$-x^2 + 4x + 1.25 = 0$$

accepted $x = 4.2913$ m ✓ or

Refused $x = -0.2913$ X

$$M_{max} = \frac{21}{4}(4.2913) - \frac{1}{3}(4.2913-2)^3$$

$M_{max} = 18.5195$ kN.m

@ $x = 4.2913$ m

See → B.M.D → $\boxed{\text{P. } 1/6}$

$\boxed{3/6}$ Problem (2)

Use Flexural Formula

$$\boxed{\sigma = \frac{M_{max}}{Z} = \frac{\sigma_y}{n_d}}$$

Yield strength given = 390 MPa

Design factor given = 3

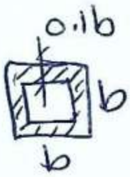
Sectional Modulus

$$Z = \frac{M_{max}}{[\sigma_y / n_d]} = \frac{18519.5 * 10^3}{[390/3]}$$

$$Z = 142.5 * 10^3 \text{ mm}^3$$

as Z 

$= \frac{a^3}{6} \Rightarrow a = 94.9$ mm

as Z 

$= 0.08133 b^3 \Rightarrow b = 120.6$ mm

For I_{y-y} and I_{x-x} Go to Table and select $Z_{st} \geq Z = 142.5 * 10^3$

use $a_{st} = 95$ mm

$b_{st} = 125$ mm

From Table $I_{y-y} \Rightarrow Z_{st.} = 151 * 10^3$

From Table $I_{x-x} \Rightarrow Z_{st.} = 159 * 10^3$

$I_{y-y} \Rightarrow$ W 200X46

$I_{x-x} \Rightarrow$ W 150X22

To calculate the factor of safety $\overset{n}{}$ for each standard cross-section get Z_{st}.

$$Z_{st.\ \underset{95}{▨}95} = \frac{(95)^3}{6} = 142.896 * 10^3\ mm^3$$

$$Z_{st.\ \underset{125}{\overset{12.5}{▣}}125} = 0.081333(125)^3 = 158.854 * 10^3\ mm^3$$

$$\boxed{n = \frac{\sigma_y \cdot Z_{st}}{M_{max}}}$$

$n_{\underset{95}{▨}95} = 3.01$

$n_{\underset{125}{\overset{12.5}{▣}}125} = 3.35$

$n_{I_{y-y}} = 3.18$

$n_{I_{x-x}} = 3.35$

problem (2)

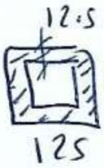
To Calculate the Mass of each Cross-Sectional beam use the following

Mass = Volume * density

volume = area * Length

For 

$\Rightarrow W(kg) = (9.5)^2 * (800) * \frac{7.8}{1000}$

For 

$\Rightarrow W(kg) = \left[(12.5)^2 - (0.8*12.5)^2\right] * 800 * \frac{7.8}{100}$

For I_{y-y} W 200 X 46 indicates 46 kg / 1m

I_{x-x} W 150 X 22 indicates 22 kg/1m

the Required Answers for Weight and Cost summarizes in the following table

P 6/6

$\boxed{6/6}$ Problem (2)

Shape	$Z_{st.} * 10^3$	n	Standard Dimensions	Weight Kg	Cost SAR
▨	142.896	3.01	95X95	563.2	1126
▣	158.854	3.35	125X125	351	702
I Y-Y	151	3.18	W200X46	368	736
I X-X	159	3.35	W150X22	176	352

Saved money = 11263 - 3520 = 7743 SA

Per Beam

the Best cross-section is I_{x-x}

Then Box ▣

Then I_{y-y}

Then solid ▨

For aircraft and automobile applications