Internal Assessment Test 1 Solution – April 2023

Design Of Steel Structural Elements - 18CV61

1	What are advantages and disadvantages of steel structures? **The following are the advantages of steel structures** 1. High strength resulting in the reduction of dead weight. 2. Speedy construction is possible in the case of steel structures, where as R.C. structures can be constructed only stage by stage, giving enough interval of time for setting, curing, hardening etc. 3. Dismantling and reuse of steel structures will be possible where as it is not possible in the case of R.C. structures. 4. They are more economical than concrete structures for tall buildings. 5. The properties of steel do not change appreciably with time. 6. They have large strength to weight ratio. On the basis of the strength/weight ratio, steel is at least 3.5 times more efficient than concrete. 7. Alterations or modifications of sectional properties can be easily carried out in the steel members. 8. They can be easily repaired and retrofitted to carry higher loads or easy to strengthen the existing structures. 9. Steel members occupy less space than R.C. members. 0. They are gas and water tight due to high density of steel. 1. They assure quality, reliability and durability. 2. Steel is a ductile material. 3. Structural steel is recyclable and environment-friendly. 4. Easy inspection and maintenance. 5. Steel is highly suitable for prefabrication and mass production. **The following are the disadvantages of steel structures** 1. They are susceptibility to corrosion. 2. They looses its strength at high temperature. 3. Steel members are costly. 4. Steel elements can not be made to any desired size or shape as in the case of R.C. elements. 5. They required skilled labour for erection. 6. It requires electricity for fabrication and erection of members. 7. They are susceptibility to buckling, fatigue fracture and brittle fracture.
2	Define the terms i) plastic hinge ii)Shape factor iii) Collapse mechanism and iv) upper bound theorem. Plastic Hinge – Plastic hinge is a zone of yielding due to flexure in a structural member. It is defined as a yielded zone due to flexure in a structure in which rotation can take place at a constant restraining moment Mp of the section or Plastic hinge may be defined as the yielded zone of the member at which infinite rotation can take place at a constant plastic moment at the section. Shape factor, S - The ratio of plastic moment to yield moment (elastic moment) is called the shape factor. It is the property of cross sectional area and is not dependent on material properties. Shape factor, $S = \frac{M_P}{M_y} = \frac{f_y Z_P}{f_y Z_e} = \frac{Z_P}{Z_e} = \frac{Z_P}{Z}$ $\quad$ I $Z = Z_e$ = elastic section modulus

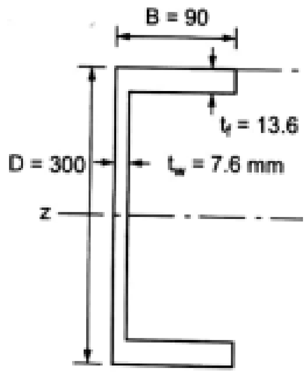
Table 1.7 : Shape factors of different cross-section

Sl.No.	Cross-section	Shape Factor
1.	Rectangle	1.5
2.	Circle	1.7
3.	Diamond (equal diagonals)	2.0
4.	Triangle	2.34
5.	Thin walled circular tube	1.35
6.	Wide flange I-section (about major axis)	1.14
7.	Channel (about major axis)	1.18
8.	Equal angles	1.82
9.	Unequal angles	1.80

Collapse Mechanism – When a structure is subjected to a system of loads, it is stable and hence functional until a sufficient number of plastic hinges have been formed to render the structure unstable. As soon as the structure reaches an unstable condition, it is considered to have been failed. The segment of the beam between the plastic hinges are able to move without an increase of load. This condition in a member is called mechanism.

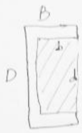
Upper bound theorem – “The load computed from any assumed kinematically admissible mechanism is greater than or equal to the collapse load (M >=Mp) or (W>=Wc) and has a smaller factor of safety.

3 Calculate the shape factor for the figure 1.



To locate centroid.

$M_y = f_y \cdot \frac{I}{y}$



$I = \frac{BD^3}{12} - \frac{bd^3}{12}$

$= \frac{90 \times 300^3}{12} - \frac{82.4 \times 272.8^3}{12}$

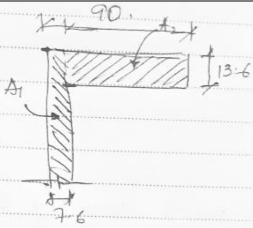
$= 63.094 \times 10^6\ mm^4$

$M_y = 420.63 \times 10^3 f_y$.

To locate the equal area axis, equating area on both sides of the axis.

$A = (300 \times 7.6) + [2(90 - 7.6) \times 13.6]$

$= 4521.28\ mm^2$



$A_1 = 150 \times 7.6 = 1140\ mm^2$

$A_2 = (90 - 7.6) \times 13.6$

$= 1120.64\ mm^2$

$y_1 = \frac{150}{2} = 75\ mm$

$y_2 = 150 - \frac{13.6}{2} = 143.2\ mm$

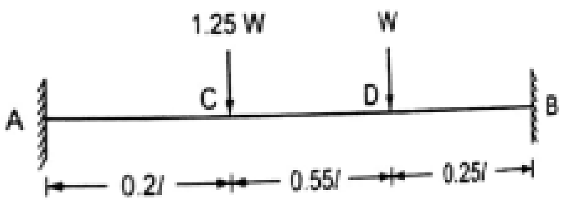
$\therefore M_p = f_y\,(1140 \times 75 + 1120.64 \times 143.2) \times 2$

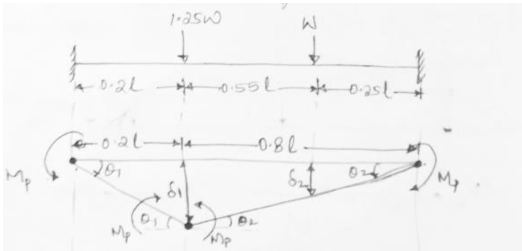
$= 491.95 \times 10^3\ f_y$

$S = \frac{M_p}{M_y} = \frac{491.95 \times 10^3 \times f_y}{420.63 \times 10^3 \times f_y}$

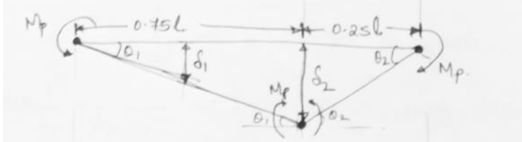
$\therefore \boxed{S = 1.17}$

4 Determine the collapse load for fixed beam as shown in figure 2.





Beam mechanism under 1.25W



Beam mechanism under W.

Case I. For beam mechanism under 1.25W load.

$\delta_1 = 0.2l\,\theta_1 = 0.8l\,\theta_2$

$\therefore \theta_2 = \frac{0.2l\theta_1}{0.8l}$ $\therefore \theta_2 = 0.25\theta_1$

$\therefore \boxed{\theta_1 = 4\theta_2}$ ——(i)

Work done by hinges or internal work done.

$= M_p \cdot \theta_1 + M_p(\theta_1 + \theta_2) + M_p\,\theta_2$

$= M_p \cdot \theta_1 + M_p(\theta_1 + 0.25\theta_1) + M_p \times 0.25\theta_1$

$= 2.5 M_p\,\theta_1$ or $= 10 M_p\,\theta_2$ —(ii)

Work done by load or external work done.

$= 1.25W \times \delta_1 + W \times \delta_2$

$= 1.25W \times 0.8l\,\theta_2 + W \times \delta_2$ —(iii)

From beam mechanism under load W.

$\delta_2 = 0.75l\,\theta_1 = 0.25l\,\theta_2$ (iv).

$\theta_2 = \frac{0.75l\,\theta_1}{0.25l}$

$\boxed{\therefore \theta_2 = 3\theta_1}$

from (I) & (IV)

$\delta_2 = \left(\frac{0.25 l \theta_2}{0.8 l \theta_2}\right) \delta_1$

$\boxed{\delta_2 = 0.3125\, \delta_1}$ —— (V)

Substituting δ_2 in equation (iii)

Work done by load =

$1.25\, W \times 0.8 l \theta_2 + W \times 0.3125 \times 0.8 l \theta_2$

$= 1 W l \theta_2 + 0.25 W l \theta_2$

$= 1.25 W l \theta_2$

Equating both the work done

$10 M_p \theta_2 = 1.25\, W_c \cdot l \cdot \theta_2$

$\boxed{W_c = \frac{8 M_p}{l}}$

External work done $= W_c \times 0.75 l \theta_1 + 1.25 \times 0.75 l \theta_1 \times 0.325$

$= 1.04\, W_c \cdot l \cdot \theta_1$

by Principle of virtual work

Work done by plastic hinges = Work done by load.

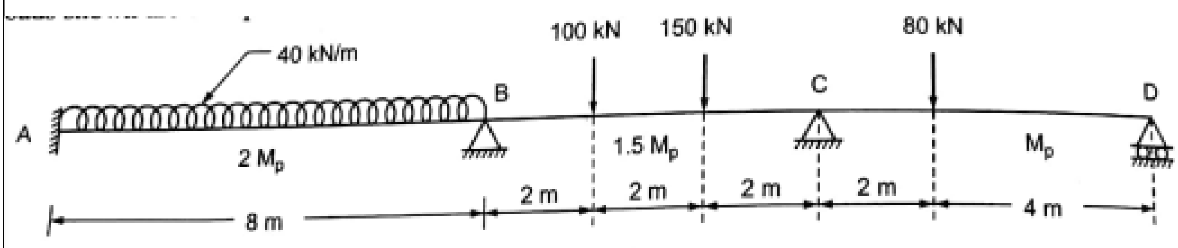
$8 M_p \theta_1 = 1.04\, W_c\, l \cdot \theta_1$

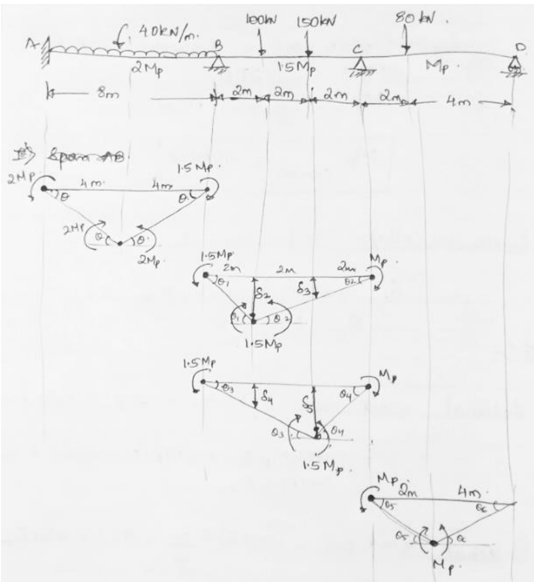
$\boxed{W_c = \frac{7.7 M_p}{l}}$

Hence, the collapse mechanism will occur at W_c load, since the collapse load in case II has lesser value.

$\boxed{W_c = \frac{7.7 M_p}{l}}$

5 Find required value of plastic moment capacity of the continuous beam as shown in figure 3. The loads shown are collapse loads.





I) Span AB

$\delta_1 = 4\theta$

Internal work done $= 2M_p\theta + 2M_p(\theta+\theta) + 1.5 M_p \theta$

$= 7.5 M_p \theta$

External work done $= 40 \times 8 \times \frac{\delta_1}{2} = 320 \times \frac{4\theta}{2}$

$= 640\theta$

Internal work done = External work done.

$7.5 M_p \theta = 640\theta$

$M_p = \frac{640}{7.5}$

$\boxed{\therefore M_p = 85.34 \text{ kN-m}}$

II) Span BC (100 kN).

$\delta_2 = 2\theta_1 = 4\theta_2$

$\delta_3 = 4\theta_1 = 2\theta_2$

$\therefore \theta_1 = 2\theta_2$ & $\delta_2 = 2\delta_3$ or $\delta_3 = \frac{1}{2}\delta_2$

Internal work done $= 1.5 M_p \cdot \theta_1 + 1.5 M_p(\theta_1 + \theta_2) + M_p\theta_2$

$= 1.5 M_p (2\theta_2) + 1.5 M_p(2\theta_2 + \theta_2) + M_p\theta_2$

$= 8.5 M_p \theta_2$. — (i)

External work done $= 100 \times 4\theta_2 + 150 \times 2\theta_2$

$= 700\theta_2$ — (ii)

$\therefore$ Equating (i) & (ii)

$8.5 M_p \theta_2 = 700\theta_2$

$\therefore M_p = \frac{700}{8.5} = 82.35$ kN-m

Span BC (150 kN)

$\delta_5 = 4\theta_3 = 2\theta_4$

$\delta_4 = 2\theta_3$

$\theta_4 = 2\theta_3$

Internal work done $= 1.5 M_p \theta_3 + 1.5 M_p(\theta_3 + \theta_4) + M_p \cdot \theta_4$

$= 1.5 M_p\theta_3 + 1.5 M_p(\theta_3 + 2\theta_3) + M_p \cdot 2\theta_3$

$= 8 M_p \theta_3$

External work done $= 100 \times 2\theta_3 + 150 \times 4\theta_3$

$= 800\theta_3$

$\therefore 8 M_p\theta_3 = 800\theta_3$

$M_p = 100$ kN-m

III) Span CD

$\delta_6 = 2\theta_5 = 4\theta_6$

$\theta_5 = 2\theta_6$

Internal work done $= M_p\theta_5 + M_p(\theta_5 + \theta_6)$

$= M_p(2\theta_6) + M_p(2\theta_6 + \theta_6)$

$= 5 M_p \theta_6$

External work done $= 80 \times 4\theta_6$

$= 320\theta_6$

$\therefore 5 M_p \theta_6 = 320\theta_6$

$\therefore M_p = \frac{320}{5} = 64$ kN-m

Hence, from all the mechanism, required value of plastic moment capacity of beam is the highest value.

i.e. $M_p = 100$ kN-m