LECTURE NOTES

ON

BASIC CIVIL & MECHANICAL ENGINEEING
ACADEMIC YEAR 2021-22

I B.Tech.–II SEMESTER (R20)

V.V.S.MANOJ, Assistant Professor

DEPARTMENT OF HUMANITIES AND BASIC SCIENCES

V S M COLLEGE OF ENGINEERING
RAMACHANDRAPURAM
E.G DISTRICT
533255

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
KAKINADA – 533 003, Andhra Pradesh, India

DEPARTMENT OF MECHANICAL ENGINEERING

I Year - II Semester		**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**
BASIC CIVIL & MECHANICAL ENGINEEING					

Course Objectives:

COB 1: To impart basic principles of stress, strain, shear force and bending moment.
COB 2: To teach principles of strain measurement using electrical strain gauges.
COB 3: To impart basic characteristics of building materials.
COB 4: To familiarize the sources of energy, power plant economics and environmental aspects.
COB 5: To make the students to understand the basics concept of Boilers & I.C. engines.

UNIT – I:

Basic Definitions of Force Stress Strain Elasticity. Shear force Bending Moment Torsion. Simple problems on Shear force Diagram and bending moment Diagram for cantilever and simply supported beam.

UNIT II:

Measurement of Strain - Electrical Capacitance and Resistance Strain gauges multichannel strain indicators. Rosette analysis Rectangular and Triangular strain rosettes.

UNIT – III:

Characteristics of common building materials Brick Types Testing; Timber Classification Seasoning Defects in Timber; Glass Classification uses; steel and its applications in construction industry.

UNIT IV

Hydraulic Turbines And Pumps:

Introduction to Power transmission tools, Hydraulic Turbines: Classification- Difference between Impulse and Reaction Turbine.
Pumps: Classification of Pumps, Centrifugal Pump-Applications-Priming- Reciprocating Pumps, Single Acting & Double acting-Comparison with Centrifugal Pump

UNIT V

I.C Engine: Heat Engine Types of Heat Engine Classification of I.C. Engine-Valve Timing Diagram, Port Timing Diagram- Comparison of 2S & 4S Engines- Comparison of Petrol Engine and Diesel Engine-Fuel System of a Petrol Engine-Ignition Systems.
Boilers: Classification of Boilers – – Simple Vertical Boiler – Cochran Boiler – Babcock and Wilcox Boiler Benson Boiler Difference between Fire Tube and Water Tube Boilers Boiler Mountings and Accessories.

Text Books:

1. Basic Civil and Mechanical Engineering, by Prof.V.Vijayan, Prof.M.Prabhakaranand
2. Er.R.Viashnavi, S.Chand Publication.
3. Elements of Mechanical Engineering Fourth Edition S Trymbaka Murthy,University Press.
4. Shanmugam G and Palanichamy M S, "Basic Civil and Mechanical Engineering", Tata McGraw Hill Publishing Co., New Delhi.

Course Outcomes:

At the end of this course, the student will be able to

CO 1 :	Apply Shear force diagram & Bending moment diagram principles for Cantilever and Simply supported beams.
CO 2 :	Apply concepts of Rosette analysis for strain measurements.
CO 3 :	Analyze the characteristics of common building materials.
CO 4 :	Compare the working characteristics of Internal Combustion engines.
CO 5 :	Compare the differences between boiler mountings and accessories.

VSM COLLEGE OF ENGINEERING

RAMACHANDRAPRUM- 533255

DEPARTMENT OF ELECTICAL AND ELECTRONICS ENGINEERING

Course Title	Year-Sem	Branch	Contact Periods/Week	Section
BCME	1-2	EEE	6	-

Course Outcomes:

At the end of this course, the student will be able to

CO 1 : Apply Shear force diagram & Bending moment diagram principles forCantilever and Simply supported beams.
CO 2 : Apply concepts of Rosette analysis for strain measurements.
CO 3 : Analyze the characteristics of common building materials.
CO 4 : Compare the working characteristics of Internal Combustion engines.
CO 5 : Compare the differences between boiler mountings and accessories

Mapping of Course Outcomes with Program Outcomes

CO/PO	PO 1 (K3)	PO 2 (K4)	PO 3 (K5)	PO 4 (K3)	PO 5 (K3)	PO 6 (K3)	PO 7 (K2)	PO 8 (K3)	PO 9 (K2)	PO 10 (K2)	PO 11 (K3)	PO12 (K)
CO1 (K3)	3	2	-	-	-	-	2	-	-	-	-	-
CO2 (K3)	3	2	-	-	-	-	3	-	-	-	-	-
CO3 (K4)	3	3	-	-	-	-	3	-	-	-	-	-
CO4 (K4)	2	3	-	-	-	-	3	-	-	-	-	-
CO5 (K4)	3	3	-	-	-	-	3	-	-	-	-	-

Mapping of Course Outcomes with Program Specific Outcomes

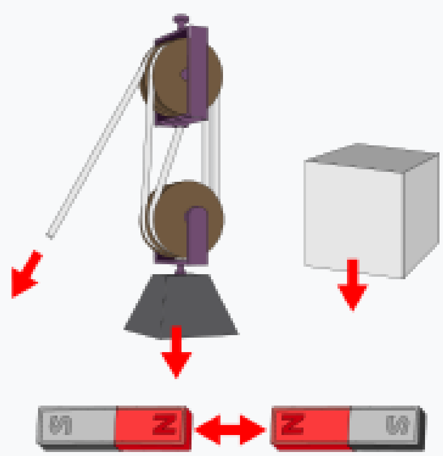
CO / PSO	PSO 1(K5)	PSO 2(K5)	PSO 3(K3)
CO1 (K3)	-	-	-
CO2 (K3)	-	1	-
CO3 (K4)	-	2	-
CO4 (K4)	-	-	-
CO5 (K4)	-	2	-

UNIT – 1

DEFINATION OF FORCE:

In physics, a **force** is an influence that can change the motion of an object. A force can cause an object with mass to change its velocity (e.g. moving from a state of rest), i.e., to accelerate. Force can also be described intuitively as a push or a pull. A force has both magnitude and direction, making it a vector quantity. It is measured in the SI unit of Newton (N). Force is represented by the symbol **F** (formerly **P**).

Force

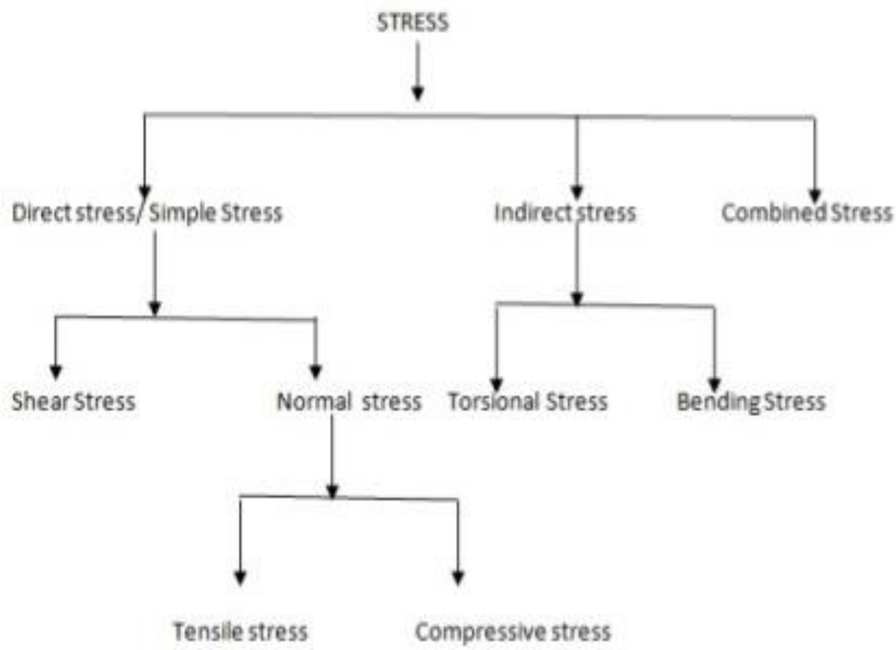


Forces can be described as a push or pull on an object. They can be due to phenomena such as gravity, magnetism, or anything that might cause a mass to accelerate.

Common symbols	$\vec{F}$, F, $\mathbf{F}$
SI unit	newton (N)
Other units	dyne, pound-force, poundal, kip, kilopond
In SI base units	kg·m/s^2
Derivations from	$\mathbf{F} = m\mathbf{a}$ (formerly $P = mf$)

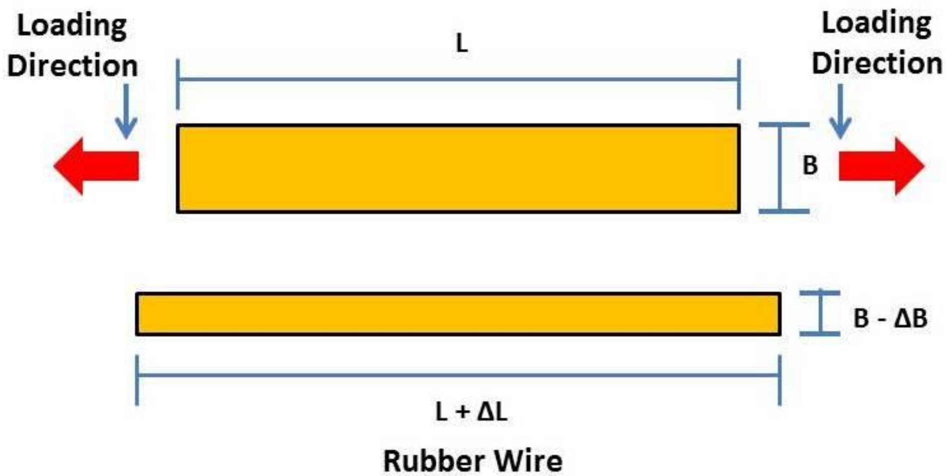
STRESS :

stress, in physical sciences and engineering, force per unit area within materials that arises from externally applied forces, uneven heating, or permanent deformation and that permits an accurate description and prediction of elastic, plastic, and fluid behavior.



STRAIN:

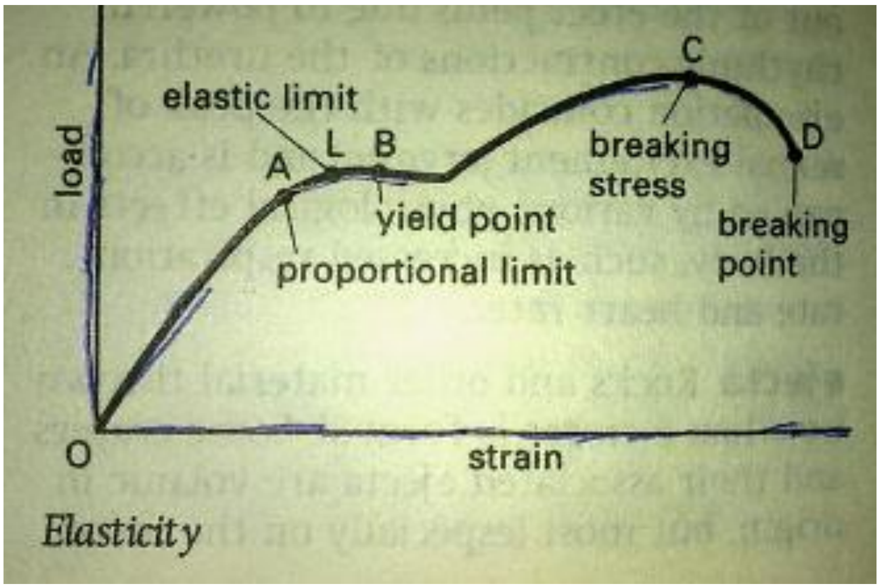
Engineering strain refers to the degree of deformation that a material withstands in the direction of applied forces in relation to its original length. Engineering strain is directly proportional to the amount of



ELASTICITY:

In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to *plasticity*, in which the object fails to do so and instead remain in its deformed state.

The physical reasons for elastic behavior can be quite different for different materials. In metals, the atomic lattice changes size and shape when forces are applied (energy is added to the system). When forces are removed, the lattice goes back to the original lower energy state. For rubbers and other polymers, elasticity is caused by the stretching of polymer chains when forces are applied.



Shear force and bending moment of beams

Beams

A beam is a structural member resting on supports to carry vertical loads. Beams are generallyplaced horizontally; the amount and extent of external load which a beam can carry depends upon:

a. The distance between supports and the overhanging lengths from supports;
b. The type and intensity of load;
c. The type of supports; and

d. The cross-section and elasticity of the beam.

Classification of beams

1. Cantilever Beam

A **Built-in** or **encastre'** support is frequently met. The effect is to fix the direction of the beam at the support. In order to do this the support must exert a "fixing" moment M and a reaction R on the beam. A beam which is fixed at one end in this way is called a **Cantilever**.If both ends are fixed in this way the reactions are not statically determinate. In practice, it isnot usually possible to obtain perfect fixing and the fixing moment applied will be related tothe angular movement of the support. When in doubt about the rigidity, it is safer to assume that the beam is freely supported.

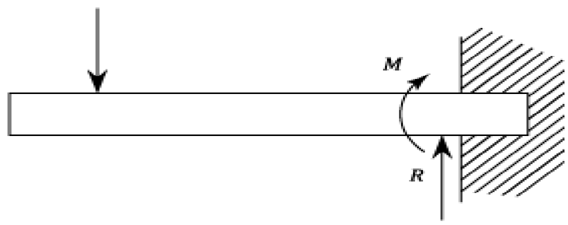


Fig. 8 Cantilever beam

2. Simply Supported Beam

It is a beam having its ends freely resting on supports.

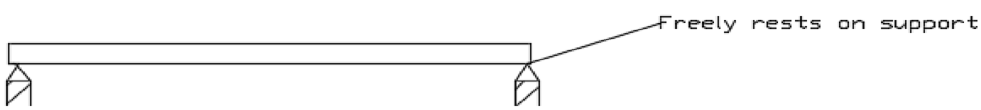


Fig. 9 Simply supported beam

Overhanging Beam

A beam having one or both ends extended over supports is known as overhanging beam.

Fig. 10. (i) Overhanging at one end (ii) Overhanging at both ends

3. Propped Cantilever Beam

When a support is provided at some suitable point of a Cantilever beam, in order to resist the deflection of the beam, it is known as propped Cantilever beam.

Fig. 11. Propped Cantilever beam

4. Fixed Beam

A beam having its both ends rigidly fixed or built0in to the supporting walls or colums isknown as fixed beam.

Fig. 12. Fixed beam

TYPES OF LOADING

1. Point Load or Concentrated Load

These loads are usually considered to be acting at a point. Practically point load cannot be placed on a beam. When a member is placed on a beam it covers some space or width. But forcalculation purpose, we consider the load as transmitting at the central with of the member.

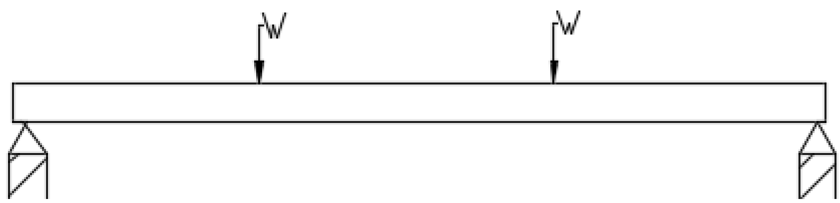


Fig. 13. Concentrated load

2. Uniformly Distributed Load or U.D.L

Uniformly distributed load is one which is spread uniformly over beam so that each unit oflength is loaded with same amount of load, and are denoted by Newton/metre.

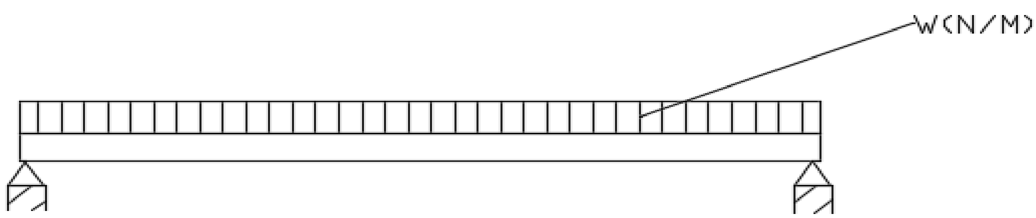


Fig. 14. UDL

3. Gradually Varying Load

If the load is spread, varying uniformly along the length of a beam, then it is called uniformlyvarying load.

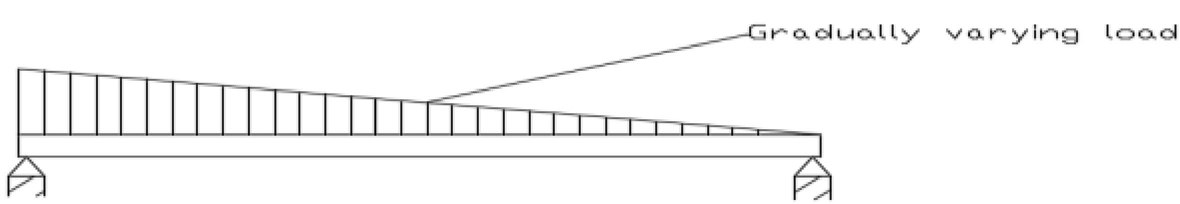


Fig. 15 Gradually varying load

4. Continuous Beam

A beam which rests on more than two supports is known as continuous beam. This may either be overhanging at one or both ends.

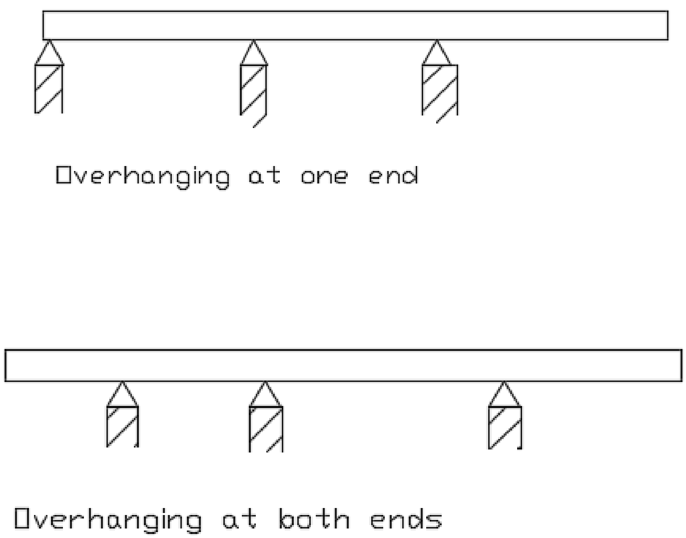


Fig. 16. Overhanging beam

Span

Clear Span: This is the clear horizontal distance between two supports

Effective Span: This is the horizontal distance between the Centre of end bearings of support.

Effective Span = clear span + oce bearing.

Fig. 17. Effective and clear span

Shear force

At any section in a beam carrying transverse loads the shearing force is defined as the algebraic sum of the forces taken on either side of the section. Similarly, the bending moment at any section is the algebraic sum of the moments of the forces about the section, again taken **on** either side. In order that the shearing-force and bending-moment values calculated **on** either side of the section shall have the same magnitude and sign, a convenient sign convention has to be adopted. Shearing-force (S.F.) and bending-moment (B.M.) diagrams show the variation of these quantities along the length of a beam for any fixed loading condition.

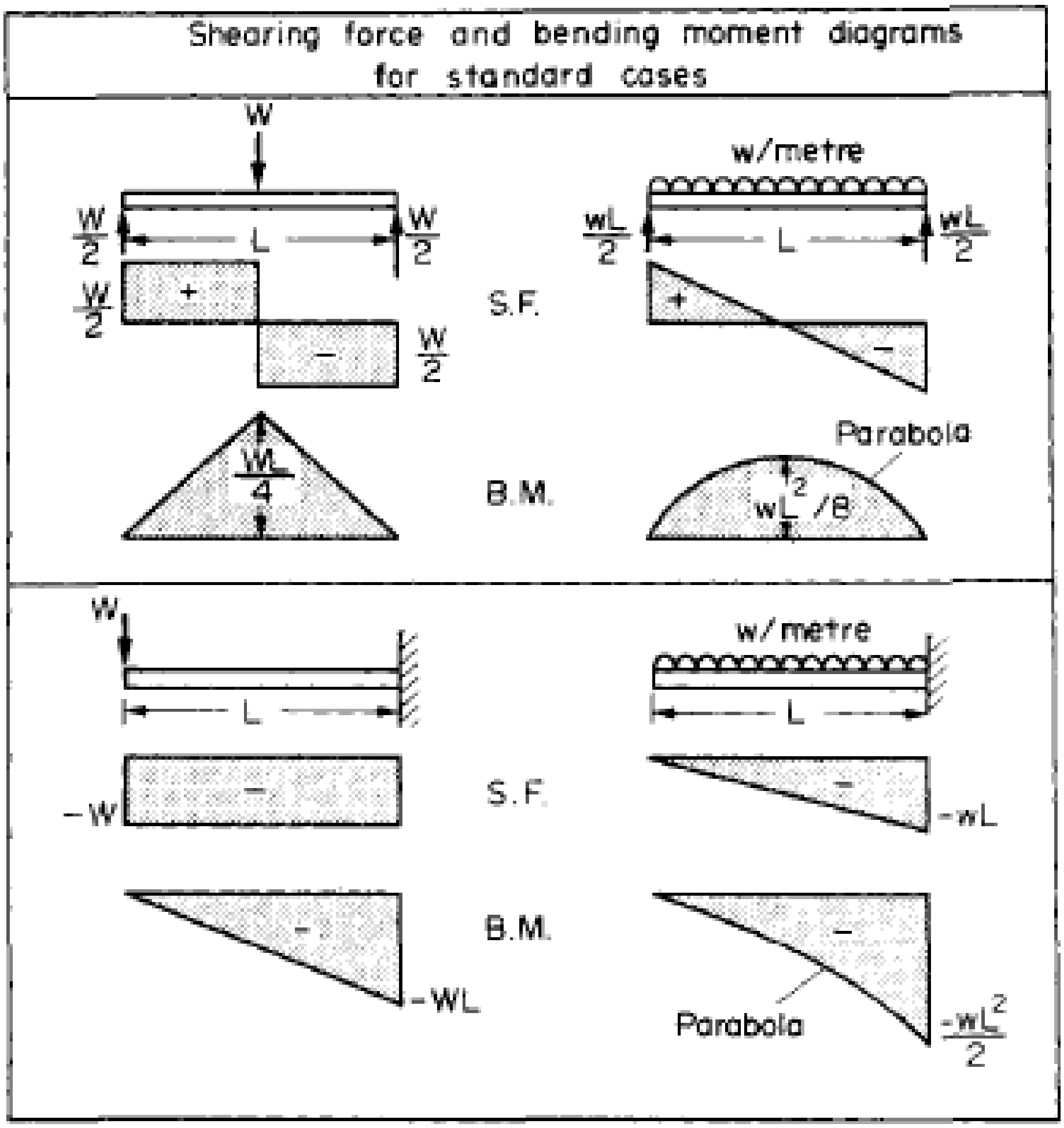


Fig. 18 Shear force and bending moment diagram

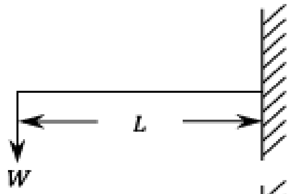
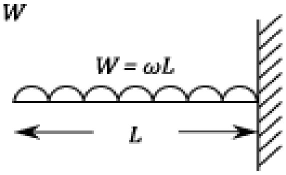
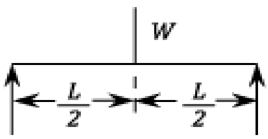
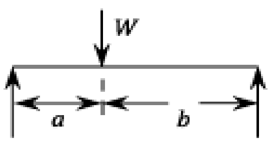
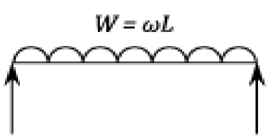
LOADING	$\hat{F}$	$\hat{M}$
	W	WL (Fixed End)
	W (Fixed End)	$\frac{WL}{2}$ (Fixed End)
	$\frac{W}{2}$	$\frac{WL}{4}$ (Centre)
	$\frac{Wb}{L}$	$\frac{Wab}{L}$ (Load)
	$\frac{W}{2}$ (Support)	$\frac{WL}{8}$ (Centre)

Fig. 19 Loading in beams, shear force and bending moment

At every section in a beam carrying transverse loads there will be resultant forces on either side of the section which, for equilibrium, must be equal and opposite, and whose combined action tends to shear the section in one of the two ways. *The shearing force (S.F.) at the section is defined therefore as the algebraic sum of the forces taken on one side of the section.* Which side *is* chosen is purely a matter of convenience but in order that the value obtained on both sides shall have the same magnitude and sign a convenient sign convention has to be adopted.

a. *Shearing force (S.F.) sign convention*

Forces upwards ***to*** the left of a section or downwards to the right of the section are positive. Thus Fig. --a shows a positive S.F. system at X-X and Fig. ---b shows a negative S.F. system

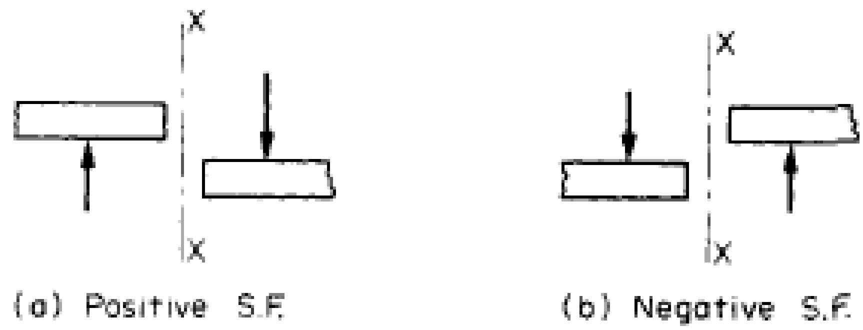


Fig. 20 shear force sign convection

In addition to the shear, every section of the beam will be subjected to bending, i.e. to a resultant **B.M.** which is the net effect of the moments of each of the individual loads. Again, for equilibrium, the values on either side of the section must have equal values. *The bending moment (B.M.) is defined therefore as the algebraic sum of the moments of the forces about the section, taken on either side of the section.* As for *S.F.*, a convenient sign convention must be adopted.

b. Bending moment (B.M.) sign convention

Clockwise moments to the left and counterclockwise to the right are positive. Thus
Fig. a - shows a positive bending moment system resulting in *sagging* of the beam at X-X andFig. b- illustrates a negative **B.M.** system with its associated *hogging* beam.

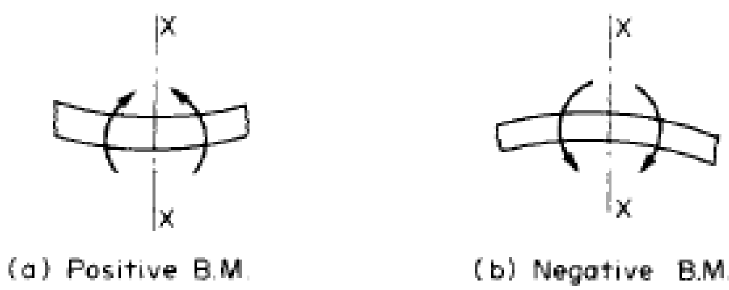


Fig. 21 Bending moment sign cnvection

It should be noted that whilst the above sign conventions for S.F. and **B.M.** are somewhat arbitrary and could be completely reversed, the systems chosen here are the only ones which yield the mathematically correct signs for slopes and deflections of beams in subsequent workand therefore are highly recommended.

c. Shearing force

The shearing force (SF) at any section of a beam represents the tendency for the portion of the beam on one side of the section to slide or shear laterally relative to the other portion. The diagram shows a beam carrying loadsW_1, W_2 and W_3. It is simply supported at two points where the reactions are R_1 and R_2. Assume that the beam is divided into two parts by a section XX. Theresultant of the loads and reaction acting on the left of AA is F vertically upwards, and since the whole beam is in equilibrium, the resultant force to the right of AA must be F downwards. F is called the **Shearing Force** at the section AA. It has been defined as *The shearing force at any section of a beam is the algebraic sum of the lateral components of the forces acting on either side of the section.* Where forces are neither in the lateral or axial direction they must be resolved in the usual way and only the lateral components are used to calculate the shear force.

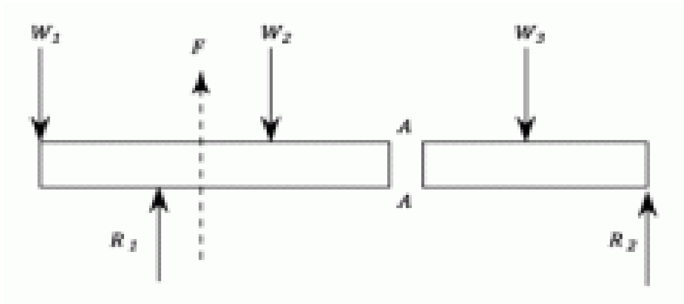


Fig 22 shear force through a section

d. Bending Moment

In a similar manner it can be seen that if the Bending moments (BM) of the forces to the left of AA are clockwise, then the bending moment of the forces to the right of AA must be anticlockwise.

Bending Moment at AA has been defined as the algebraic sum of the moments about the section of all forces acting on either side of the section. Bending moments are considered positive when the moment on the left portion is clockwise and on the right anticlockwise. This is referred to as a **sagging** bending moment as it tends to make the beam concave upwards at AA. A negative bending moment is termed **hogging**.

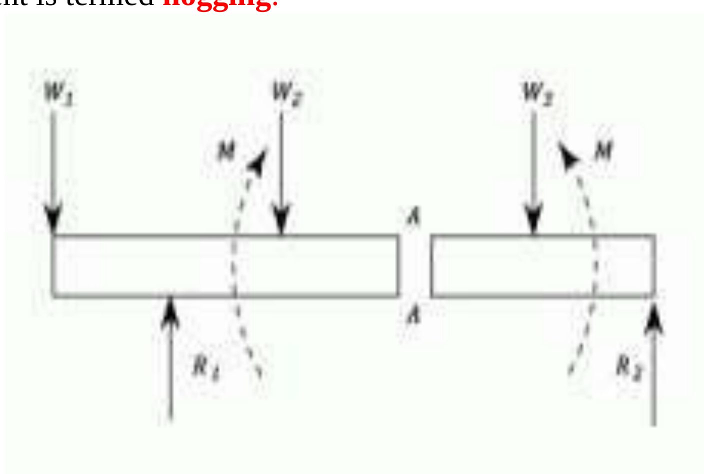


Fig. 23 mendinng moment through a section

RELATIONSHIP BETWEEN LOAD (w), SHEAR FORCE (F), AND BENDING MOMENT (M).

In the following diagram δx is the length of a small slice of a loaded beam at a distance x fromthe origin O

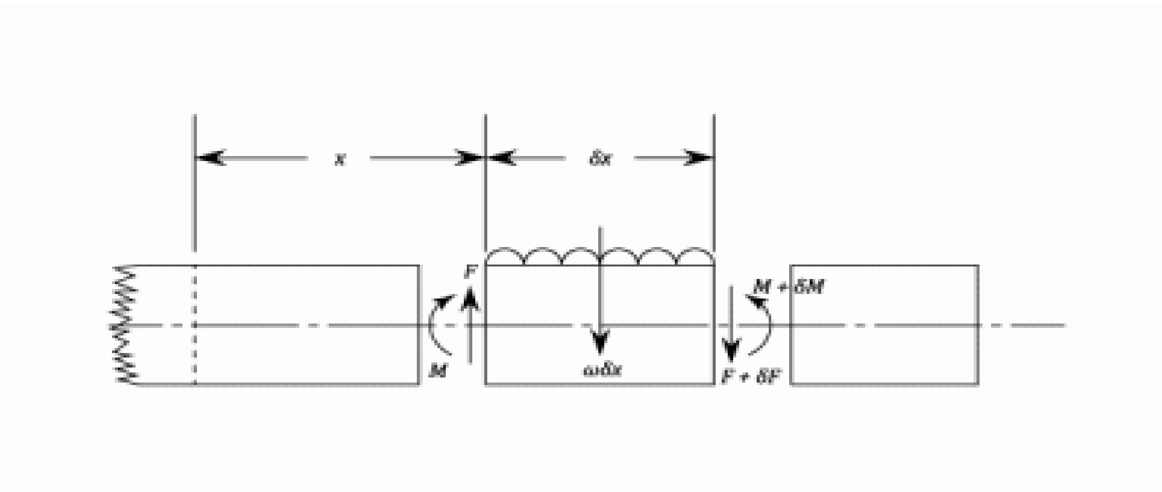


Fig. 24 Loaded beam of length x from origin O

Let the shearing force at the section x be F and at $x = \delta x \;\; be \;\; F + \delta F$. Similarly, the bending moment is M at x, and $M + \delta M \;\; at \;\; x + \delta x$. If w is the mean rate of loading of the length δx then the total load is $w\delta x$, acting approximately (exactly if uniformly distributed) through the centre C. The element must be in equilibrium under the action of these forces and couples and the following equations can be obtained:-

Taking Moments about C:

$$M + F.\frac{\delta x}{2} + (F + \delta F)\,\frac{\delta x}{2} = M + \delta M$$

(1)

Neglecting the product $\delta F.\delta x$ in the limit:

$$F = \frac{dM}{dx}$$

(2)

Resolving vertically:

$$w\delta x + F + \delta F = F$$

(3)

$$Or \qquad w = -\frac{dF}{dx}$$

(4)

$$= -\frac{d^2 M}{dx^2} \qquad from\ equation\ (2)$$

(5)

From equation (2) it can be seen that if M is varying continuously, zero shearing force corresponds to either maximum or minimum bending moment. It can be seen from the examples

that "peaks" in the bending moment diagram frequently occur at concentrated loads or reactions,and these are not given by $F = \frac{dM}{dx} = 0$; although they may in fact represent the greatest bending moment on the beam. Consequently, it is not always sufficient to investigate the points of zero shearing force when determining the maximum bending moment.
At a point on the beam where the type of bending is changing from sagging to hogging, thebending moment must be zero, and this is called a point of *inflection* or *contraflexure*.
By integrating equation (2) between the x = a and x = b then:

$$M_b - M_a = \int_a^b F\, dx \tag{6}$$

Which shows that the increase in bending moment between two sections is the area under theshearing force diagram.
Similarly integrating equation (4)

$$F_a - F_b = \int_a^b w\, dx \tag{7}$$

equals the area under the load distribution diagram.
Integrating equation (5) gives:

$$M_a - M_b = \int \int_a^b w\, dx.dx \tag{8}$$

These relations can be very valuable when the rate of loading cannot be expressed in an algebraicform as they provide a means of graphical solution.

Concentrated Loads

Tutorials.

Problem 1. A Cantilever of length *l* carries a concentrated load *W* at its free end. Draw theShear Force (SF) and Bending Moment (BM) diagrams.

Solution:

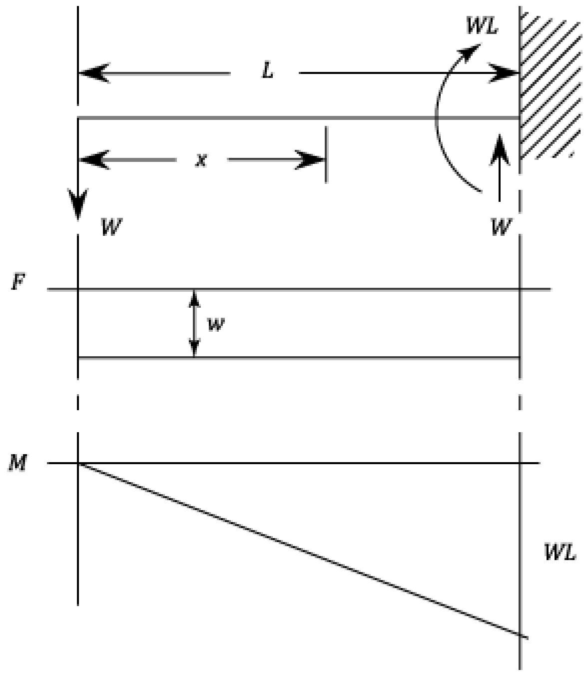
A Cantilever of length *l* carries a concentrated load *W* at its free end. Draw the Shear Force (SF)and Bending Moment (BM) diagrams.

Consider the forces to the left of a section at a distance *x* from the free end. Then F

= - W and is constant along the whole cantilever i.e. for all values of *x*
Taking Moments about the section gives M = - W *x* so that the maximum Bending Momentoccurs when *x* = *l* i.e. at the fixed end.

$$\hat{M} = W\, l \quad (Hogging) \tag{1}$$

From equilibrium considerations it can be seen that the fixing moment applied at the built in endis WL and the reaction is W. Hence the **SF** and **BM** diagrams are as follows:



The following general conclusions can be drawn when only concentrated loads and reactions are involved.

- The shearing force suffers sudden changes when passing through a load point. The change is equal to the load.
- The bending moment diagram is a series of straight lines between loads. The slope of lines is equal to the shearing force between the loading points.

Uniformly Distributed Loads

Problem 2. Draw the SF and BM diagrams for a simply supported beam of length *l* carrying a uniformly distributed load *w* per unit length which occurs across the whole Beam.

Solution.

The Total Load carried is *wl* and by symmetry the reactions at both end supports are each w*l*/2If *x* is the distance of the section measured from the left-hand support then:

$$F = \frac{wl}{2} - wx = w\left(\frac{l}{2} - x\right)$$

(2)

This give a straight line graph equal to the rate of loading. The end values of Shearing Force are

$$\pm \frac{w\,l}{2}$$

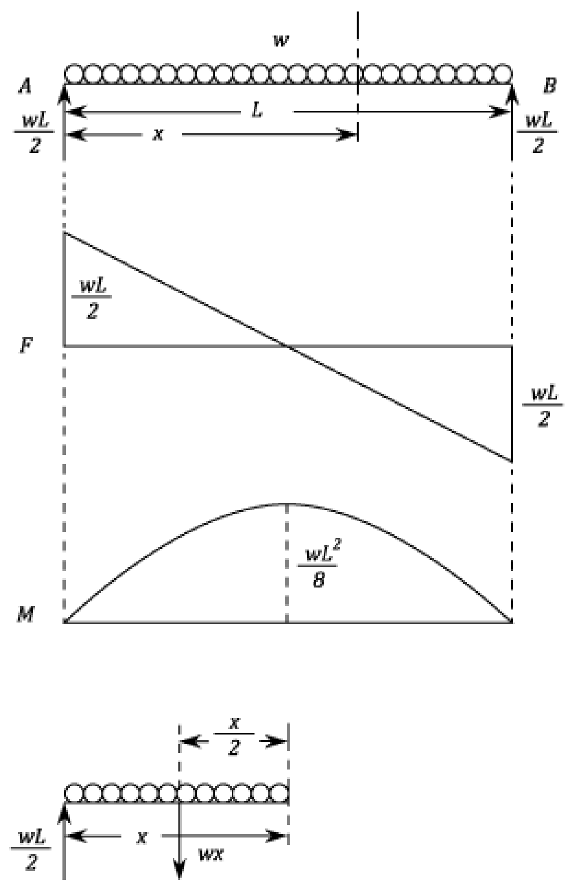
The Bending Moment at the section is found by assuming that the distributed load acts throughits center of gravity which is *x/2* from the section.

$$Hence \qquad M = \left(\frac{w\,l}{2}\right) x - (wx)\,\frac{x}{2}$$

(3)

$$= \left(\frac{wl}{2}\right)(l - x)$$

(4)



This is a parabolic curve having a value of zero at each end. The maximum is at the center and corresponds to zero shear force.
From Equation (2)

$$\hat{M} = \left(\frac{w\,l}{4}\right)\left(l - \frac{l}{2}\right)$$

(5)

Putting $x = l/2$

$$\hat{M} = \frac{w\,l^2}{8}$$

(6)

Combined Load

Problem 3. A Beam 25 m. long is supported at A and B and is loaded as shown. Sketch the SF and BM diagrams and find (a) the position and magnitude of the maximum Bending Momentand (b) the position of the point of contra flexure.

Solution

Taking Moments about B

$$20\,R_a = 10 \times 15 + 2 \times 5 - 3 \times 5$$

(7)

(The distributed load is taken as acting at its centre of gravity.)

∴ R_a = 7.25 k N **(8)**

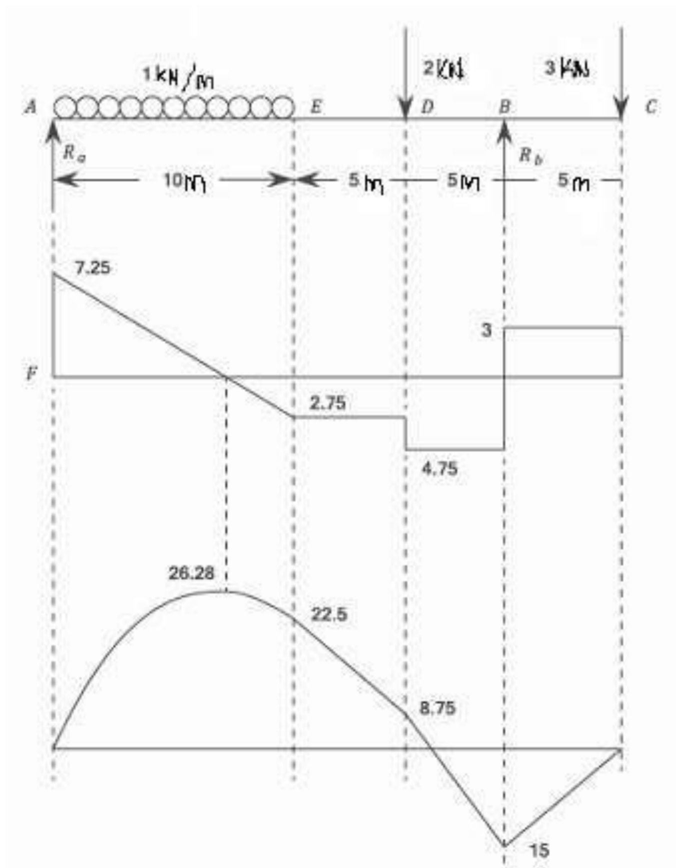
∴ R_b = Total Load - R_a = 10 + 2 + 3 – 7.25 = 7.75 k N **(9)**

The Shearing Force

Starting at A, F = 7.25. As the section moves away from A F decreases at a uniform rate of w perunit length (i.e. f = 7.25 – w x) and reaches a value of - 2.75 at E.

Between E and D, F is constant (There is no load on Ed) and at D it suffers a sudden decrease of2 kN (the load at D). Similarly there is an increase at B of 7.75 k N (the reaction at B).

This results in a value of F = 3k N at B which remains constant between B and C. Note this valueagrees with the load at C.



Bending Moment from A to E:

$$M = R_a\,x - \frac{w\,x^2}{2} = 7.25\,x - \frac{x^2}{2} \quad since \quad (x = 1) \tag{10}$$

This is a parabola which can be sketched by taking several values of x. Beyond E the value of xfor the distributed load remains constant at 5 ft. from A

Between E and D

$$M = 7.25\,x - 10(X - 5) \; = -2.75x + 50 \tag{11}$$

This produces a straight line between E and D. Similar equations apply for sections DB and BC. However it is only necessary to evaluate M at the points D and B since M is zero at C. The diagram consists in straight lines between these values.

At D

$$\mathrm{M} = -2.75 \times 15 + 50 = 8.75\ \mathrm{kN.m} \tag{12}$$

At B

$$\mathrm{M} = -3 \times 5 = -15\ \mathrm{kN.m} \tag{13}$$

This last value was calculated for the portion BC

We were required to find the position and magnitude of the maximum BM. This occurs wherethe shearing force is zero.

i.e. .at 7.25 m. from A

$$\therefore \quad M = 7.25 \times 7.25 - \frac{7.25^2}{2} = 26.28 \text{ k N. m}$$

(14)

The point of contraflexure occurs when the bending moment is zero and this is between D and Bat:

$$\left(\frac{15}{15+8.75}\right) \times 5 = 3.16 \text{ m from B} \quad \textbf{(15)}$$

Varying Distributed Loads

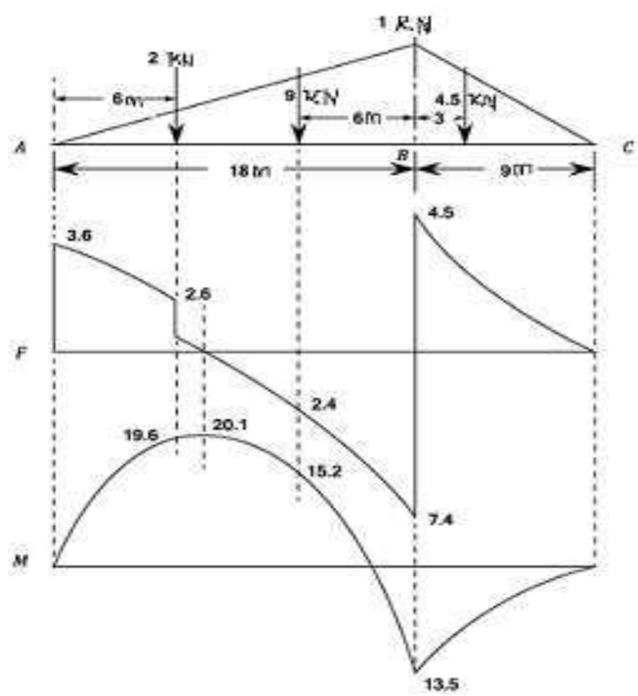
Problem

A Beam ABC, 27m long, is simply supported at A and B 18 m. across and carries a load of 2 kNat 6 m. from A together with a distributed load whose intensity varies in linear fashion from zeroat A and C to 1 kN/m. at B.

Workings

Draw the Shear Force and Bending Moment diagrams and calculate the position and magnitudeof the maximum B.M.

The Total Load on the beam (i.e. the load plus the mean rate of loading of 1/2 kN/m) is given by: $Load = 2 + \frac{1}{2} \times 27 = 15.5$ kN



The Total distribute load on $AB = \frac{1}{2} \times 18 = 9\ kN$ and on $BC = \frac{1}{2} \times 9 = 4.5\ kN$ each of which act through their centres of gravity. These are $\frac{2}{3} \times 18 = 12\ m$ from A and $\frac{2}{3} \times 9 =$ $6\ m$ from C in the other case.

(**Note**. These are the centroids of the triangles which represent the load distribution)Taking Moments about B

$$R_1 = \left(\frac{2\times12+9\times6-4.5\times3}{18}\right) = 3.6 \text{ kN} \tag{16}$$

$$\therefore \quad R_2 = 2 + 9 + 4.5 - 3.6 = 11.9 \text{ k N} \tag{17}$$

At a distance x (<18) from A the loading is x/18 tons/ft.. The Total distributed load on this lengthis:

$$\text{(Mean rate of loading)} \times = \frac{1}{2}\left(\frac{x}{18}\right) x = \frac{x^2}{36} \text{ kN} \qquad 18)$$

The centre of gravity of this load is $\frac{2}{3} x$ from A. **For 0<x<6**

$$F = 3.6 - \frac{x^2}{36} \tag{19}$$

At x = 6 m
F =2.6 kN

(20)

$$M = 3.6\,x - \left(\frac{x^2}{36}\right) \times \frac{x}{3} = 3.6\,x - \frac{x^3}{108}$$

At x = 6 m
M = 19.6 KN m. *(21)*

(22)

6< x <18

$$f = 3.6 - 2 - \frac{x^2}{36}$$

$$At\ x = 12\ kN. \qquad F = -2.4\ kN$$

(23)

$$At\ x = 18kN. \qquad F = -7.4\ kN$$

$$F = 0 \; when \; x = 6\sqrt{1.6} = 7.58 \text{ K N.} \quad \textbf{(24)}$$

$$M = 3.6x - 2(x-6) - \frac{x^3}{108} = 1.6x + 12 - \frac{x^3}{108} \quad \textbf{(25)}$$

$$At \; x = 12 \; k \; N. \quad M = 15.2 \text{ k N m.} \quad \textbf{(26)}$$

$$At \; x = 12 \; k \; N. \quad M = -13.5 \text{ k N m}$$

The maximum Bending Moment occurs at zero s earing force 1.e.x = 7.58 kN.

$$M = 20.1 \; kN \; m.$$

The section BC can be more easily calculated by using a variable X measured from C. Then by asimilar argument:-

$$F = \frac{1}{2} \left(\frac{x}{9}\right) x = \frac{x^2}{18} \text{ k N.} \quad \textbf{(27)}$$

At x = 9 kN. F = 4.5 k N.

$$M = -\frac{1}{2} \left(\frac{x}{9}\right) . x . \left(\frac{x}{3}\right) = -\left(\frac{x^3}{54}\right) \; kN.m \quad \textbf{(28)}$$

$$At \; x = 9 \; kN \qquad M = -13.5 \; kN.m \quad \textbf{(29)}$$

The complete diagrams are shown. It can e seen that for a uniformly varying distributed load, theShearing Force diagram consists of a series of parabolic curves and the Bending Momentdiagram is made up of "cubic" discontinuities occurring at concentrated loads or reactions. It has been shown that Shearing Forces can be obtained by integrating the loading function and Bending Moment by integrating the Shearing Force, from which it follows that the curves produced will be of a successively "higher order" in x (See equations (6) and(7))

Graphical Solutions

This method may appear complicated but whilst the proof and explanation is fairly detailed, the application is simple and straight forward. The change of Bending Moment can be given by the double Integral of the rate of loading. This integration can be carried out by means of a **funicularpolygon**. Suppose that the loads carried on a simply supported beam are W_1, W_2, W_3, and W_4; and that R_1 and R_2 are the reactions at the supports. Letter the spaces between the loads and reactions A, B, C, D, E, and F.

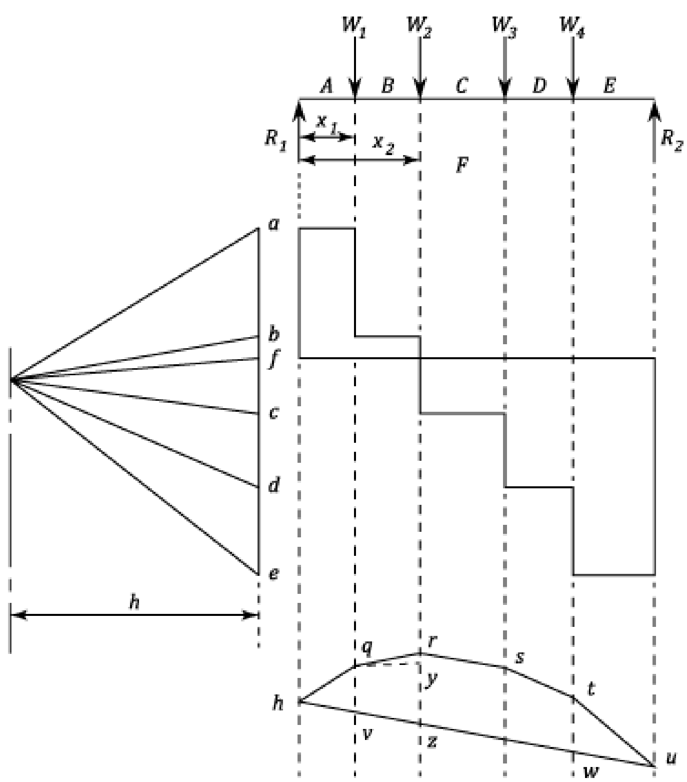
i. Draw to scale a vertical line such that:

$$a\,b = W_1; \quad b\,c = W_2; \quad c\,d = W_3; \quad and \quad d\,e = W_4. \quad \textbf{(1)}$$

ii. Now take any point "O" to the left of the line and join O to a, b, c, d, and e. This is called **The Polar Diagram**

iii. Commencing at any point p on the line of action of R_1 draw **pq** parallel to **Oa** in the space "A" , qr parallel to **Ob** in the space "B" and similarly rs, st, and tu. Draw Of parallel to pu. $W_1, W_2, W_3, and W_4, and that R_1 \ and \ R_2$

It will now be shown that **fa** represents R_1. Also, **pqrstu** is the Bending Moment diagram drawnon a base pu, M being proportional to the vertical ordinates. W_1 is represented by ab and acts through the point q; it can be replaced by forces **a O** along qp and Ob along qr.
Similarly, W_2 can be replaced by forces represented by **b O** along rq and Oc along rs, W_3 by **c O** along **s r** and **O d** along **s t** etc. All of these forces cancel each other out except **aO** along **qp** and**Od** along **te**, and these two forces must be in equilibrium with$R_1 \ and \ R_2$. This can only be so if R_1 is equivalent to a force **Oa** along **pq** and **fO** along up, R_2 being equivalent to **eO** along utand **Of** along **pu**. Hence, R_1 is represented by **fa** and R_2 by **ef.**



triangles **pqv** and **Oaf** are similar and hence:

$$q\,v = a\,f.\frac{pv}{Of}$$

(2)

$$Or \qquad qv \propto a\,f\,\frac{x_1}{h}$$

Where x_1 is the distance from W_1 from the left-hand end of the beam, and h is the length of the perpendicular from **O** on to **ae**. But $ay\,.\,x_1 \;\propto\; R_1\,x_1 \quad i.e.\, the\; BM\; at\; x_1$

Hence for a given position of the pole **O**, **qv** represents the B>M> at x_1 to a certain scale.If **qy** is drawn parallel **tp pu**, then the triangle **qry** is similar to **Obf** and:

$$r\,y = b\,f\left(\frac{qy}{of}\right) = b\,f\left(\frac{x_2 - x_1}{h}\right)$$

(3)

$$\therefore \qquad rz = qv + ry = af\;\left(\frac{x_1}{h}\right) + bf\left(\frac{x_2\; - x_1}{h}\right)$$

(4)

$$which\; is\;\; \propto R_1x_1 = (R_1 - W_1)(x_2 - x_1) = R_1x_2 - W_1(x_2\; - X_1)$$

(5)

Which is the Bending Moment at x_2.

Similarly, the ordinates at the other load points give the Bending Moments at those points, the scale being determined as follows: If the load scale of the Polar Diagram is 1cm = S_1 kN then thelength scale along the beam is,. and the Bending Moment scale required is 1cm = S_3 kN m, then the length

$$qv \propto af.\frac{x_1}{h} \text{ as shown above } = \frac{W_1x_1}{s_1\,s_2h} = \frac{M}{s_1\,s_2h}$$

(6)

But,

$$qv = \frac{M}{s_3}$$

(7)

$$\therefore \qquad h = \frac{s_3}{s_2\,s_2}\;in.$$

If a base on the same level as f is drawn and the points a, b, c, d, and e are projected across fromthe Polar Diagram, then the Shearing Force diagram is obtained.

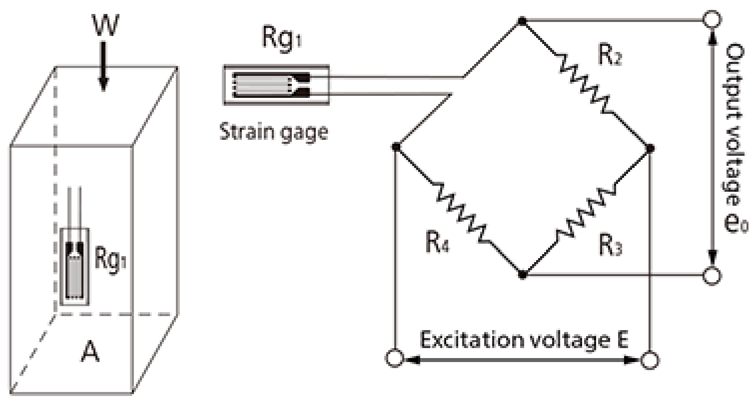
This method can be equally well used for distributed loads by dividing the loading diagram intostrips and taking the load on a strip to act as if it were concentrated at its centre of gravity.

For cantilevers, if the Pole O is taken on the same horizontal level as the point a, then the base ofthe Bending Moment will be horizontal.

UNIT – 2

MEASURMENT OF STRAIN:

A strain gauge is a resistor used to measure strain on an object. When an external force is applied on an object, due to which there is a deformation occurs in the shape of the object. This deformation in the shape is both compressive or tensile is called strain, and it is measured by the strain gauge



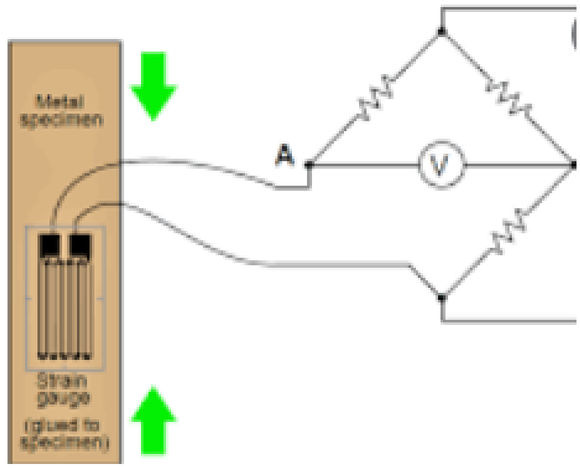
Tensile/Compressive Stress Measurement
with Quarter-bridge System

ELECTRICAL CAPACITANCE:

Capacitance is the ratio of the amount of electric charge stored on a conductor to a difference in electric potential. There are two closely related notions ...
SI unit: farad
Other units: µF, nF, pF
In SI base units: F = A2 s4 kg−1 m−2
Dimension: M−1 L−2 T4 I2

RESISTANCE STRAIN GAUGE :

What is the working principle of Strain Gauge? A strain gauge works on the principle of electrical conductance and its dependence on the conductor's geometry. Whenever a conductor is stretched within the limits of its elasticity, it doesn't break but, gets narrower and longer.



MULTI CHANNEL STRAI INDICATOR:

The Software **Multichannel strain gauge meter** is used for performing all types of strain gauge measurements using strain gauge sensors (for instance, force and torque sensors, bridge and semi-bridge circuits based on resistive strain sensors), **strain measurement data acquisition modules** ZET 017-T and digital strain gauge sensors of **ZETSENSOR** series. The program enables simultaneous processing of up to 128 measuring channels using strain gauge station and up to 500 measuring channels in the case if digital sensors are used.
Depending on **Multichannel Strain gauge meter** program settings, the measurement results can be represented as force, weight, displacement, torque and other parameters. Integrated strain gauge system generator is used as a power supply source for the sensors (it is possible to select circuit power supply type).
The software **Multichannel Strain gauge meter** allows to use thermal compensation channel for results viewing without temperature effect.

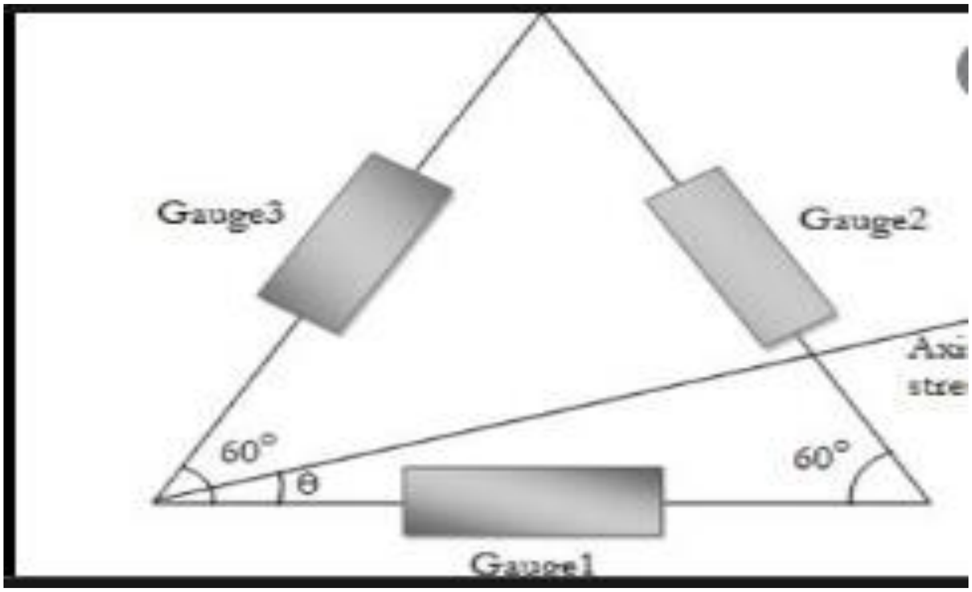
STRAIN ROSETTES:

A strain gauge rosette is a term for an arrangement of two or more strain gauges that are positioned closely to measure strains along different directions of the component under evaluation. Single strain gauges can only measure strain effectively in one direction, so the use of multiple strain gauges enables more measurements to be taken, providing a more precise evaluation of strain on the surface being measured

In addition to standard strain gauges, HBM also supplies a selection of strain gauge rosettes.

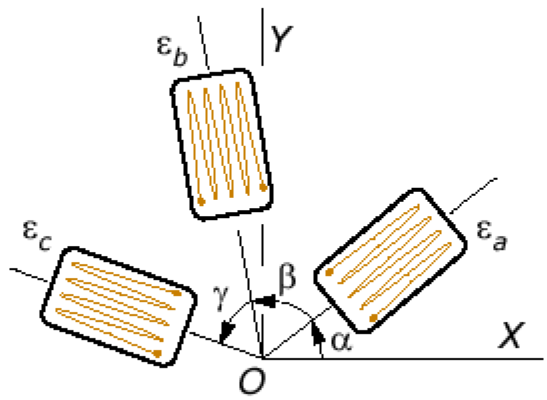
The RY strain gauge rosettes have three measuring grids for analyzing biaxial stress states with unknown principle directions. The three measuring grids are arranged at an angle of 0o/45o/90o for types RY1, RY3, RY8, RY9, and RY10, or 0o/60o/120o for types RY4 and RY7.

The XY strain gauge rosettes have two measuring grids for analyzing biaxial stress states with known principle directions and measurements on tension and compression bars. All of these strain gauge rosettes are arranged at a 90o offset from each other.



TRIANGLE ROSEETTE:

A wire strain gage can effectively measure strain in only one direction. To determine the three independent components of plane strain, three linearly independent strain measures are needed, i.e., three strain gages positioned in a rosette-like layout.



Consider a strain rosette attached on the surface with an angle a from the *x*-axis. The rosette itself contains three strain gages with the internal angles b and g, as illustrated on the right.

Suppose that the strain measured from these three strain gages are e_a, e_b, and e_c, respectively.

The following coordinate transformation equation is used to convert the longitudinal strain from each strain gage into strain expressed in the *x*-*y* coordinates,

$$\varepsilon_{x'} = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\theta + \varepsilon_{xy} \sin 2\theta$$

UNIT-3

CHARACTERISTICS OF BUILDING MATERIALS:

For a material to be considered as building material, it should have required engineering properties suitable for construction works. These properties of building materials are responsible for its quality and capacity and helps to decide applications of these material. Such properties of building materials are categorized as follows.

- Physical properties
- Mechanical properties
- Chemical properties
- Electrical properties
- Magnetic properties
- Thermal properties

Group	**Properties**
Physical	Shape, Size, Density, Specific Gravity etc.,
Mechanical	Strength, Elasticity, Plasticity, Hardness, Toughness, Ductility, Brittleness, Creep, Stiffness, Fatigue, Impact Strength etc.,
Thermal	Thermal conductivity, Thermal resistivity, Thermal capacity etc.,
Chemical	Corrosion resistance, Chemical composition, Acidity, Alkalinity etc.,
Optical	Colour, Light reflection, Light transmission etc.,
Acoustical	Sound absorption, Transmission and Reflection.
Physiochemical	Hygroscopicity, Shrinkage and Swell due to moisture changes

- **Density**: It is defined as mass per unit volume. It is expressed as kg/m^3.
- **Specific gravity**: It is the ratio of density of a material to density of water.
- **Porosity**: The term porosity is used to indicate the degree by which the volume of a material is occupied by pores. It is expressed as a ratio of volume of pores to that of the specimen.
- **Strength**: Strength of a material has been defined as its ability to resist the action of an external force without breaking.
- **Elasticity**: It is the property of a material which enables it to regain its original shape and size after the removal of external load.

- **Plasticity**: It is the property of the material which enables the formation of permanent deformation.
- **Hardness**: It is the property of the material which enables it to resist abrasion, indentation, machining and scratching.
- **Ductility**: It is the property of a material which enables it to be drawn out or elongated to an appreciable extent before rupture occurs.
- **Brittleness**: It is the property of a material, which is opposite to ductility. Material, having very little property of deformation, either elastic or plastic is called Brittle.
- **Creep**: It is the property of the material which enables it under constant load to deform slowly but progressively over a certain period.
- **Stiffness**: It is the property of a material which enables it to resist deformation.
- **Fatigue**: The term fatigue is generally referred to the effect of cyclically repeated stress. A material has a tendency to fail at lesser stress level when subjected to repeated loading.

- **Impact strength**: The impact strength of a material is the quantity of work required to cause its failure per its unit volume. It thus indicates the toughness of a material.
- **Toughness**: It is the property of a material which enables it to be twisted, bent or stretched under a high stress before rupture.
- **Thermal Conductivity**: It is the property of a material which allows conduction of heat through its body. It is defined as the amount of heat in kilocalories that will flow through unit area of the material with unit thickness in unit time when difference of temperature on its faces is also unity.
- **Corrosion Resistance**: It is the property of a material to withstand the action of acids, alkalis gases etc., which tend to corrode (or oxidize).

BRICKS

Different types of bricks are used in masonry construction based on material such as clay, concrete, lime, fly ash etc. Filed field identification of bricks for their properties, uses and suitability for different construction works are important. A brick is an important construction material which is generally available in rectangular shape manufactured from clay. They are very popular from olden days to modern days because of low cost and durability.

Types of Bricks used in Masonry Construction

Based on the manufacturing process, bricks are broadly classified into two types, 1. Sun-Dried or unburnt bricks 2. Burnt bricks

1. Sun-Dried or Unburnt Clay Bricks

Sun-dried or unburnt bricks are less durable and these are used for temporary structures. Unburnt bricks preparation involved in 3 steps they are preparation of clay, molding and drying. After molding, bricks are subjected to sunlight and dried using heat from sun. So, they are not that much strong and they also have less water resistance and less fire resistance. These bricks are not suitable for permanent structures.

2. Burnt Clay Bricks

Burnt bricks are good quality bricks but however they also consist some defected bricks. So, burnt bricks are classified into four types and they are

- First class bricks
- Second class bricks
- Third class bricks
- Fourth class bricks

3. Fly Ash Bricks

Fly ash bricks are manufactured using fly ash and water. These bricks have better properties than clay bricks and great resistant to freeze thaw cycles. These bricks contains high concentration of calcium oxide which is used in cement production, thus it is also called as self-cementing brick. Fly ash bricks are lightweight and thus it reduces self weight of structures. The advantages of fly ash bricks over clay bricks are that they have high fire insulation, high strength, uniform sizes for better joints and plaster, lower water penetration, does not require soaking before use in masonry construction. **Read More on Fly Ash Bricks and Comparison with Clay Bricks**

4. Concrete Bricks

Concrete bricks are manufacturing using concrete with ingredients as cement, sand, coarse aggregates and water. These bricks can be manufactured in sizes as required. The advantages of using concrete bricks over clay bricks are that they can be manufactured at construction site, reduces quantity of mortar required, can be manufactured to provide different colors as pigmented during its production. Concrete bricks are used for construction of masonry and framed buildings, facades, fences, and provide an excellent aesthetic presence. **Read More: Types of Concrete Blocks or Concrete Masonry Units Used in Construction**

5. Engineering Bricks

Engineering bricks have high compressive strength and are used special applications where strength, frost resistance, acid resistance, low porosity is required. These bricks are commonly used for basements where chemical or water attacks are prevalent and for damp proof courses.

6. Sand Lime or Calcium Silicate Bricks

Calcium silicate bricks are made of sand and lime and popularly known as sand lime bricks. These bricks are used for several purposes in construction industries such as ornamental works in buildings, masonry works etc. **Read More on Calcium Silicate Bricks or Sand Lime Bricks for Masonry Construction**

Types of Tests on Bricks for Construction Purpose

Following tests are conducted on bricks to determine its suitability for construction work.

1. Absorption test
2. Crushing strength test
3. Hardness test
4. Shape and size
5. Color test
6. Soundness test
7. Structure of brick

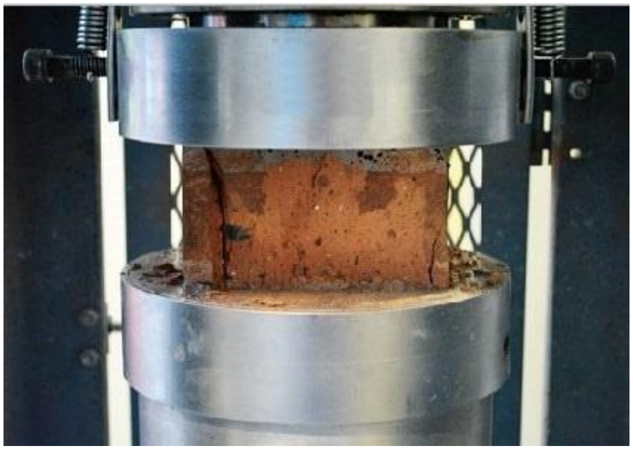
1. Absorption Test on Bricks

Absorption test is conducted on brick to find out the amount of moisture content absorbed by brick under extreme conditions. In this test, sample dry bricks are taken and weighed. After weighing these bricks are placed in water with full immersing for a period of 24 hours. Then weigh the wet brick and note down its value. The difference between dry and wet brick weights will give the amount of water absorption. For a good quality brick the amount of water absorption should not exceed 20% of weight of dry brick.

2. Crushing Strength or Compressive Strength Test on Bricks

Crushing strength of bricks is determined by placing brick in compression testing machine. After placing the brick in compression testing machine, apply load on it until brick breaks.

Note down the value of failure load and find out the crushing strength value of brick. Minimum crushing strength of brick is 3.50N/mm^2.if it is less than 3.50 N/mm^2, then it is not useful for construction purpose.



3. Hardness Test on Bricks

A good brick should resist scratches against sharp things. So, for this test a sharp tool or finger nail is used to make scratch on brick. If there is no scratch impression on brick then it is said to be hard brick.

4. Shape and Size Test on Bricks

Shape and size of bricks are very important consideration. All bricks used for construction should be of same size. The shape of bricks should be purely rectangular with sharp edges. Standard brick size consists length x breadth x height as 19cm x 9cm x 9cm. To perform this test, select 20 bricks randomly from brick group and stack them along its length , breadth and height and compare. So, if all bricks similar size then they are qualified for construction work.

5. Color Test of Bricks

good brick should possess bright and uniform color throughout its body.

6. Soundness Test of Bricks

Soundness test of bricks shows the nature of bricks against sudden impact. In this test, 2 bricks are chosen randomly and struck with one another. Then sound produced should be clear bell ringing sound and brick should not break. Then it is said to be good brick.

7. Structure of Bricks

To know the structure of brick, pick one brick randomly from the group and break it. Observe the inner portion of brick clearly. It should be free from lumps and homogeneous.

CLASSIFICATION SEASONING DEFECTS IN TIMBER:

There are various types of defects in timber as a construction material. These defects in timber can be due to natural forces, fungi, insects, and during seasoning and conversion. Types of these defects in wood are discussed in detail. Trees give us the timber, which is converted into the required form and finally used. Before reaching this final stage, timber comes across many critical stages like growing without defects, cutting at the right time, seasoning, converting, and using. Different types of defects occur in timber at these various stages.

Types of Defects in Timber as a Construction Material

In general, the defects in timber are mainly due to:

1. Natural forces
2. Fungi
3. During Seasoning
4. During conversion
5. Insects

Defects in timber due to Natural Forces

1. Wind cracks
2. Shakes
3. Twisted fibers
4. Upsets
5. Rind galls
6. Burls
7. Water stain
8. Chemical stain
9. Deadwood

1. Wind Cracks in Timber

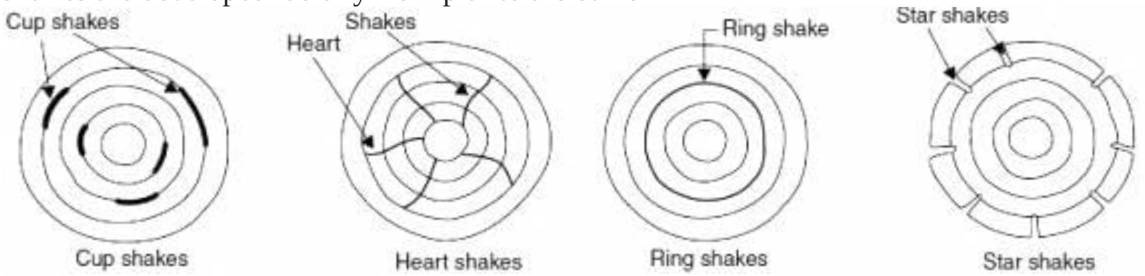
If the wood is exposed continuously to the high-speed winds, the outer surface shrinks and forms crack externally, which are called wind cracks.

2. Shakes in Timber

Shakes are nothing but cracks which separate the wood fibers partly or completely. Different shakes are formed in different conditions as follows:

- **Cup shakes** are formed due to the non-uniform growth of a tree or excessive bending by cyclones or winds. In this case, the shakes develop between annual rings and separate them partly.
- **Heart shakes**, the other type of shakes which develop in maturity approaching trees whose inner part is under shrinkage. The shake spread from pith to sapwood following the directions of medullary rays.
- **Ring shakes** are similar to cup shakes, but they completely separate the annual rings.
- **Star shakes** are formed due to extreme heat or severe frost action. They develop wider cracks on the outside of timber from bark to the sapwood.

- **Radial shakes** are developed radially from pith to the bark.

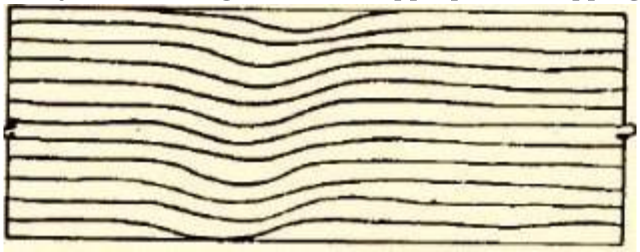


3. Twisted Fibers in Timbers

When the tree in its younger age is exposed to high-speed winds, the fibers of wood gets twisted. This type of wood is not suitable for sawing. So, this can be used for making poles, posts, etc.

4. Upsets

Upsets, a defect of timber in which the fibers of the wood are crushed and compressed by fast blowing winds or inappropriate chopping of trees.



5. Rind Galls

Rind galls are curved swellings of trees which are formed at a point where a branch of the tress is improperly removed or fell down.

7. Water Stain

When the wood is in contact with water for some time, the water will damage the color of the wood and forms a stain on its surface. This defect is called as water stain.

8. Chemical Stain

Chemical stain is formed on the wood by the action of any external chemical agents like reaction by the gases present in the atmosphere etc. The stain area gets discolored in this defect.

GLASS:

Glass is a **non-crystalline amorphous solid** that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics.

Types of Glass

Water glass: It is manufactured from the compound of sodium silicate (Na_2Si0_3) by heating sodium carbonate and silica. It is soluble in water.

Photo chromatic glass: This is a special type of glass which turns black in sharp shining light thus such glasses are used as light protector and eyes reliever and thereby utilised in making eye lenses and goggles. The main reason of being black of such glasses is the presence of silver iodide.

Pyrex glass: It is also called borosilicate glass. It has some specific characteristics of chemical durability and more thermal inmalleable resistance power.

Lead crystal glass: This is a special type of glass which is used in making various ornamental items by the appropriate decorative, cutting and designing. Infact on cutting such glasses the optical phenomenon of total internal reflection takes place very sharply and thus a pleasureous dazzling light is produced.

Soda glass: It is also called soft glass which is brittle and the cheapest and most commonly existing glasses. This can be broken very conveniently and by the alternation of temperature some cracks appear in such glasses.

Xena Glass: It is the best form of glass and from it chemical containers and equipments for the scientific purposes are manufactured. This glass is basically composed from zinc and barium borosilicate which produces the soft and good quality of glass.

Flint Glass: It is manufactured from sodium, potassium and lead silicates which are used in making idol objects of cultural importance, costly glass equipments or devices. Such glasses are also used in making electric bulbs, lenses of telescopes, microscopes, camera and prisms, etc.

Crown glass: Usually this is a soda-lime-silica glass and it is frequently used in making lenses of eye glasses.

Crookes glass: In this glass mainly cerium oxide (CiO_2) is present which sharply absorbs the ultraviolet rays from the sunlight so utilised in making lenses of eye glasses.

Quartz glass: This is also called silica glass because it is obtained by melting silica and ultraviolet rays emerge out through it. Thus it is used in making bulb of ultraviolet lamp, in making container of chemical reagents, laboratories equipments etc.

Glasses	Composition	Uses
Soda Glasses	Sodium Carbonate, Calcium Carbonate and Silica	In making tube light, bottles, equipments of laboratory, daily useable domestic utensils
Flint Glass	Potassium Carbonate	In making of electric bulbs, lenses of camera and telescope etc.
Crooks Glass	Cerium Oxide and Silica	In making lenses of goggles.
Potash Glass	Potassium Carbonate, Calcium Carbonate and Silica	In making glass container and laboratory equipments, glass utensils which are heated up to very high temperature.
Pyrex Glass	Barium Silicate and Sodium Silicate	In making laboratory equipments and pharmaceutical containers or vessels.
Crown Glass	Potassium Oxide, Barium Oxide and Silica	In making lenses of eyes glass.
Lead crystal glass	Potassium Carbonate, lead Oxide and Silica	In making costly glass containers or vessels etc.

Uses of Structural Steel in the Construction Industry

Structural steel is the no. 1 choice for all engineers, designers, architects, and fabricators. The innumerable benefits of structural steel are enough to make it one of the best materials used in the construction industry. In most constructions, mild steel is used. It has immense strength, which makes it an ideal choice for constructing buildings. Apart from that structural steel is tensile, ductile, flexible, and cost-effective.

Metal Fabricators across the world prefer using structural steel for construction. It is widely used:

1) To Build High Rise Buildings

Structural steel is resistant to external forces such as wind and earthquakes. It is a flexible metal, so in the case of a storm or an earthquake, the steel component in the building will not break but bend.

2) To Build Industrial Sheds

Another benefit of structural steel is that it is cost effective. With the availability of ready-made steel sections, structural frameworks can be erected in no time. Moreover, a lot of work can be pre- done in the industrial site, thereby saving time and money.

3) To Build Residential Buildings

As mentioned above, these buildings have to stand the test of time. They should be able to withstand external forces such as wind, earthquakes, and storms. The plasticity and flexibility of structural steel make it suitable for the construction of residential buildings. A technique called light gauge steel construction is used to build residential buildings.

4) To Build Bridges

Steel has a high strength to weight ratio, which means, steel is a tensile metal. It is durable and can withstand the weight of a fleet of cars and people. These qualities enable engineers, designers, and fabricators to build large, monumental bridges that can stand the test of time.

5) To Build Parking Garages

Structural steel is useful to build parking garages for the same reasons as mentioned above. But another quality that makes it distinctly suitable in construction is that it is lightweight. This makes it easier to construct structures.

Steel tends to lose its strength when exposed to intense heat, it is for this purpose that steel structures are now covered with materials to make them fire resistant. There are other materials which are coated on these structures which make them corrosion, mold, and vermin resistant.