2014

Structure analysis -I Lab Manual

Prepared by: Parveen Berwal
Approved by:Dr.Arbinda Sharma

Civil Engineering Department
BRCM College of Engg & Technology
Bahal-127 028, Bhiwani
Haryana

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

LIST OF EXPERIMENTS

1) To verify moment area theorem regarding the slope and deflection of the beam.

2) To determine the deflection of a pin connected truss analytically & graphically and verify the same experimentally.

3) To verify the clerk Maxwell's reciprocal theorem.

4) To determine the compressive strength of bricks.

5) To study the behavior of struts and column with various end conditions

6) To find out the elastic properties of a beam.

7) To determine the horizontal thrust in a three hinged arch for a given system of loads experimentally and verify the same with calculated values.

Experiment no.1

Aim: - To verify the moment area theorem regarding the slopes and deflections of the beam.

Apparatus: - Moment of area theorem apparatus.
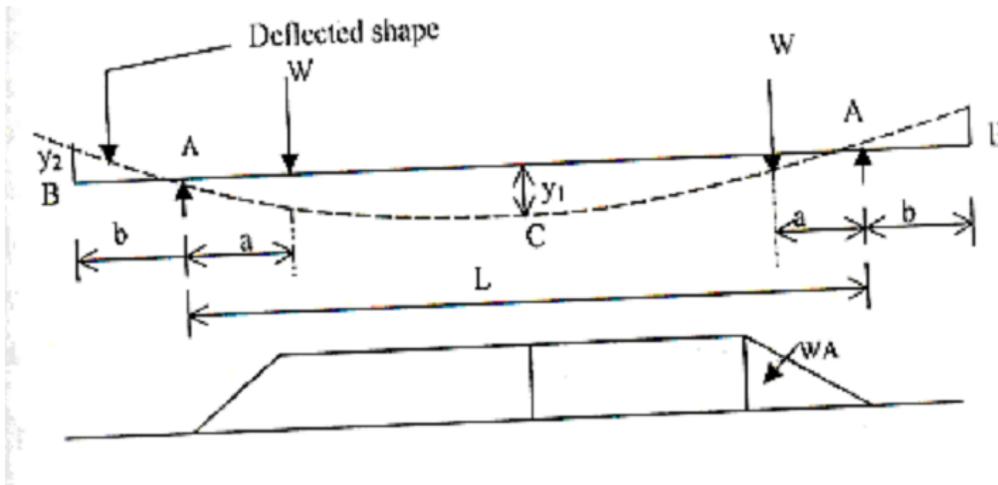
Theory : -

According to moment area theorem

1. The change of slope of the tangents of the elastic curve between any two points of the deflected beam is equal to the area of M/EI diagram between these two points.
2. The deflection of any point relative to tangent at any other point is equal to the moment of the area of the M/EI diagram between the two point at which the deflection is required.
Slope at B= Y2 / b

Since the tangent at C is horizontal due to symmetry,

Slope at B= shaded area / EI = 1 / EI [Wa2 / 2 + WA (L/2 – a)] Displacement at B with respect to tangent at C = (y1 + y2) = Moment of shaded area about B / EI

$$= 1 / EI [Wa2 / 2 (b+2/3a) + Wa(L/2 –a)(b+ a/2+L/2)]$$

Procedure: -

1. Measure a, b and L of the beam
2. Place the hangers at equal distance from the supports A and load them with equal loads.
3. Measure the deflection by dial gauges at the end B (y2) and at the center C (y1)
4. Repeat the above steps for different loads.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Observation Table:-

Length of main span, L (cm)   =

Length of overhang on each side, a (cm) =

Modulus of elasticity, E (kg/cm^2)   = 2 x 10^6

| Sl . No.	Load at each Hanger (kg)	Central Deflection Y1 (cm)	Deflection at Free end y2 (cm)	Slope at B Y2 / b	Deflection at C= Deflection at B (y1)

Calculation:-

1. Calculate the slope at B as y2 / b (measured value).
2. Compute slope and deflection at B theoretically from B.M.D. and compare with experimental values.
3. Deflection at C = y1(measured value).
4. Deflection at C = Average calculated value

Result :- The slope and deflection obtained is close to the slope and deflection obtained by suing moment area method.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

EXPERIMENT NO.2

Aim : - To determine the deflection of a pin connected truss analytically & graphically and verify the same experimentally.

Apparatus: - Truss Apparatus, Weight's, Hanger, Dial Gauge, Scale, Verniar caliper.

Truss Model
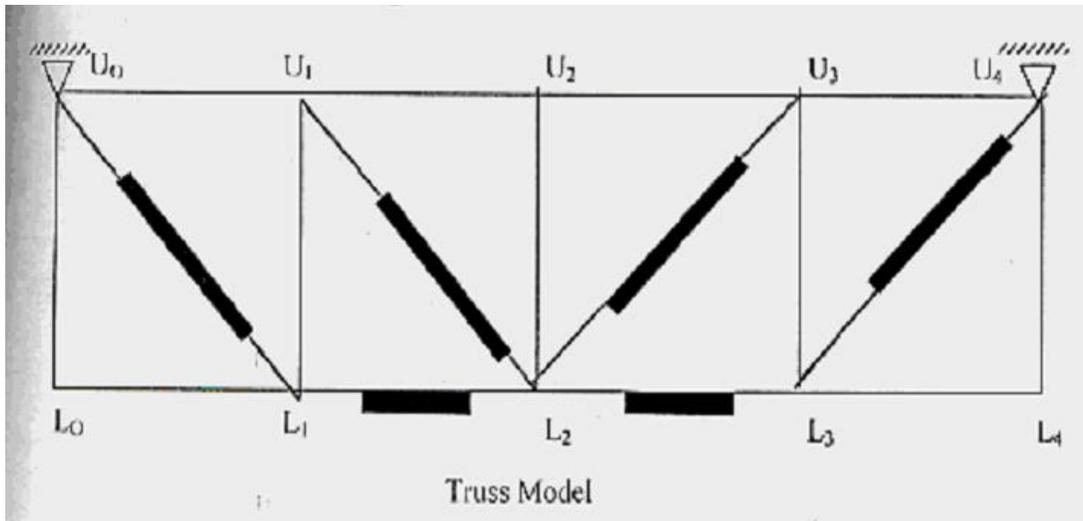
Theory :-The deflection of a node of a truss under a given loading is determined by:

$$0 = (TUL/AE)$$

Where, 0 = deflection at the node point.

T = Force in any member under the given loading.

U = Force in any member under a unit load applied at the point where the deflection is required. The unit load acts when the loading on the truss have been removed and acts in the same direction in which the deflection is required.

L = Length of any member.

A = Cross sectional area of any member.

E = Young's modulus of elasticity of the material of the member.

Here, (L/AE) is the property of the member, which is equal to its extension per unit load. It may be determined for each member separately by suspending a load from it and noting the extension.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Procedure: -

(1) Detach each spring from the member. Plot extension against load by suspending load from the spring and nothing the extension. From the graph, obtain the extension per unit load (stiffness).

(2) For initial position of the truss, load each node with 0.5 kg load to activate each member. Now place the dial gauges in position for measuring the deflections and note down the initial reading in the dial gauge .Also put additional load of 1kg, at L1, 2kg, L2, and 1kg at L3, and note the final reading in the dial gauges. The difference between the two readings will give the desired deflection at the nodal points. Central deflection y.

(3) Calculate the deflection for the three nodes L1, L2, and L3 from the formula given in Eq. (1) and compare the same with the experimental values obtained in step 3.

(4) Draw the Willot – Mohr diagram for deflection and compare the deflection so obtained experimentally and analytically.

Observation Table:-

Experimental Deflection Values

S.No.	Node Deflection	L1	L2	L3
1	Initial dial gauge reading (mm)			
2	Additional loads (kgs)			
3	Final dial gauge Reading (mm)			
4	Deflection (3) – (1) (mm)			

Sample Calculation: - Member =

$$L/AE = ...$$

Analytical deflection:= FUL/AE

Result :-The theoretical and experimental deflection in various members is found same.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

EXPERIMENT NO.3

Aim: - To verify clerk Maxwell's reciprocal theorem

Apparatus: - Clerk Maxwell's Reciprocal Theorem apparatus, Weight's, Hanger, Dial Gauge,
Scale, Verniar caliper.

Theory : -

Maxwell theorem in its simplest form states that deflection of any point A of any elastic structure
due to load P at any point B is same as the deflection of beam due to same load applied at A
It is, therefore easily derived that the deflection curve for a point in a structure is the same as the
deflected curve of the structure when unit load is applied at the point for which the influence curve
was obtained.

Procedure: -

i) Apply a load either at the centre of the simply supported span or at the free end of the beam,

the deflected form can be obtained.

ii) Measure the height of the beam at certain distance by means of a dial gauge before and after

loading and determine the deflection before and after at each point separately.

iii) Now move a load along the beam at certain distance and for each positions of the load,

the deflection of the point was noted where the load was applied in step 1 .This deflection should

be measured at each such point before and after the loading, separately.

iv) Plot the graph between deflection as ordinate and position of point on abssica the plot for graph

drawn in step2 and 3 .These are the influence line ordinates for deflection of the beam.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Observation Table:-

Distance from the pinned end	Load at central point/ cantilever end		Deflection of various points (mm) 2-3	Load moving along beam		Deflection of various points (mm) 5-6
	Beam unloaded Dial gauge reading (mm)2	Beam loaded Dial gauge reading (mm)3	Beam unloaded Dial gauge reading (mm)5	Beam unloaded Dial gauge reading (mm)5	Beam loaded Dial gauge reading (mm)6	

Result : - The Maxwell reciprocal theorem is verified experimentally and analytically.

Precaution: -   i) Apply the loads without any jerk.

         ii) Perform the experiment at a location, which is away from any
         iii) Avoid external disturbance.
         v) Ensure that the supports are rigid.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

EXPERIMENT NO.4

Aim: To determine the compressive strength of bricks

Apparatus: bricks, oven, scale etc…

Theory: bricks are used in construction of either load bearing walls or in portion walls incase of frame structure. In bad bearing walls total weight from slab and upper floor comes directly through brick and then it is transferred to the foundation. In case the bricks are loaded with compressive nature of force on other hand in case of frame structure bricks are used only for construction of portion walls, layers come directly on the lower layer or wall. In this case bricks are loaded with compressive nature of force. Hence for safely measure before using the bricks in actual practice they have to be tested in laboratory for their compressive strength.

Procedure:

1) Select some bricks with uniform shape and size.
2) Measure its all dimension.
3) Now fill the frog of the bricks with fine sand.
4) Place the bricks on the lower platform of compressive testing machine and lower the spindle till the upper motion of rams offered by a specimen the oil pressure start increasing the pointer start returning to zero leaving the drug pointer that is maximum reading which can be noted down.

Observation table:

SR. NO.	LBH (CM^3)	AREA (CM^2)	LOAD (N)	COMPRESSIVE STRENGTH (N/MM^2)	AVERAGE COMPRESSIVE STRENGTH

Calculation:
Compressive strength = maximum load at failure / loaded area of bricks
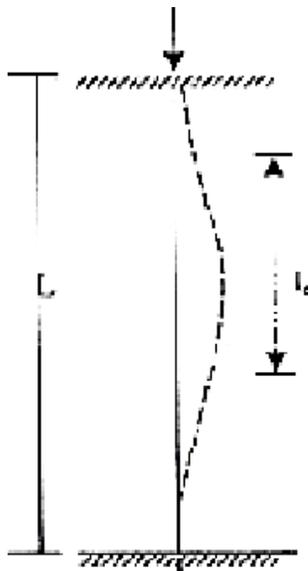
Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

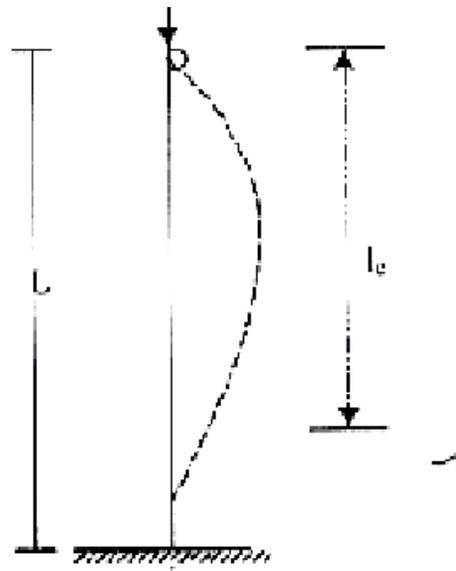**Result:** the average compressive strength of new brick sample is found to be ………
kg/cm^2

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

EXPERIMENT NO. 5

Aim: To study the behavior of struts and column with various end conditions.
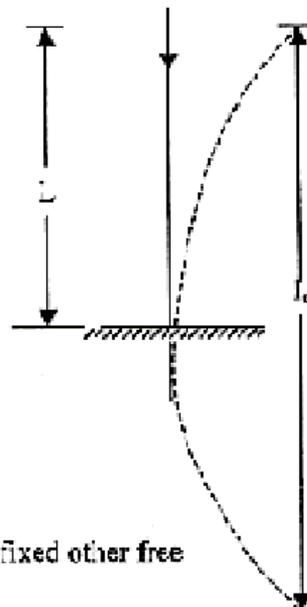**Apparatus**: model of struts and columns.

(i) Both ends fixed

(ii) One end fixed other pinned
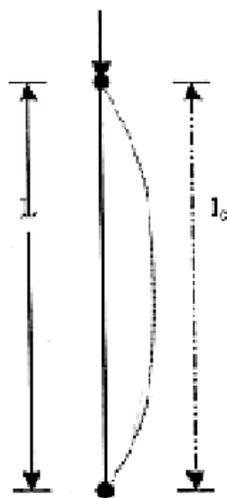
(iii) Both ends pinned

(iv) One end fixed other free

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Theory:

Struts – a bar or a member of a structure in any position other than vertical, subjected to an axial compressive load is called a strut.

Column – a bar or a member of a structure inclined at 90^0 to the horizontal and carrying an axial compressive load is called a column.

Procedure:

End condition – a loaded column and struts can have only one of the following four end condition -:

(a) Both end hinged or pin jointed –

In this case the end of the column cannot have any lateral displacement but can take slope when the column buckle on loading as shown in figure..

(b) Both end fixed –

In this case both ends are rigidly fixed. The end cannot have any lateral displacement and also cannot take slope as shown in figure..

(c) On end fixed and other hinged-

In this case one end of the column and struts is hinged and the other end is fixed. The fixed end can neither more laterally nor it take any slope but the hinged end can take slope when the column is loaded as shown in figure..

(d) One end fixed and other free-

In this case one end is secured both in position and direction and the other end is free to take any position and slope as shown in figure..

EXPERIMENT NO.6

Aim: To find out the elastic properties of a beam.

Apparatus: - Strain gauge Indicator, weights, hanger, scale, verniar caliper.

Formula: - $f = \dfrac{M\,y}{I}$

Theory : - When a beam is loaded with some external loading, moment & shear force are set up at each strain. The bending moment at a section tends to deflect the beam & internal stresses tend to resist its bending. This internal resistance is known as bending stresses.

Following are the assumptions in theory of simple bending.

1. The material of beam is perfectly homogeneous and isotropic (i.e. have same elastic properties in all directions.)

2. The beam material is stressed to its elastic limits and thus follows Hook's law.

3. The transverse section which are plane before bending remains plane after bending also.
4. The value of young's modulus of elasticity 'E' is same in tension and compression.

The bending stress at any section can be obtained by beam equation.

$f = (M/I)\,y$

Where, M= moment at considered section.

f = extreme fiber stresses at considered section. I = Moment of inertia at that section.

y= Extreme fiber distance from neutral axis.

f_{max} = maximum stress at the farthest fiber i.e. at ymax from neutral axis.

Digital strain indicator is used to measure the strain in static condition. It incorporates basic bridge balancing network, internal dummy arms, an amplifier and a digital display to indicate strain value.

Strain can be calculated analytically at the section by using Hook's law. Distrainindicator is used to measure the extreme fiber at particular section. It basically incorporates basic bridge balancing network, internal dummy arms, amplifier & digital display to indicate strain value.

Two -Arm Bridge requires two strain gauge and will display the strain value two times of actual. Four -Arm Bridge requires four strain gauge and will display the strain value four times of actual.

Procedure: -

i) Mount the beam with hanger, at the desired position and strain gauges, over it supports properly and connect the strain gauges to the digital indicator as per the circuit diagram.

ii) Connect the digital indicator to 230(+/- 10%) colts 50 Hz single phase A.C. power supply and switch 'ON' the apparatus.

iii) Select the two/four arm bridge as required and balance the bridge to display a '000' reading.

iv) Push the 'GF READ' switch and adjust the gauge factor to that of the strain gauge used (generally 2.00)

v) Apply load on the hanger increasingly and note the corresponding strain value.

Observation: - 1) Width of the beam model, B (cm)   =

           2) Depth of the beam model, D (cm)   =

           3) Span of the beam, L (cm)   =

           4) Moment of inertia of beam, I   =

                  $Y_{max} = D/2$ =

           5) Modulus of elasticity of beam material, E   =

Observation Table:-

S.No	Load applied on the hanger P (kg)	Moment at the mid span section (kg cm) = PL/4	$f_{max} = (M/I) \, Y_{max}$	Theoretical S t r a i n $\varnothing$ = f max	Observed strain on the display
1					
2					
3					
4					
5					

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Sample Calculation: - For reading No. ....

Load applied on the hanger P (kg)

Moment at the mid span section (kg cm) = PL/4

$f_{max=}$ $^{(M/I)}$ Y_{max}

Theoretical Strain Ø = f max E

Observed strain on the display

Result : - From observation table, it is seen that, the theoretical and observed value of strain is same.

EXPERIMENT NO. 7

Aim: - To determine the horizontal thrust in a three hinged arch for a given system of loads experimentally and verify the same with calculated values.

Apparatus: - The model has a span of 100cm and rise 25cm with hinges at supports and chain one of the end rests on rollers. Along the horizontal span of the end rests on rollers. Along the horizontal span of the arch various points are marked at the equidistance for the application of load. A dial gauge with magnetic base is applied with the apparatus.

Theory:- A three hinged arch is a statically determination structure with the axial thrust assisting in maintaining the stability the horizontal thrust H in the arch for a number of loads can be obtained as follows:

Taking moment about Av

$$R_B \; X \; L = W1a_1 + W_2a_2 + W_3a_3$$

Or $\quad R_B = \dfrac{W1a_1 + W_2a_2 + W_3a_3}{L}$

Taking moment about B

$$R_A = \dfrac{W_1 (L-a_1) + W_2 (L - a_2) + W3 (L-a_3)}{L}$$

Taking the moment of all the forces on left hand side about C, wt get

$$H \; X \; Y + W1 (L/2 - a_1) + W_2 (L/2 - a_2) + R_A \; X \; L/2$$

$H = 1/r [1/2 [W_1 (L-a_1) + W_2 (L-a_2) + W_3 (L-a_2) - W_1 (/2/L-a_1) - W_2 (L/2-a_1)]]$

The value of horizontal reaction can be evaluated by Equ. (1)

The influence line of any reaction at a point is a graph showing the variation of functions, moments, shear forcers, stress at deflections at a point for various positions of unit moving load. Therefore to draw the influence lone for H, a unit load of 14g is placed the influence lone for H, a unit load of 14g is placed at varying distance from either of the supports.

Let a load of 1kg be placed at a distance from A $R_B = X/L$ then, taking moment about for all the forces on R.H.S. of c we have

---

$$= x/2 \text{ X } l/2 - Hr = 0$$

$$H = x/2r \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Thus the equation (2) is the equ. Of a straight line and gives the influence line diagram of the horizontal reaction.

Procedure: -

1) Use lubricating oil the roller end of the arch so as to have a free movement of the roller end. Balance the self weight of the arch by placing load on the hanger for horizontal thrust until the fest equilibrium conditions are obtained. Note down the loads in kgs.

2) Place a few loads on the arch in any chosen positions. Balance these by placing additional weights on the hanger for horizontal thrust. The additional weights on the thrust hanger give the experimental value of the horizontal thrust.

3) To obtain the influence line for H, place a load of 2kg in twin on each hanger one by one and find the balancing weights required on the thrust hanger.

4) Plot the ordinate representing 1/2 of the balancing weights on the load positions as base. This gives the influence line diagram for horizontal thrust.

Calculation: -

Span of the arch, L =100cm

Central rise, h =25cm

Initial load on the thrust hanger for balancing kg =1.5kg

Precaution: -

1) Plot weight in thrust hanger very gently without a jerk.

2) Measure the distance of loaded points from left hand support accurately.

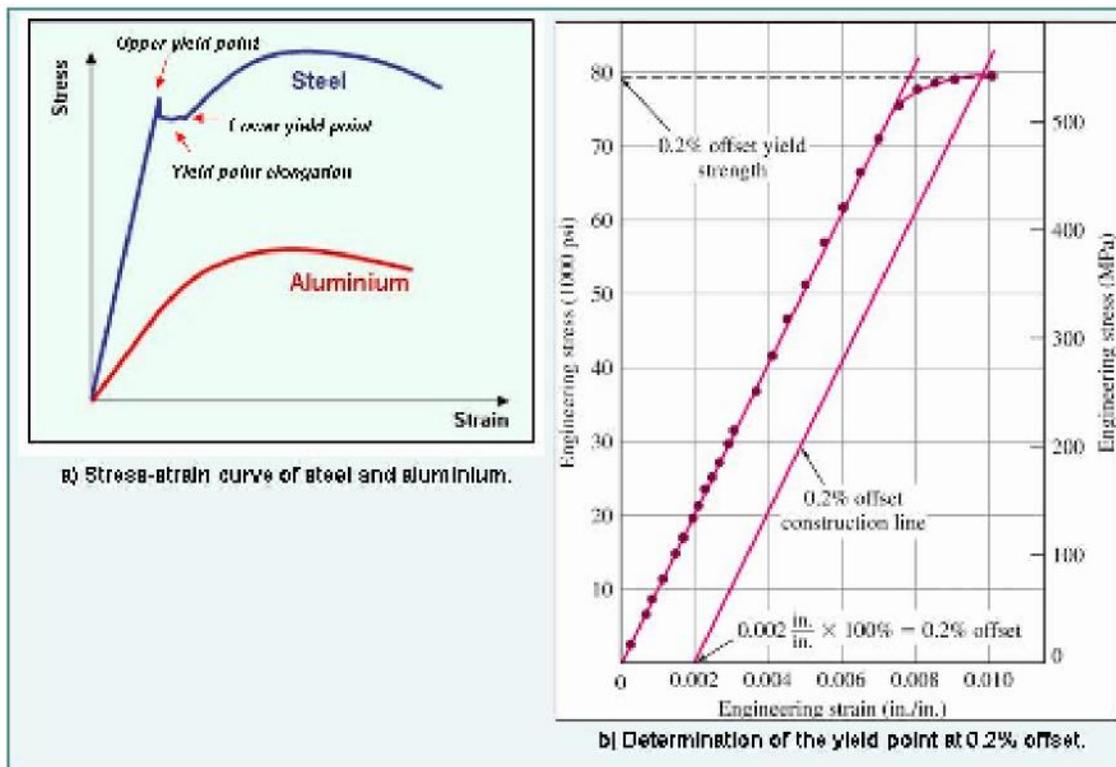3) Perform the experiment away from vibration and other disturbance.

EXPERIMENT NO. 8

Objective- Uniaxial tension test for steel

Theory

Uniaxial tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus. These important parameters obtained from the standard tensile testing are useful for the selection of engineering materials for any applications required. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history.

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

Comparative stress-strain relationships of low carbon steel and aluminum alloy

Apparatus :

2.1 Tensile specimens

2.2 Micrometer

2.3 Universal testing machine

2.4 Stereoscope

Procedure

(1) The specimens provided are made of aluminum, steel and brass. Measure and record specimen dimensions (diameter and gauge length) in a table provided for the calculation of the engineering stress and engineering strain. Marking the location of the

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

gauge length along the parallel length of each specimen for subsequent observation of necking and strain measurement.

(2) Fit the specimen on to the universal Testing Machine (UTM) and carry on testing. Record load and extension for the construction of stress-strain curve of each tested specimen.

(3) Calculate Young's modulus, yield strength, ultimate tensile strength, fracture strain, % elongation and % area of reduction of each specimen and record on the provided table.

(4) Analyze the fracture surfaces of broken specimens using stereoscope, sketch and describe the results.

(5) Discuss the experimental results and give conclusions.

Results

Details	Aluminium	Steel	Brass
Diameter (mm)			
Width (mm)			
Thickness (mm)			
Cross-sectional area (mm^2)			
Gauge length (mm)			
Young's modulus (GPa)			
Load at yield point (N)			
Yield strength (MPa)			
Maximum load (N)			
Ultimate tensile strength (MPa)			
% Elongation			

Civil Engineering Department

BRCM COLLEGE OF ENGINEERING & TECHNOLOGY
Bahal - 127028 (Distt. Bhiwani) Haryana, India

% Area of reduction			
Fracture strain			
Work hardening exponent (n)			
Fracture mode			
Fracture surfaces (Sketch)			

Experimental data for tensile testing.