POSTAL BOOK PACKAGE 2027

CIVIL ENGINEERING

CONVENTIONAL PRACTICE SETS VOLUME - I

CONTENTS

CONSTRUCTION PRACTICE, PLANNING AND MANAGEMENT

CONVENTIONAL PRACTICE SETS

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1 CHAPTER Construction Planning and Management

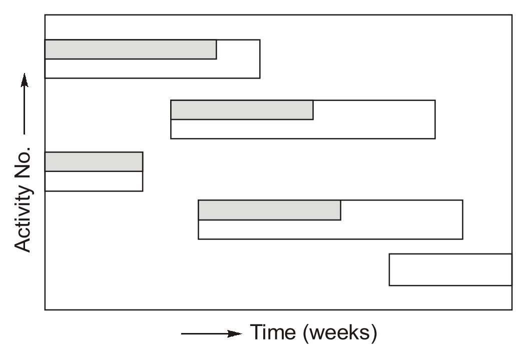
Q.1 Briefly answer the following:

(i) How can an existing bar chart be modified to depict the project progress made?

(ii) Differentiate between 'Forward Planning' and 'Backward Planning' for network construction.

Solution:

(i) A bar chart doesn't show the progress of work and hence it cannot be used as a control device. Controlling is essential for rescheduling the remaining activities. However, an existing bar chart can be modified to depict the progress made. This can be done by showing the progress of each of each activity, by hatched lines along the corresponding bar of the activity. Generally, hatching is done in half the width of the bar.



(ii) 'Forward Planning': In this method, the planner starts from the initial event and builds up the events and activities logically and sequentially until the end event is reached. In this method, while considering activity, a planner asks himself the following questions:

What event comes next?

What are dependent events?

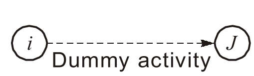
What events can take place concurrently?

Backward planning: In this method, the planner starts with the end event and arranges the events and activities until the initial event is reached. Keeping the goal in view, the planner asks himself if we want to achieve this, what events or activities should have taken place.

Q.2 Define 'dummy operation' and discuss its purpose in a network.

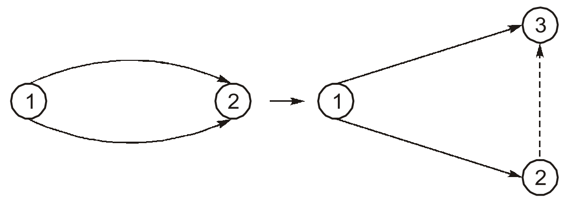
Solution:

Dummy operation: A dummy is a type of operation in the network which neither requires any time nor any resources, but act as merely as a device to identify a dependence among operations in activity on arrow diagram. A dummy is thus a connecting link for control purpose or for maintaining uniqueness of activity. A dummy is represented by arrow but since it is not really an activity it is represented by dashed arrow.



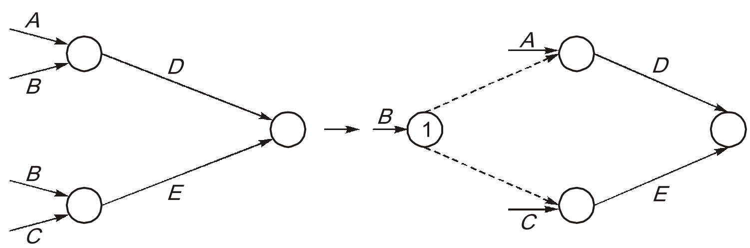
Dummy activity serves two purposes in a network:

(a) Grammatical purpose: A dummy is used to prevent two arrows having same beginning and end point, so as to maintain uniqueness of an activity in activity on arrow network diagram.



Incorrect representation   Correct representation

(b) Logical purpose: Dummy also is used to give logical clear representation in a network having an activity common to two set of operations running parallel to each other.



Incorrect representation   Correct representation

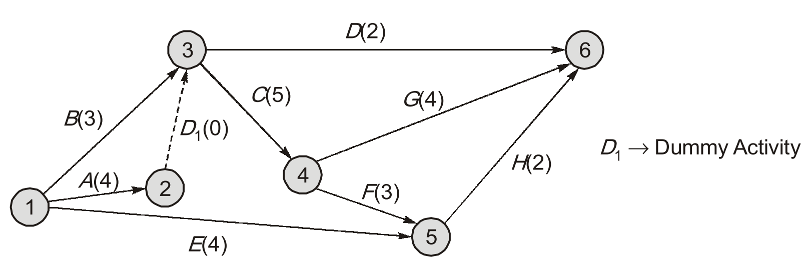
Q.3 A construction project consists of 8 major activities. Their interdependency is given below. Draw the network and determine the time for completion of the project. also mention duration for each path.

(i) Activities *A*, *B* and *E* can start concurrently. (Starting of the project)
(ii) Activities *C* and *D* are concurrent and depend on the completion of *A* and *B*.
(iii) Activities *F* and *G* are concurrent and can start after completion of *C*.
(iv) Activity *H* depends on the completion of *C*, *E* and *F*.
(v) Project ends with the completion of *G* and H.

Time needed for each activity is

A — 4 weeks   *B* — 3 weeks   *C* — 5 weeks   *D* — 2 weeks
E — 4 weeks   *F* — 3 weeks   *G* — 4 weeks   *H* — 2 weeks

Solution:



The paths of project are as follows:

S.No.	Path	Duration along path (weeks)
1.	$B \to D$	5
2.	$A \to D_1 \to D$	6
3.	$B \to C \to G$	12
4.	$B \to C \to F \to H$	13
5.	$A \to D_1 \to C \to G$	13
6.	$A \to D_1 \to C \to F \to H$	14
7.	$E \to H$	6

∴ The time taken for the completion of project is 14 weeks.

Q.4 What are the deficiencies of bar chart?

Solution:

A bar chart has following deficiencies:

- It can only be used for small and simple project.
- It is used only for project that are repetitive in nature.
- As bar chart lacks in showing project progress. It makes controlling of project with bar chart difficult.
- In bar chart sub-activities of an activity cannot be represented, so bar chart lacks in degree of details.
- Interdependencies between the activities cannot be depicted in bar chart.
- Critical and non-critical activities are not separated by use of bar chart.

Q.5 Explain various steps involved in the development of networks.

Solution:

Various steps involved in the development of networks are as follows:

(i) **Objective:** During the planning of a project, the first and foremost step is to define the project and to decide the way in which it is to be carried out. The task to be undertaken requires to be set down as specific, definite, complete and well defined verbal statement. Specific verbal statement means the specific description of particular dimensions, type of materials, plants, etc. necessary for the project. Objective specifies the task to be undertaken and policy of its execution. This specification defines the project and determines the way in which it is to be carried out.

(ii) **Plan breakdown:** After establishing objective of the task, the planner has to adopt either forward planning or backward planning (or mixed planning) to achieve the goal. This backward to forward thinking will give a list of activities or jobs to be performed to achieve the task and also stages in the project execution.

(iii) **Sequencing:** In the second step we have obtained a general list of various activities and events necessary for the completion of the project. This general list is to be reviewed so that in each of the main group, those with definite similarities can be put in suitable subgroups.

(iv) **Location of nodes:** Now the events listed above are required to be located on paper so that a visual effect of movement along a time scale is obtained. Events should be located in such a way that they represent initial picture of the relation amongst them. This relationship results from the proposed use of manpower, money, material and other resources during a particular period of time.

(v) **Drawing Arrows:** Events having close and direct relationship are joined to each other by arrows representing activity to be performed for passing from one stage of the project to the other. These activities should fall in logical sequence.

(vi) **Checking:** At this stage, the diagram is checked with respect to content, sequence and sense and degree of detail.

It is essential to check the diagram for events and activities in respect of logic and accuracy. Particular attention should be paid to multiple events, i.e., those events at which more than one arrows enters and/or more than one arrows leave, since it is at this point that errors are most likely to occur. The checking ensures that the network correctly represents the sequence.

It should be ensured that network does not contain loops or cycles. If located these should be removed. Also, it should be checked whether there is any event (other than first) which has only outgoing arrows, or whether there is any event (other than last one) which has only incoming arrows. Such situation, if found, should be rectified. There should be no dead ends left.

An arrow should always represent singular situation but an event may represent commencement of more than one operations. In respect of sufficient detail, a ratio, known, as E/A ratio given as

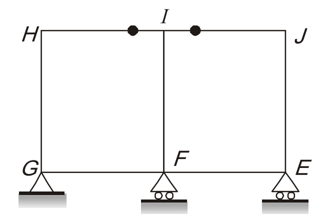
STRUCTURAL ANALYSIS

CONVENTIONAL PRACTICE SETS

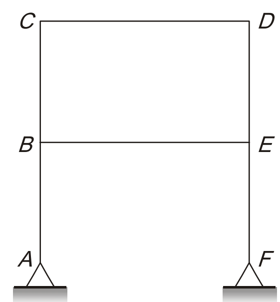
ILD & Rolling Loads and Determinacy

Q.1 (i) What do you understand by static indeterminacy and kinematic indeterminacy of a 2-*D* framed structure? Explain with an example of a fixed end beam.

(ii) The degree of static indeterminacy of the rigid frame having two internal hinges as shown in the figure below is



(iii) Consider the frame shown in the figure given below.



If the axial and shear deformations in different members of the frame are assumed to be negligible, then what would be the reduction in the kinematic indeterminacy.

Solution:

(i) Static indeterminacy (D_S): Those structures which cannot be analysed by using condition of static equilibrium alone are called indeterminate structures. To analyse these indeterminate structures extra equilibrium condition are required, called compatibility conditions and numbers of compatibility conditions needed to analyse structure is known as degree of static indeterminacy.

D_S = Total no. of reactions present (Both internal and external) – No. of available equilibrium equations.

For 2-*D* Rigid Frame: In two dimensional rigid member, each member has three internal reactions (viz. R_x, R_y and M_z) and at each joint three equilibrium conditions (viz. $\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma M_x = 0$) are available

Let there are r_e number of external support conditions.

∴ Total no. of reaction present,

$$R = \text{External reaction + Internal reaction}$$

$$R = r_e + 3\text{m}$$

and total no. of available equilibrium conditions,

$$E = 3j$$

∴

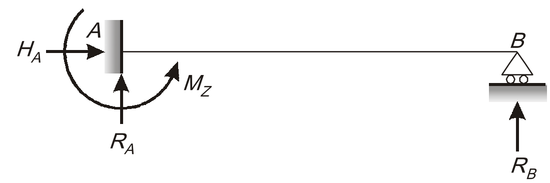
$$D_S = R - E$$

$$D_S = r_e + 3\text{ m} - 3j \quad \text{... when all joint are rigid}$$

$$D_S = r_e + 3\text{m} - 3j - r_r \quad \text{... when some joints are hybrid}$$

where r_r = Number of released reactions

Example:



Here, $r_e = 3 + 1 = 4$

$m = 1$

$j = 2$

$D_S = r_e + 3m - 3j$

$= 4 + 3 \times 1 - 3 \times 2$

$= 1$ (indeterminate to 1st degree)

Kinematic Indeterminacy (D_k): It refers to the total no. of available degree of freedom at all joints. It is equal to total no. of unrestrained displacement component at all joints.

D_k = Total degree of freedom at all joints – degree of freedom restrained by supports

2-*D* Rigid Frames: At each joint there are three degree of freedom (*viz.* Δ_x, Δ_y and θ_z). Hence at all joint there will be $3j$ degree of freedoms. But at supports displacements are not available in the direction of reaction component.

$\therefore$ D_k = unrestrained displacement component

$\Rightarrow$ $\mathbf{D_k = 3j - r_e}$ ... members are axially flexible

$\mathbf{D_k = 3j - r_e - m''}$ ...m'' member are axially rigid

Example:

$D_k = 3j - r_e$

Here, $j = 2$, $r_e = 3$

$\therefore$ $D_k = 3 \times 2 - 3$

$\Rightarrow$ $D_k = 3$ (i.e., θ_B, Δ_{HB} & Δ_{VB})

(ii) **Method-I: (By Formula)**

The degree of **static indeterminacy** for a rigid hybrid frame is given by ,

$D_s = 3m + r_e - r_r - 3(j + j')$

Where, m = total number of members = 9

r_e = total number of external reactions

$= 2 + 1 + 1 = 4$

r_r = total number of released reactions at hybrid joint

$= \Sigma(m_j - 1) = (2 - 1) + (2 - 1) = 2$

j = total number of rigid joints = 6

j' = total number of hybrid joints = 2

$\therefore$ $D_S = (3 \times 9) + 4 - 2 - 3(6 + 2)$

$= 27 + 4 - 2 - 24 = 31 - 26 = 5$

Method-II: (By Loop Method)

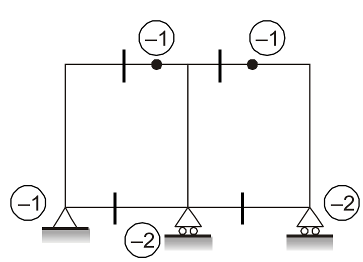
$\mathbf{D_{si} = 3C - r_r}$ where C = no. of closed loops

$= 3 \times 2 - 2 = 4$

$D_{se} = r_e - 3 = 1$

$D_s = D_{si} + D_{se} = 4 + 1 = 5$

Method-III:



D_s = 3 × Number of cuts to open-closed loops – Reaction added to make stable cantilevers

$\Rightarrow$ $D_s = (3 \times 4) - 1 - 1 - 2 - 2 = 5$

(iii) D_k (when inextensible) = D_k (when extensible) – Number of axially rigid members.

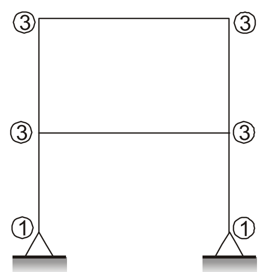
$\Rightarrow$ D_k (when extensible) – D_k (when inextensible)

= Number of axially rigid members

= 6

Key Point:

DOF of joints is shown below.

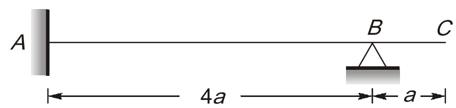


D_k (when extensible) = 3 + 3 + 3 + 1 + 1 = 14

D_k (when inextensible) = 14 – 6 = 8

Note: Reduction in $D_k = 6(\theta_A, \theta_B, \theta_C, \theta_D, \theta_E, \theta_F)$.

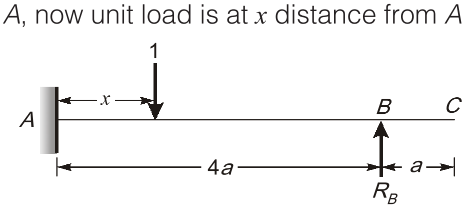
Q.2 State Muller Breslau principle. Derive the equation for influence line for the reaction R_B for the beams shown in the figure. EI is constant throughout.



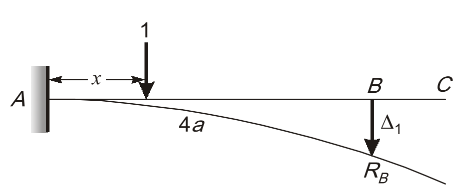
Solution:

Muller Breslau Principle: "The ILD for any stress function in a structure is represented by it's deflected shape obtained by removing the restraint offered by the stress function (SF, BM and reaction) and introducing a directly generalized unit displacement in the positive direction of that stress function".

Assume unit load travels from A, now unit load is at x distance from A

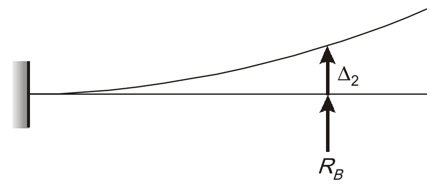


Case (i) $0 \leq x \leq 4a$



$$\boxed{\Delta_1 = \frac{1 \cdot x^3}{3EI} + \frac{1 \cdot x^2}{2EI}(4a - x)}$$ {Downward}

Where Δ_1 is deflection at B due to unit load.



$$\boxed{\Delta_2 = \frac{R_B(4a)^3}{3EI}} = \frac{64R_Ba^3}{3EI}$$

Where Δ_1 is deflection at B due to reaction R_B.
Since joint B is hinged, hence net deflection is zero

$$\boxed{\Delta_1 = \Delta_2}$$

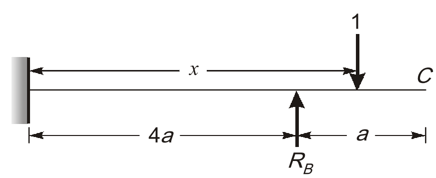
$$\frac{x^3}{3EI} + \frac{x^2(4a-x)}{2EI} = \frac{64R_Ba^3}{3EI}$$

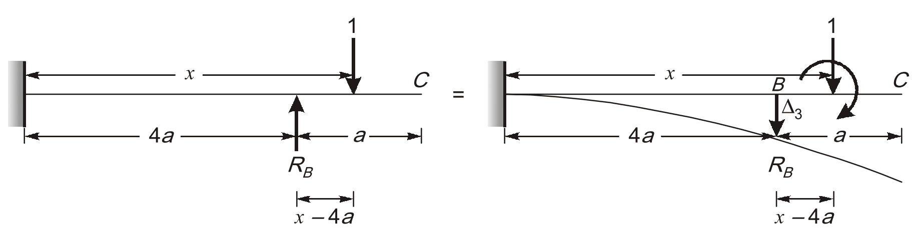
$$R_B = \frac{3EI}{64a^3}\left[\frac{x^3}{3EI} + \frac{2ax^2}{EI} - \frac{x^3}{2EI}\right]$$

$$= \frac{3EI}{64a^3}\left[\frac{2ax^2}{EI} - \frac{x^3}{6EI}\right] = \frac{3x^2}{32a^2} - \frac{1}{128}\frac{x^3}{a^3}$$

$$R_B = \frac{x^2(12a-x)}{128a^3} \qquad \text{(when } 0 \le x \le 4a\text{)}$$

Case (ii) $4a \le x \le 5a$

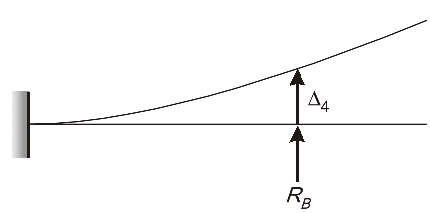




Deflection at B due to unit load at x is same as the deflection at x due to point load at B.

$$\therefore \quad \boxed{\Delta_3 = \frac{1\cdot(4a)^3}{3EI} + \frac{(4a)^2(x-4a)\cdot 1}{2EI}}$$

When Δ_3 is the deflection at B due to unit load.



$$\boxed{\Delta_4 = \frac{R_B(4a)^3}{3EI}} = \frac{64R_Ba^3}{3EI}$$

When Δ_4 is the deflection at B due to reaction R_B.
Since joint B is hinged, hence net deflection is zero.

$$\boxed{\Delta_3 = \Delta_4}$$

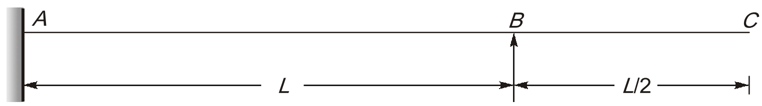
$$\frac{1\cdot(4a)^3}{3EI} + \frac{1\cdot(x-4a)(4a)^2}{2EI} = \frac{64R_Ba^3}{3EI}$$

$$R_B = \frac{3EI}{64a^3}\left[\frac{64a^3}{3EI} + \frac{16a^2(x-40)}{2EI}\right] = 1 + \frac{3EI \times 16a^2(x-4a)}{64a^2 \times 2EI}$$

$$= 1 + \frac{3}{8a}(x - 4a) = 1 + \frac{3x}{8a} - \frac{3}{2}$$

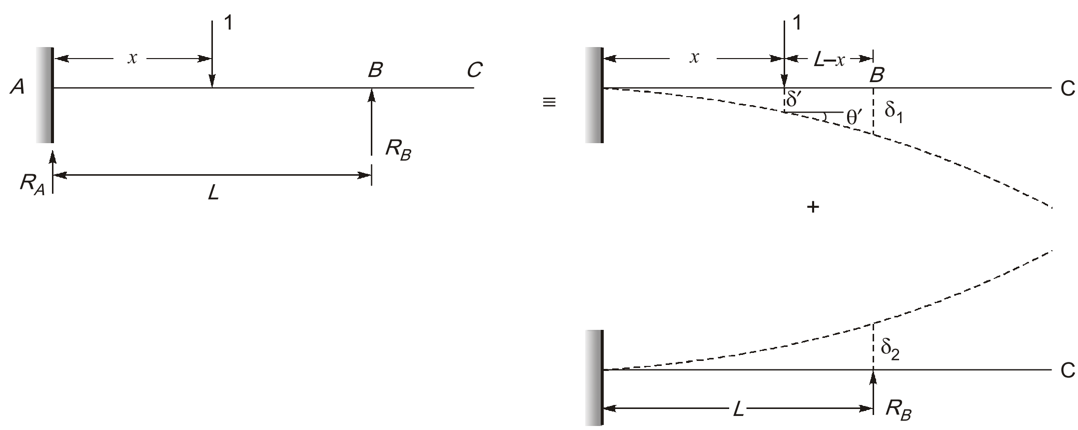
$$R_B = \frac{3x}{8a} - 0.5 \qquad \text{when } 4a \le x \le 5a$$

Q.3 A beam ABC as shown in below figure is fixed at A and is simply supported at B. Draw the qualitative diagram for influence line of vertical reaction at A.



Solution:

Case-I: When unit load lies between A and B (i.e. $\Delta \le x \le L$)



From unit load method:

$$\boxed{\delta_1 = \delta' + \theta'(L - x)}$$

$$= \frac{1.x^3}{3EI} + \frac{1.x^2}{2EI}(L - x) = \frac{x^2(3L - x)}{6EI}$$

$$\delta_2 = R_B \frac{L^3}{3EI}$$

$$\delta_B = \delta_1 - \delta_2 = 0$$

$$\Rightarrow \quad \delta_1 = \delta_2$$

$$\Rightarrow \quad R_B \frac{L^3}{3EI} = \frac{x^2(3L - x)}{6EI}$$

$$\Rightarrow \quad R_B = \frac{x^2(3L - x)}{2EI}$$

$$\therefore \quad R_A = 1 - R_B \qquad (\because \Sigma F_y = 0, \Rightarrow R_A + R_B = 1)$$

$$= \left\{1 - \frac{x^2(3L - x)}{2L^3}\right\} \qquad \text{...(Cubic)}$$

$$\frac{\partial R_A}{\partial x} = \frac{-2x(3L) - 3x^2}{2L^3}$$

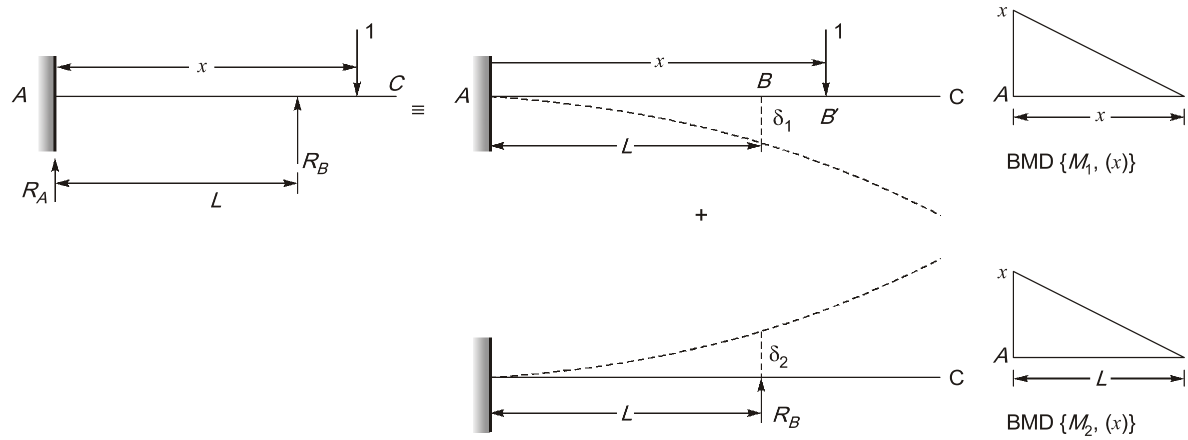
$$= \frac{-3x(2L - x)}{2L^3} < 0 \qquad \text{...(decreasing slope)}$$

Hence, ILD for R_A between A and B is cubic with a decreasing slope.

And at A, $x = 0 \Rightarrow$ $\quad R_A = 1$

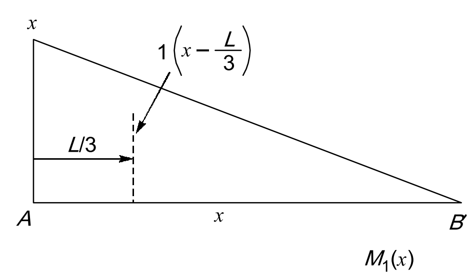
And at B, $x = \text{L} \Rightarrow$ $\quad R_A = 1 - \dfrac{L^2(3L - L)}{2L^3} = 0$

Case-II : When unit load lies between *B* and *C* ($L \le x \le 1.5\, L$)



δ_1 calculations:
By area moment method

$$= \left(\frac{1}{2} \times L \times \frac{L}{EI}\right) \times 1.\left(x - \frac{L}{3}\right) = \frac{L^2(3x - L)}{6EI}$$



$$\delta_2 = R_B \frac{L^3}{3EI}$$

$$\delta_B = \delta_1 - \delta_2 = 0$$

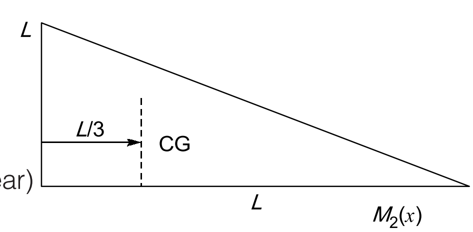
$$\Rightarrow \quad \delta_1 = \delta_2$$

$$\Rightarrow \quad R_B \frac{L^3}{3EI} = \frac{L^2(3x - L)}{6EI}$$

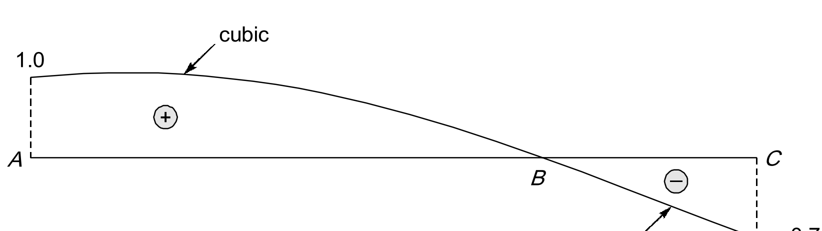
$$\Rightarrow \quad R_B = \left(\frac{3x - L}{2L}\right)$$

$$\Sigma F_y = 0$$

$$\Rightarrow \quad R_A = 1 - R_B = \left\{1 - \left(\frac{3x - L}{2L}\right)\right\} = \frac{3}{2}\left(1 - \frac{x}{L}\right) \text{ ...(Linear)}$$

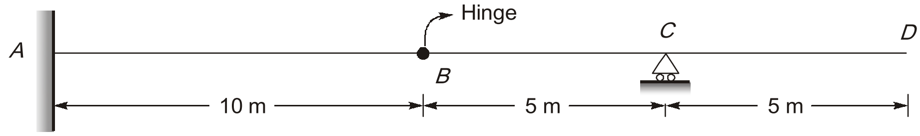


$$R_A(x = 1.5\, L) = -0.75$$



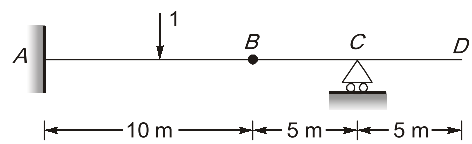
ILD for R_A

Q.4 Draw the influence line diagram for the bending moment and shear force at support *A* for the beam *ABCD* shown in the figure.



Solution:

(i) Influence line diagram for V_A (shear force at support *A*);



AB : When unit load is any where between *A* and *B*.

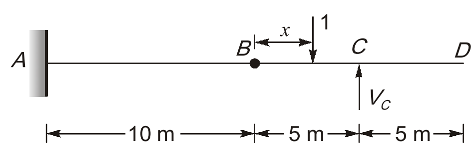
$$\Sigma M_B = V_C \times 5 = 0$$

$\Rightarrow$ $V_C = 0$

$\therefore$ $V_A + V_C = 1$

$\Rightarrow$ $V_A = 1$ = Reaction at *A*. ...(i)

BC : When unit load is between *B* and *C* (At x from *B*)



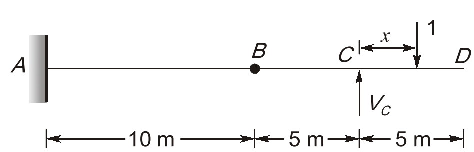
$\therefore$ $V_C \times 5 = 1 \times x$

$\Rightarrow$ $V_C = \dfrac{x}{5}$, $V_A + V_C = 1$, $V_A = 1 - \dfrac{x}{5}$ ...(ii) [$\because V_A + V_C = 1$]

At $x = 0$, $V_C = 0 \Rightarrow V_A = 1$

At $x = 5$, $V_C = 1 \Rightarrow V_A = 0$

CD : When unit load is between *C* and *D* (At x from *C*)



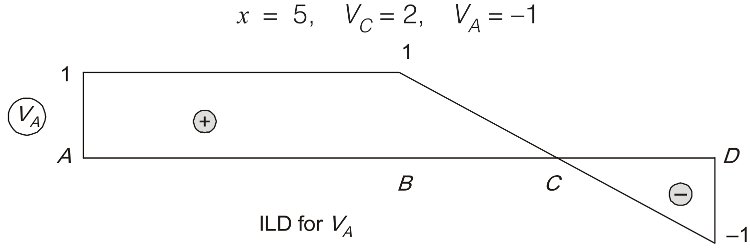
$$\Sigma M_B = 0$$

$\Rightarrow$ $V_C \times 5 = 1\,(x + 5)$

$$V_C = \frac{x+5}{5}, \quad V_A = 1 - \frac{x+5}{5}$$ ...(iii) [$\because V_A + V_C = 1$]

At $x = 0$, $V_C = 1$, $V_A = 0$

At $x = 5$, $V_C = 2$, $V_A = -1$



ILD for V_A

DESIGN OF STEEL STRUCTURES

CONVENTIONAL PRACTICE SETS

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1 CHAPTER

Rivets & Bolts

Rivets

Q.1 **Determine the rivet value of 18 mm diameter rivets connecting 10 mm plate and is in: (i) single shear, and (ii) double shear. The permissible stresses for rivets in shear and bearing are 80 MPa and 250 MPa respectively and for plate in bearing is 250 MPa.**

Solution:

Gross diameter of rivets, d = 18 + 1.5 = 19.5 mm

Strength of rivet

(i) In bearing = $\sigma_{pf} \times d \times t = 250 \times 19.5 \times 10 = 48750$ N = 48.75 kN

(ii) In single shear = $\tau_{vf} \times \frac{\pi}{4} \times d^2 = 80 \times \frac{\pi}{4} \times (19.5)^2 = 23891.8$ N = 23.89 kN

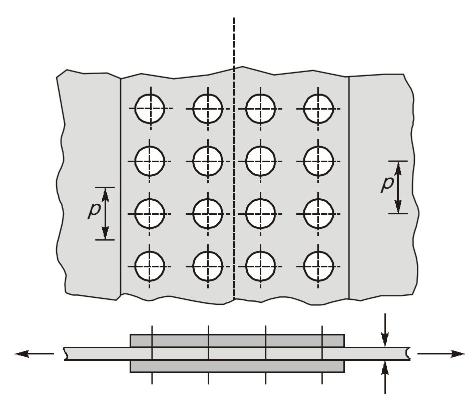
(iii) In double shear = $2 \times \tau_{vf} \times \frac{\pi}{4} \times d^2 = 2 \times 23891.8 = 47783.6$ N = 47.78 kN

∴ Rivet value in single shear = smaller of (i) and (ii) = 23.89 kN

and Rivet value in double shear = smaller of (i) and (iii) = 47.78 kN

Q.2 **Two plates each 12 mm thick are joined by double riveted double cover butt joint as shown in figure below. Using 20 mm diameter rivets, design the pitch of the rivets. Take σ_{at} = 150 MPa. Also find the efficiency of the joint. (Consider power driver shop rivet.)**

Solution:



Gross diameter of the rivets = 20 + 1.5 = 21.5 mm

For power driven shop rivets σ_{pf} = 300 MPa

and τ_{vf} = 100 MPa

Strength of rivets in bearing = $\frac{300}{1000} \times 21.5 \times 12$ = 77.4 kN

Strength of rivets in double shear = $\frac{2 \times 100}{1000} \times \frac{\pi}{4}(21.5)^2$ = 72.6 kN

Rivet value = 72.6 kN

For maximum efficiency of joint per pitch length,

Strength of plate per pitch = 2 × Rivet value

or $\sigma_{at} \times (p - d) \times t = 2 \times 72.6 \times 1000$ N

or $150 \times (p - 21.5) \times 12 = 2 \times 72.6 \times 1000$ N

or p = 102.17 mm (say 100 mm)

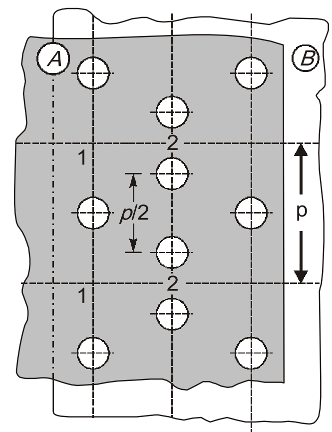
Minimum permissible pitch = 2.5 × d = 2.5 × 21.5 = 53.75 mm

∴ Adopt pitch = 100 mm

$$\text{Efficiency of joint} = \frac{150 \times (100 - 21.5) \times 12}{150 \times 100 \times 12} \times 100 = 78.5\%$$

Q.3 Two plates 10 mm and 8 mm thick are joined by a triple-riveted lap joint. Find the suitable pitch for the outer row of rivets if the pitch for central row of rivets is half of the pitch for the outer rows. Take permissible stresses for rivets in shear and bearing equal to 90 MPa and 270 MPa respectively and permissible tensile stress in plates equal to 150 MPa. Also find the efficiency of the joint.

Solution:



$$\text{Diameter of rivets} = 6.01\sqrt{t} = 6.01\sqrt{8} = 16.9 \text{ mm say } 18 \text{ mm}$$

$$\text{Gross diameter} = 18 + 1.5 = 19.5 \text{ mm}$$

Strength of rivets in single shear

$$= \frac{90}{1000} \times \frac{\pi}{4} \times (19.5)^2 = 26.88 \text{ kN}$$

$$\text{Strength of rivets in bearing on 8 mm plate} = \frac{270}{1000} \times 19.5 \times 8 = 42.12 \text{ kN}$$

$\therefore$ Rivet value = 26.88 kN

For plate A in figure the most critical section will be along 1-1 or 2-2

(i) Strength of plate per pitch along 1-1 $= \dfrac{150}{1000} \times (p - 19.5) \times 8$

$= 1.2\,p - 23.4$ kN

(ii) Strength of plate per pitch along 2-2 $= \dfrac{150}{1000} \times (p - 2 \times 19.5) \times 8 + 26.88$

$= 1.2\,p - 19.92$ kN

Comparing (i) and (ii) above, section 1-1 is weaker.

$\therefore$ Strength of plate per pitch $1.2\,p - 23.4$ kN

For maximum efficiency of joint,

Strength of plate per pitch = Strength of rivets per pitch

$\Rightarrow$ $1.2\,p - 23.4 = 4 \times 26.88$

$\Rightarrow$ $p = 109.1$ mm say 110 mm

Minimum permissible pitch = 2.5 × 21.5 = 53.75 mm

$\therefore$ Use pitch of 110 mm for outer row of rivets.

$$\text{Efficiency of joint} = \frac{4 \times 26.88 \times 1000}{150 \times 110 \times 8} \times 100 = 81.45\%$$

Q.4 Design a riveted splice for a tie of a steel bridge, 20 cm wide, 20 mm thick carrying an axial tensile force of 50,000 kg. Use 12 mm thick cover plates, 22 mm diameter rivets. Permissible stresses:
tension in plates = 1500 kg/cm^2
shear in rivets = 1000 kg/cm^2
bearing in rivets = 3000 kg/ cm^2
Give a neat sketch of the arrangement.

Solution:

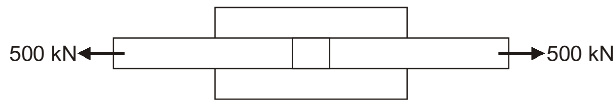
Taking $g = 10$ m/s^2 and 1 kg/cm^2 = 0.1 N/mm^2

∴ Axial tensile force, $P = \frac{50,000 \times 10}{1000} = 500$ kN

Nominal diameter of rivets = 22 mm

∴ Gross diameter of rivets $d' = 22 + 1.5 = 23.5$ mm

Designing the splice as a double cover butt joint as it will give maximum efficiency.



Given that thickness of cover plates = 12 mm

Width of main plate = 20 cm = 200 mm

Thickness of main plate = 20 mm

Assuming the width of cover plate = 200 mm

Strength of rivet in double shear $= \frac{\pi}{4}(d')^2 \times f_s \times 2 = \frac{\pi}{4} \times (23.5)^2 \times \frac{100}{1000} \times 2 = 86.75$ kN

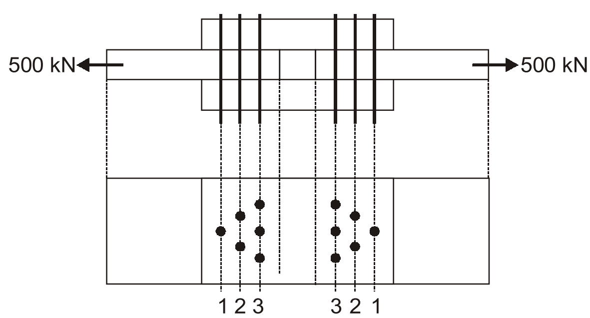
Strength of rivet in bearing $= d' t\, f_b = 23.5 \times 20 \times \frac{300}{1000} = 141$ kN

∴ Rivet value, $R_v = 86.75$ kN

Number of rivets, $n = \frac{P}{R_v} = \frac{500}{86.75} = 5.76 \approx 6$

The rivets can be arranged in diamond pattern

Checking the strength of cover plate and main plate in tearing



As we know that 3-3 is critical for cover plates.

∴ Strength of cover plates in tearing at 3-3 ≥ 500 kN

$\Rightarrow$ $(200 - 3 \times 23.5) \times 2 \times 12 \times \frac{150}{1000} = 466.2$ kN < 500. **Hence unsafe.**

Providing two rivets at 3-3, then

Strength of cover plats in tearing at 3-3 $= (200 - 2 \times 23.5) \times 24 \times \frac{150}{1000}$

$= 550.8$ kN > 500 kN (Hence safe)

Thus 2 rivets can be provided at 3-3, **Hence safe**

Thus arranging rivets in chain pattern, in 3 pairs of two rivets each.

1-1 is critical for main plate,

∴ Strength of main plate in tearing at 1-1 > 500 ≥ 500 kN

$$\Rightarrow \quad = (200 - 2 \times 23.5) \times 20 \times \frac{150}{1000} = 459 \text{ kN} < 500 \text{ kN}. \textbf{ Hence unsafe}$$

Thus one rivet can be provided at 1-1.

We can provide three rivets at 2-2, thus checking for tearing of main plate at 2-2

$$\Rightarrow \quad = (200 - 3 \times 23.5) \times 20 \times \frac{150}{1000} + R_v > 500$$

$$\Rightarrow \quad = (200 - 3 \times 23.5) \times 20 \times \frac{150}{1000} + 86.75$$

$$= 475.25 < 500, \textbf{ Hence unsafe}$$

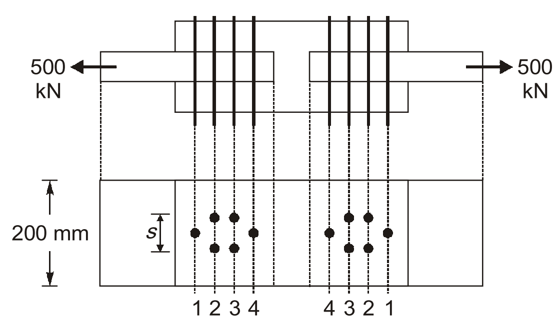
Thus, providing two rivets at 2-2

Strength of main plate in tearing at 2-2

$$= (200 - 2 \times 23.5) \times 20 \times \frac{150}{1000} + 86.75$$

$$= 545.75 > 500. \textbf{ Hence safe.}$$

Thus at 1-1 at the most one rivet can be provided. Two rivets can be provided at 2-2. Two rivets can be provided at 3-3. We have to create 4-4 in order to incorporate the remaining one rivet. Thus the arrangement will be as given below.



Equating the strength of rivet per pitch length to the strength of plate per pitch length in tearing.

$$R_v = (S - 23.5) \times 20 \times \frac{150}{1000}$$

$$\Rightarrow \quad 86.75 = (S - 23.5) \times 20 \times \frac{150}{1000}$$

$$\Rightarrow \quad S = 52.42 \text{ mm} = 60 \text{ mm} \nless 2.5 \times 22 = 55 \text{ mm}$$

Bolts

Q.5 Determine the strength of 20 mm diameter bolt of grade 4.6 for the following cases.

(a) Lap joint.

(b) Single cover butt joint with 10 mm thick cover plate.

(c) Double cover butt joint with 8 mm thick cover plates.
The main plates to be joined are 14 mm thick. Use Fe410 grade steel.

Solution:

For Fe410 steel, $f_u = 410\ \text{N/mm}^2$, $f_y = 250\ \text{N/mm}^2$

For 4.6 grade bolt, $f_{ub} = 400\ \text{N/mm}^2$, $f_y = 240\ \text{N/mm}^2$

Partial factor of safety for bolt material (γ_{mb}) = 1.25

Net tensile stress area for 20 mm diameter bolt (A_{nb}) = 245 mm² $\left(\simeq 0.78 \times \frac{\pi}{4} \times 20^2\right)$

(a) Lap joint

In lap joint, the bolts are in single shear

∴ Shear strength of bolt in single shear

$$\boxed{V_{dsb} = \frac{f_{ub} A_{nb}}{\sqrt{3}\,\gamma_{mb}}}$$

$$= \frac{400 \times 245}{\sqrt{3} \times 1.25} N = 45.26\ \text{kN}$$

Strength of bolt in bearing (V_{dpb}) $= 2.5\ k_b dt \dfrac{f_u}{\gamma_{mb}}$

For 20 mm diameter bolt, diameter of bolt hole (d_0) = 22 mm

End distance (e) = 33 mm

Let pitch (p) = 50 mm

$$\therefore \quad k_b = \text{minimum of} \begin{cases} \dfrac{e}{3d_0} = \dfrac{33}{3 \times 22} = 0.5 \\ \dfrac{p}{3d_o} - 0.25 = \dfrac{50}{3 \times 22} - 0.25 = 0.508 \\ \dfrac{f_{ub}}{f_u} = \dfrac{400}{410} = 0.976 \\ 1.0 \end{cases}$$

$$= 0.5$$

$$\therefore \quad V_{dpb} = 2.5\, k_b \frac{dt\, f_u}{\gamma_{mb}}$$

$$= 2.5 \times 0.5 \times 20 \times 14 \times \frac{410}{1.25} \text{N} = 114.8\ \text{kN}$$

Thus strength of bolt = Minimum of V_{dsb} and V_{dpb} = 45.26 kN

(b) Single cover butt joint with 10 mm thick cover plate

Here also the bolt will be in single shear and bearing. The considered thickness for bearing will be the minimum of aggregate thickness of cover plate and minimum thickness of main plates to be jointed i.e.

$t = 10$ mm

As computed in part (a) above, strength of bolt in single shear (V_{dsb}) = 45.26 kN

Strength of the bolt in bearing (V_{dsb}) $= 2.5\, k_b \dfrac{dt\, f_u}{g_{mb}}$

$$= 2.5 \times 0.5 \times 20 \times \frac{10 \times 410}{1.25}\text{N}$$

$= 82$ kN

Thus strength of bolt = Minimum of V_{dsb} and V_{dpb}

$= 45.26$ kN

(c) Double cover butt joint with 8 mm thick cover plates

Here the bolt will be in double shear and bearing. The considered thickness for bearing will be the minimum of aggregate thickness of cover plates and minimum thickness of main plates to be jointed i.e.

$t =$ Minimum of (8 + 8, 14) mm = 14 mm

Strength of bolt in double shear (V_{dsb})

$$= 2 \times \frac{f_{ub}\, A_{nb}}{\sqrt{3}\,\gamma_{mb}} = 90.53 \text{ kN}$$

Strength of bolt in bearing (V_{dpb})

$$= 2.5\, k_b \frac{dt\, f_u}{\sqrt{3}\,\gamma_{mb}}$$

$$= 2.5 \times 0.5 \times 20 \times 14 \times \frac{410}{1.25}\text{N}$$

$= 114.8$ kN

Thus strength of bolt = Minimum of V_{dsb} and V_{dpb} = 90.53 kN

Q.6 Two 10 mm thick plates are connected by lap joint to transmit a factored load of 100 kN using black bolts of 12 mm diameter and grade 4.6. What is the minimum number of bolts required for safe design? (Given f_u = 410 MPa)

Solution:

Nominal diameter of bolt, $d = 12$ mm

Gross diameter of bolt, $d_0 = 12 + 1 = 13$ mm

For grade 4.6 bolt, $f_{ub} = 400$ MPa

$\gamma_{mb} = 240$ MPa

(a) Shear strength of bolt (V_{dsb})

$$\boxed{V_{dsb} = \frac{f_{ab}}{\sqrt{3}\,\gamma_{mb}}\left(A_{nb}n_n + A_{sb}n_s\right)}$$

Since bolt is in single shear for lap joint

$n_s = 0,\ n_n = 1$

$$A_{nb} = 0.78\, A_{sb} = 0.78 \times \frac{\pi}{4} \times 12^2$$

$$\therefore \quad V_{dsb} = \frac{400}{\sqrt{3} \times 1.25} \times 0.78 \times \frac{\pi}{4} \times 12^2 \times 10^{-3}\text{kN}$$