MANUAL

ON

STRUCTURAL ENGINEERING LABORATORY

COURSE CODE: BCE05004: 0-0-3 (CR 1.5)

FIFTH SEMESTER, B TECH, CIVIL ENGINEERING

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SYLLABUS

Structural Engineering Lab (BCE05004)

(A) TEST FOR STEEL:

1. Determination of:
   - Tensile strength
   - Percentage of elongation of steel
   - Stress- strain curve of steel
   - Modulus of Elasticity
2. Bend and rebend test of steel reinforcement

(B) TEST FOR CONCRETE:

1. Mix design of Concrete
2. Testing of RCC beam
3. Non-destructive tests of concrete

(C) TEST ON SOME REGULAR STRUCTURAL ANALYSIS PROBLEMS:

1. Finding reactions and forces for three hinged arch
2. ILD for indeterminate structure

Course Content:

Structural Engineering Lab (BCE05004)

Subject to Revision

EXPERIMENT NO: 1

AIM OF THE EXPEREIMENT

To determine the unit mass (kg/m) and the effective cross-sectional area of given HYSD bar sample as per ***IS: 1786-2008***.

APPARATUS REQUIRED

(1) Scale or Tape

(2) Weighing Machine

THEORY

Unit mass defined as the mass per unit length= mass (W) / unit length (L)

Where W= mass of HYSD bar in kg

L= Unit length of rod measured in meters

Density of steel (γ) = 78.5 kN/m^3 = 7850 kg/m^3 = 7850 $kg/m^2/m$ = **0.00785** $kg/mm^2/m$ = **0.00785** L kg/mm^2

Density = mass / volume = mass / (Cross Sectional Area x length)

Cross Sectional Area = mass/ (density x length)

Effective Cross-Sectional Area (mm^2), **A = W / 0.00785 L**

Where, W= mass (kg)

L= unit length (m)

Steel density= 0.00785 L

Tolerance Limit-It is the allowable variation in any measurable property.

Here the unit mass should be within the given tolerance limit **(Table 2, IS 1786: 2008)**

DIAMETER OF BAR	INDIVISUAL (%)	BATCH (%)
UPTO 10 mm	+/- 8	+/- 7
10 – 16 mm	+/- 6	+/- 5
>16 mm	+/- 4	+/- 3

PROCEDURE

1. Any identification mark like brand name, trade mark on distinguishing mark of the manufacturer was checked and ascertained the grade and size of the bar.

Manufacturer: _____________

Nominal size (example): 10 mm, 12 mm, 16 mm, 20 mm

2. The number of test specimen were selected as per of **IS**: **1786-2008**

3. The length and mass of the sample were measured by tape and weighing balance and found out the mass of the sample steel rod per unit length.

4. the actual cross-sectional area (CA in mm^2) was calculated from the given section

$$\mathbf{A = W / 0.00785L}$$

where, W = mass in **kg** weighed to the precision of (+/-) 0.5%

and L length in **m** measured to the precision of (+/-) 0.5%

5. The values were compared with the values given as per the nominal size of the sample given in **Table 1, IS 1786: 2008.**

Nominal size (in mm)	Cross sectional area (in mm^2)	Mass per meters (in kg)
4	12.6	0.099
5	19.6	0.154
6	28.3	0.222
8	50.3	0.395
10	78.6	0.617
12	113.1	0.888
16	201.2	1.58
18	254.6	2.00
20	314.3	2.47
25	491.1	3.85
28	616.0	4.83
32	804.6	6.31
36	1018.3	7.99
40	1257.2	9.86

Results of Unit mass (Experimental):

Nominal size(mm)	Actual unit mass (kg) (Experimental)	Value as per Table-1	Percentage variation	Remarks
10				
12				
16				
20				

Result of Cross-sectional area (Experimental):

Nominal size(mm)	Actual cross-sectional area (mm^2) (Experimental)	Value as per Table-1	Percentage variation	Remarks
10				
12				
16				
20				

Nominal size (mm)	Actual cross-sectional area (mm^2) (Experimental)	Actual Nominal diameter (mm)	Percentage variation	Remarks
10				
12				
16				
20				

CONCLUSION

From the above experiment, the unit mass/meter, area of cross section and diameter of HYSD bar have been found out of which the diameter of 10, 12 and 16 mm are recommended to be used and diameter of 20 mm is not falling in to recommended range. Hence, that should not be used in civil engineering project.

QUIZES FOR EXPERIMENT NO: 1

1.Define unit mass?

Ans – Unit mass is defined as the mass per meter length = W/L

2.Define Ultimate stress?

Ans: The quantity of the utmost tensile, compressive, or shearing stress that a given unit area of a certain material is expected to bear without failing.

3.What is HYSD steel bar?

Ans: High Yielding Strength Deformed are steel rods made with heat treatment. While applying heat, the bars are cold twisted for shaping. Steel bars used to be low on tensile strength and fragile hence did not garner much attention.

4.Where is HYSD steel used?

These types of bars are used for lightweight structures as well as heavy loaded structures. When we look at the surface of this bar, it has ribs on its surface. Due to this rib, the bonding between the steel and the concrete is very good as compared to mild.

5.What is the ultimate tensile stress of a material?

Ultimate tensile stress (UTS) refers to the maximum stress that a given material can withstand under an applied force.

6.Ultimate stress of mild steel is______?

Ans: 400 -550 MPa.

7. Write the full form of HYSD bar.

Ans: High Yielding Strength Deformed Steel.

8. What is strain?

Strain is simply the measure of how much an object is stretched or deformed. Strain occurs when force is applied to an object. Strain deals mostly with the change in length of the object.

9. Define true stress?

Stress is the applied load divided by the actual cross-sectional area of a material.

10.What does yield stress mean?

Ans: Yield stress, marking the transition from elastic to plastic behaviour, is the minimum stress at Which a solid will undergo permanent deformation or plastic flow without a significant increase in the load or external force.

11.What is yield strength in simple words?

Ans: The stress at which a piece under strain is deformed some definite amount.

12.What is the yield stress of Aluminium?

Ans: Aluminium alloy has a yield tensile strength of 276 MPa.

13.Cross sectional area (A in mm^2) from the given relation formula?

Ans: A=W/0.00785L.

14.What is ultimate shear stress?

Ans: The stress at a section which is loaded to its maximum in shear.

15.What is Fy and Fu?

Ans: fy stand for yield strength of steel and term fu stand for ultimate tensile strength of Steel.

16. What is F_C concrete?

Ans: F_C is the specified compressive strength of concrete using standard cylinders of six inches diameter and twelve inches height. Usually this is prescribed at the age of 28 days.

17.What is MPa strength?

Ans; A megapascal (MPa) is a measure of the compressive strength of concrete.

18.What is the density of steel?

Ans: 7850 kg/m^3.

##

Subject to Revision

EXPERIMENT NO: 2

AIM OF THE EXPERIMENT:

To check the transverse cracks in the bent position, after bend and rebend test of HYSD bars sample as per ***IS: 1786-2008***.

APPARATUS REQUIRED:

(1) Universal Testing Machine (UTM)

Specifications of UTM with us: M/s Blue Star Engineering Co Pvt. Ltd

UTM capacity 100 tones

3 phase – 220V/30 Amp-50 Hz

Model- Year 1995 UTE 100

THEORY:

(1) It is not uncommon that steel reinforcement is bent prior to installation into concrete structures. However, upon the bending process steel reinforcement may fracture owing to the following reasons-

a) The ribs of the steel bars serve as location of stress concentration which is the potential weak point for fracturing.

b) Owing to their intrinsic high strength, large force is required during the bending process.

c) The radius of bending is too light.

(2) Temperature is also an important factor for controlling the risk of steel fracture. The risk of fracture is increased when there is a drop of temperature, because steel has lower toughness at lower temperature.

(3) Therefore, the bend test can be carried out for reinforcing steel to test their bending performance.

The purpose of the rebend test is to measure the effect of strain ageing on the steel. Strain ageing has embrittlement effect which takes place after cold deformation by diffusion of nitrogen instead. Hence, there is a limitation stated in some design code to restrict the nitrogen content of steel to 0.012%.

PROCEDURE:

i) Take two bars of known diameter. Example: 10 mm and 12 mm diameters respectively

ii) Put the two bars on the bending table of UTM successively

iii) Then apply load on the bar to bend it to make an angle of **135^0**.

iv) Then, again place the bar again on the bending table of UTM with the vortex facing upward.

v) For rebending of the bar, apply the load on the vortex to make an angle of **157.5^0**.

vi) Then measure the angle and check for cracks.

OBSERVATION:

The observation for the above bend and rebend test is as follows-

Diameter of Bar (in mm)	Bending Angle	Rebending Angle
10		
12		

CONCLUSION: -

The given diameter bars did not show any visible cracks at the bend portion after the bend and rebend test. So, these bars samples are ok to be used in construction purposes.

QUIZES FOR EXPERIMENT NO: 2

1) What is the purpose of the bend and re-bend test in TMT bars?

Ans: The bending test of TMT bars is performed to test the steel ductility without affecting the steel strength. Conversely, the re-bend test is used to measure the effects of strain aging on steel. In steel, embrittlement can occur due to the diffusion of nitrogen after cold deformation that occurs with strain aging.

2) When pure bending is observed?

Ans: When there is no internal shear acting in mid-span of specimen.

3) Which is the IS code used for rebend test on steel?

Ans: IS: 1786-2008

4) What is bending strength?

Ans: It is the ability of a material to resist deformation under load.

5) How failure in ductile and brittle materials occurs under bending load?

Ans: Brittle materials fail in tension. Ductile materials are weak in shear. Hence ductile materials failure occurs due to principal shear stress.

7) What is the bend and rebend angle observed from the experiment?

Ans: bend angle is 135^0 and rebend angle is 157.5^0.

8) What is the purpose of this experiment?

Ans: To measure the effect of strain ageing on the steel.

##

Subject to Revision

EXPERIMENT NO: 3

AIM OF THE EXPERIMENT:

To determine the ultimate tensile strength and percentage elongation of given HYSD bar samples as per *IS*:***1608-2005***.

APPARATUS REQUIRED:

(1) Universal Testing Machine (UTM)

(2) Test specimen

(3) Vernier Caliper

(4) Ruler

THEORY:

According to Table 3, **IS: 1786-2008**-code the various mechanical properties of HYSD bars are as follows:

Grade	Fe415	Fe500	Fe550
Minimum percentage of elongation (%)	14.5	12.0	10.0
Minimum tensile strength (N/mm^2)	485	545	585
Minimum proof stress (N/mm^2)	415	500	550

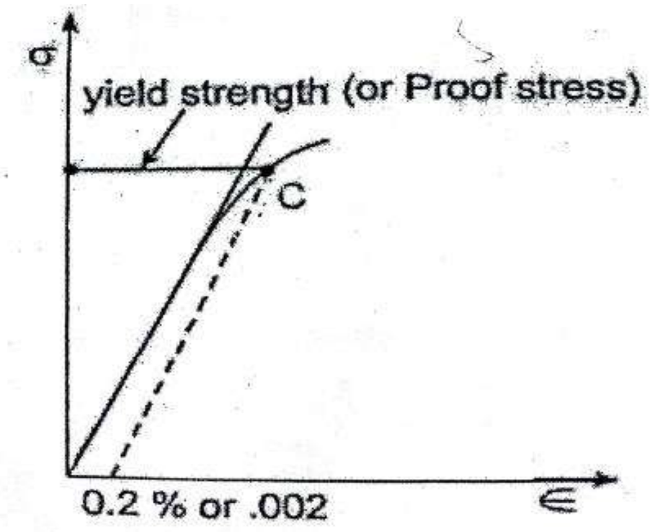


Figure: Typical stress-strain curve of HYSD bars

PROCEDURE:

i) Let us find the tensile strength of Fe500 HYSD bar of given diameter for the test from the data supplied and form the graph.

ii) Measure the weight and length of the given sample.

iii) Put marks on the rod at a distance of **gauge length** (G) from an initial point at distances of gauge length measured by:

$$G = 5.65 \sqrt{A}$$ in mm where A is cross sectional area of HYSD bar in mm^2

iv) Its **diameter** can be calculated by the formula:

$$d = \sqrt{(4/\Pi) * w / 0.00785 * L}$$

where,

d = diameter of the bar in mm

w = weight of the bar in kg

L = Length of the bar in meter

v) Check the diameter of the bar to be in the range of 14% tolerance limit.

vi) Select Jaws for gripping and suitable load scale on testing machine.

vii) Set the automatic graph recording system.

viii) Start the UTM and observe and take readings.

ix) Apply the load till the specimen breaks and then stop the machine.

OBSERVATION AND CALCULATION:

ULTIMATE TENSILE STRENGTH:

1) Diameter of the given sample =

Cross-sectional area =

Ultimate load =

Ultimate stress =

Check whether this Ultimate stress > Minimum proof stress as per table above

PERCENTAGE OF ELONGATION:

1) Diameter of the given sample =

Initial length =

Final length =

Percentage of elongation= {(Final length - Initial length) / Initial length} * 100 =

Check whether this Percentage of elongation > Minimum percentage of elongation as per table above

CONCLUSION:

As the Ultimate tensile stress and Percentage of elongation in the provided HYSD bars exceed the minimum values as per Table 3, IS: 1786-2008 respectively corresponding to their grades, therefore they are acceptable for use in civil engineering purposes.

QUIZES FOR EXPERIMENT NO: 3

1) What is the unit of ultimate tensile strength?

Ans- N/mm^2

2) The ability of the material to withstand tensile force, without breaking, is known as:

Ans- Tensile strength

3) With an increase in the degree of cold working, tensile strength of material __.

Ans-Increases

4) Whether tensile strength is used as a design criterion for ductile materials.

Ans- No

5) How to identify the yield stress of a material while testing under UTM?

Ans- The particular stress where a material shows specified elongation under a load

6) What is the yield point of a material?

Ans- Point where there is a substantial increase in elongation without a rise in load

7) Percentage elongation measured during tensile testing indicates ____.

Ans- Ductility

8) With an increase in strain rate, ductility __ and tensile strength ___

Ans- Decreases, increases

9) Yield and flow strength at lower plastic strain is more dependent on __ than ___

Ans- Strain rate, tensile strength

10) The slope of the stress-strain curve in the plastic range is ___

Ans- Rate of strain hardening

11) When equal and opposite forces applied to a body, tend to elongate it, the stress so produced

called ____

Ans- Tensile stress

12) In a tensile test, near the elastic limit zone ____

Ans- Tensile stress decreases at a faster rate

13) The phenomenon of slow growth of strain under a steady tensile stress is called

Ans- Creeping

Subject to Revision

EXPERIMENT NO: 4

AIM OF THE EXPERIMENT:

To determine the ultimate tensile strength, yield strength and percentage elongation of mild steel coupon as per *IS*:***1608-2005***.

APPARATUS REQUIRED:

1) Dog bone shape specimen (mild steel coupon)

2) Universal Testing Machine (UTM)

3) Measuring Scale

THEORY:

UTM (Universal Testing Machine):

A machine designed to perform tensile, compressive, bend and shear test is called UTM. It mainly consists of two parts: -

- Loading unit and control unit. In addition to these two units, there are certain accessories like bending table, jaws for gripping recorders etc.
- Loading unit consists of two crossheads i.e., upper cross head and lower cross head and a table.

The initial slope is where stress is directly proportional to strain and the material behaves like this up to its elastic limit where it reaches its yield strength. Beyond this the material deforms permanently. The material then becomes strain hardened until you reach ultimate strength and necking starts to occur and the material becomes weaker again until it breaks apart.

Yield stress is the stress at which the material deforms permanently and ultimate stress is the stress at which material breaks. Hard steels and non-ferrous metals do not have defined yield limit, therefore a stress, corresponding to a definite deformation (0.1% or 0.2 %) is commonly used instead of yield limit. This stress is called proof stress or offset yield limit.

Yield strength: The stress at which elastic deformation changes to plastic deformation causing permanent deformation.

Tensile strength: Ultimate loads taken by the material before failure is known as failure load stress and corresponding to this is known as tensile strength. It is recommended by maximum stress strain curve and indicates when cracking will occur, its value does not depend on the size of the specimen.

Ultimate strength: The maximum stress that the material can withstand when subjected to tension on compression on shear is ultimate strength. It is the maximum stress in the stress-strain curve.

Breaking strength: The stress corresponding to the point of rupture on the stress-strain curve

Let the initial length of specimen = L_1

Final length of specimen =L_2

Change in length (ΔL) = $L_1 - L_2$

Percentage elongation= $(L_1 - L_2) / L_1 \times 100$

Yield strength= load at yield point / cross-sectional area

Ultimate strength = Ultimate load/ cross-sectional area in MPa

As per, **Table 1, IS 432-1982**

Thickness (mm)	**Φ < 20 mm**	**20 mm< Φ < 50 mm**
Ultimate Tensile Stress (min)	410 N/mm^2	410 N/mm^2
Yield stress (min)	250 N/mm^2	240 N/mm^2
Percentage Elongation (Min)	23.0	23.0

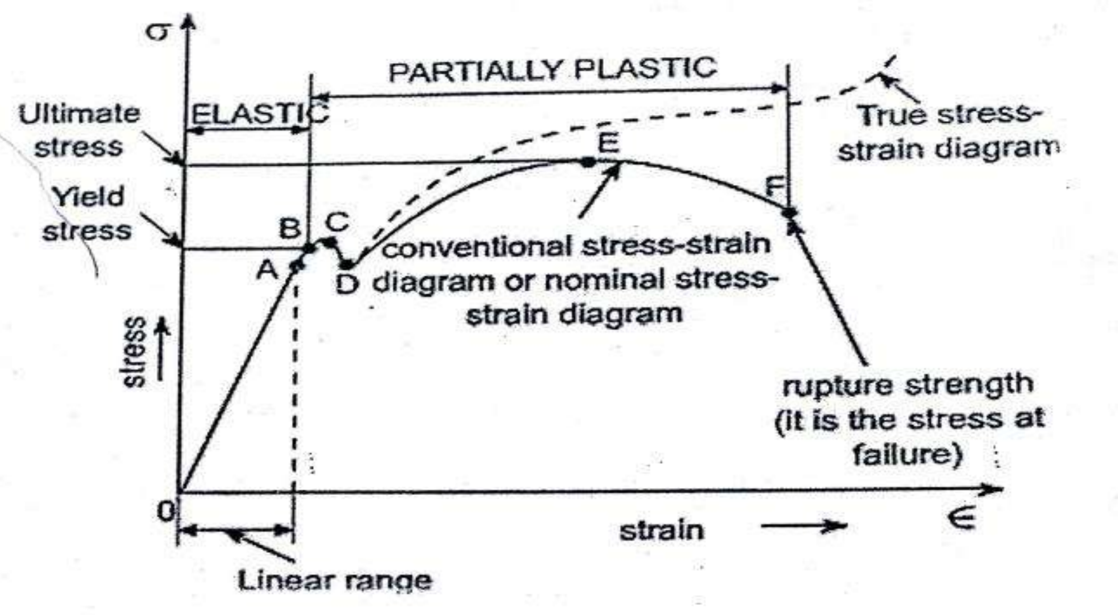
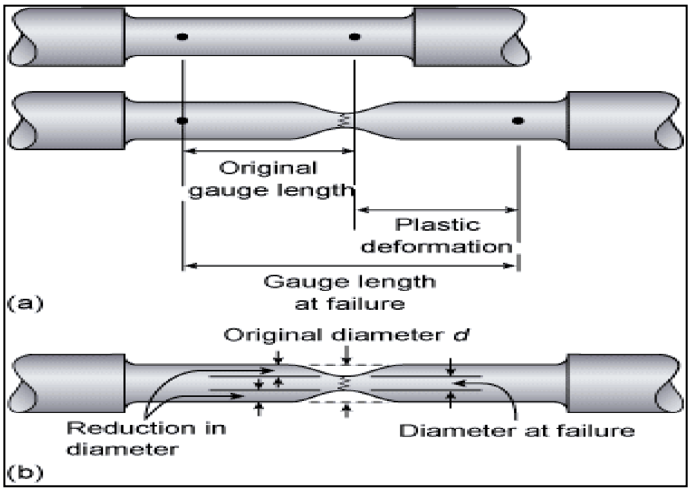


Figure: Typical stress-strain curve of mild steel



PROCEDURE:

i) The sample of dog bones shape specimen was collected and the gauge length was measured by using a measuring scale.

ii) The width and thickness of the specimen is to be measured by screw gauge (LC - 0.01mm) and the cross-section area was calculated.

iii) Then the dog bone shape specimen was gripped in the UTM and the tensile force was applied to the specimen.

iv) The loads in kN were recorded from the recording device at ultimate point and at the yield point.

v) Then the stresses were calculated for the corresponding points.

vi) The ultimate stress (f_u) and the yield stress (f_y), were calculated.

vii) The stress vs strain curve is prepared.

OBSERVATIONS:

Width of the dog bone shape specimen (b) in mm

Thickness of the dog bone specimen (t) in mm

Hence, Cross-sectional area (A) =b x t in mm^2

Ultimate Stress (f_u)= Peak load/Area in N/mm^2

Yield Stress (fy) = Ultimate stress x Factor of safety (**0.67)** in N/mm^2

Initial Length (L_1) = 50 mm

Final Length (L_2) in mm

Percentage elongation= L_2-L_1 / L_1 x 100

Check, whether Yield stress > 250 N/mm^2 and Percentage elongation > 23%

Hence if above clause is satisfied, then mild steel is accepted for use.

CONCLUSION:

We have used mild steel coupon of dimensions (250 mm x10 mm x 12 mm) and found that the yield strength and the percentage of elongation are **greater than the permissible values as per Table 1, IS 432-1982**, therefore the mild steel coupon can be used for civil engineering purposes.

QUIZES FOR EXPERIMENT NO: 4

1.Mild steel is a ______steel.

Ans- Low carbon

2.Mild steel is used for ____

Ans- Structural works in beams, joints and girders

3.What will be the unit of tensile stress?

Ans- N/mm^2

4.The ultimate tensile stress of mild steel compared to ultimate compressive stress is ____.

Ans- More

5.During a tensile test on a ductile material ____.

Ans-True stress at fracture is higher than the ultimate stress

6.When equal and opposite forces applied to a body, tend to elongate it, the stress so produced, is called ____.

Ans- Tensile stress

7.The phenomenon of slow growth of strain under a steady tensile stress is called ____ .

Ans- Creeping

8.The ultimate tensile stress of mild steel compared to ultimate compressive stress is______.

Ans- More

9.A thin mild steel wire is loaded by adding loads in equal increments till it breaks. The extensions noted with increasing loads will behave as under ____.

Ans- Increase rapidly first and then uniformly

10.In a tensile test on mild steel specimen, the breaking stress as compared to ultimate tensile stress is ____.

Ans- Less

11.Tensile test can be performed on ____.

Ans- Universal testing machine

12.For which purpose UTM is used?

Ans- UTM is designed to perform tensile, compressive, bend and shear test on materials.

13.In universal testing machine, for a circular section specimen, the gauge length is taken to be______

Ans-5.65 $\sqrt{A}$ mm

14.The shape of mild steel specimen used in tensile test______

Ans- Dog bone shape specimen

15.The term "Gauge length" refers to______.

Ans- The part of a test specimen actually being measured for elongation during a tensile test.

16.Minimum percentage elongation for mild steel is______.

Ans-23%

17.Which parameters are actually measured during tensile testing of a specimen using UTM?

Ans- Load and elongation

18.UTM consists of how many units and what are they?

Ans- 2 units i.e., Loading unit and Control unit

19.Minimum Proof stress of mild steel is______.

Ans-410 N/mm^2

20.What does percentage elongation indicate during tensile test?

Ans- It is measure of ductility of a material

##

Subject to Revision

EXPERIMENT NO: 5

AIM OF THE EXPERIMENT:

To determine the quality of concrete using non-destructive testing of concrete by Ultrasonic Pulse Velocity method using Pundit lab ultrasonic instrument as per ***IS 13311 p1: 1992.***

APPARATUS REQUIRED:

1) Concrete cube

2) Pundit Instrument

THEORY:

The ultrasonic pulse velocity test (UPV) is one of the popular methods while one used to obtain information about the interior of the concrete structure with two accessible surfaces (transducers). The most known instrument which we use in lab is Pundit portable ultrasonic instrument (non-destructive digital testing machine). This comes with two transduces and one calibration rod to adjust the reading before test.

One of the important things in this test is having good coupling between the faces of the transduces with concrete surfaces. The concrete surface us an acoustic coupling such as a **petroleum jelly**.

PROCEDURE:

i) Switch on the main of machine and apply little amount of jelly to the transduces faces.

ii) The reference bar to check was used to calibrate the reading of the instrument.

iii) The pulse velocity was determined by providing the measured instruments of the path length between the two transducers.

iv) The transducer was pressed hardly onto the concrete opposite surface and it was hold for a while to allow the reading be taken until a consistent reacting appear on the display screen.

v) The stable reading was recorded which is the pulse velocity.

As per IS 13311 p1: 1992

If pulse velocity (v)

- $v > 4.5$ km/s, it is declared as excellent concrete grade
- $3.5 \text{ km/s} < v < 4.5$ km/s, it is declared as good concrete grade

- 3.0 km/s < v < 3.5 km/s, it is declared as medium concrete grade
- v < 3.0 km/s, it is declared as doubtful concrete grade

OBSERVATION:

SL.NO	TIME TAKEN (sec)	VELOCITY (km/s)	QUALITY
1			
2			
3			

CONCLUSION:

From the above experiment it is found out that the above concrete cube has pulse velocity of xxxx km/s which suitable for construction.

QUIZES FOR EXPERIMENT NO: 5

1.An ultrasonic pulse velocity test is an ______________.

Ans-In-situ, non-destructive test

2. In the UPV test, the strength and quality of concrete or rock is assessed by measuring the ___ of an ultrasonic pulse.

Ans-Velocity

3. Mechanical pulse having an oscillation frequency in range of `______________

Ans-40 kHz to 50 kHz

4. When the motion of the particles of a medium are at right angles to the direction of wave motion, the wave being transmitted is called a ____________.

Ans-Longitudinal wave

5. Ultrasonic testing is done in materials to determine

Ans-Cracks/flaws below the surface

6.A concrete sample to be characterized as good quality, its pulse velocity should lie in the range of___________.

Ans: 3.5 km/sec to 4.5 km/sec

7. The difference between pulse velocity obtained by direct method and indirect method may vary from _______.

Ans: 5 to 20 percent

8. A minimum path length of _____ mm is recommended for the direct transmission method involving one un-moulded surface

Ans: 150 mm

EXPERIMENT NO: 6

AIM OF THE EXPERIMENT:

To assess the available compressive strength in concrete using non-destructive testing by Rebound Hammer method as per ***IS 13311 p2: 1992.***

APPARATUS REQUIRED:

1) Concrete cube

2) Rebound hammer

3) Compression Testing Machine (CTM)

THEORY:

Various **non-destructive test methods** adopted to evaluate the compressive strength of concrete are:

i) Cone-Cut Test.

ii) Pull-Out Test

iii) Surface Hardness Test

iv) X-Ray Test

v) Electrical Field Test

vi) Ultrasonic Test.

vii) Rebound Hammer Test

The most suitable one is Rebound Hammer (RH) test. The error percentage is less than compared to other methods.

When plunger of the rebound hammer is pressed against concrete surface, the spring-controlled mass rebounds and the extent of rebound depends on the surface hardness of concrete. The surface hardness and hence rebound is related to the compressive strength of concrete. The rebound is read off from the graduated scale and termed as rebound number. The rebound number is correlated to the compressive strength of concrete from the available chart, which depends on the direction of surface strike with the help of rebound hammer. The chart for taking the rebound hammer reading is available for vertically downward, vertically upward, horizontal plunger movement. Point of impact of RH on cube should be more than 20 mm from the edge of the specimen and distance between two consecutive impact points should be more than 20 mm.

PROCEDURE:

i) After curing period of concrete cube is over, take out the cube from the curing tank.

ii) Smooth, clean and dry the cube surfaces.

iii) The test cube (150mm*150mm * 150mm) is held under CTM with a fixed stress of 7 N/mm^2, so that the cube in the laboratory will not be displaced while pressing the cube with RH plunger.

iv) Around each point of observation, six readings of RH is taken and the average of all these six is interpreted as the result of the test point.

v) Record the rebound number and correlate the number with the available chart and declare the strength of that point on concrete surface.

vi) On one concrete cube surface, nine equal spaced symmetric points are chosen and strength is accessed and average of all is taken.

vii) Similar test is continued on other available cube surfaces.

viii) Average of all is declared and is the compressive strength of concrete cube by RH method.

ix) Then compare the results from rebound hammer test and compressive testing machine.

x) The cube used is made by concrete mix design mix method.

xi) The difference between the compressive strength results obtained from this RH NDT test and destructive test result by crushing the concrete cube under CTM is ±25%.

OBSERVATION:

<table>
<tr><th>SL.NO.</th><th>Rebound Number (RN)</th><th>Average Rebound Number</th><th>Compressive Strength</th></tr>
<tr><td rowspan="6">Surface 1 of Cube</td><td>RN at Point 1 =</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>RN at Point 2 =</td></tr>
<tr><td>RN at Point 3 =</td></tr>
<tr><td>RN at Point 4 =</td></tr>
<tr><td>RN at Point 5 =</td></tr>
<tr><td>RN at Point 6 =</td></tr>
<tr><td rowspan="6">Surface 2 of Cube</td><td>RN at Point 1 =</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>RN at Point 2 =</td></tr>
<tr><td>RN at Point 3 =</td></tr>
<tr><td>RN at Point 4 =</td></tr>
<tr><td>RN at Point 5 =</td></tr>
<tr><td>RN at Point 6 =</td></tr>
<tr><td rowspan="6">Surface 3 of Cube</td><td>RN at Point 1 =</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>RN at Point 2 =</td></tr>
<tr><td>RN at Point 3 =</td></tr>
<tr><td>RN at Point 4 =</td></tr>
<tr><td>RN at Point 5 =</td></tr>
<tr><td>RN at Point 6 =</td></tr>
</table>

Surface 4 of Cube	RN at Point 1 =		
	RN at Point 2 =		
	RN at Point 3 =		
	RN at Point 4 =		
	RN at Point 5 =		
	RN at Point 6 =		

- Compressive strength from rebound hammer test (NDT) = ___ N/mm^2

- From compressive strength machine,
  Cube crushing load under CTM is ___ N
  Area of cube = 150 × 150 = 22500 mm^2
  Compressive strength from destructive test = Cube crushing load / Area of cube (N/mm^2)

- Difference between above two tests should be **+/- 25%**

CONCLUSION:

The test result using non-destructive technique adopting rebound hammer test is acceptable as the difference between this result and that using compressive testing machine is well within +/- 25%.

QUIZES FOR EXPERIMENT NO: 6

1) What is non-destructive test?

Ans- Non-destructive tests are applications for detecting flaws in materials without impairing their usefulness.

2)What is a destructive test?

Ans-Destructive tests are applications for detecting flaws that impair the use of the materials such as pressure testing.

3) What are the disadvantages of Rebound Hammer Test?

Ans- Flaws cannot be detected with accuracy

4) Mention the factors influencing rebound hammer test?

Ans: Type of cement, Type of aggregate, Curing and age of concrete, Surface condition and nature content

5. What is the principle of rebound hammer test?

Ans: Rebound hammer test is based on the principle that the rebound of the elastic mass depends on the hardness of the concrete surface against which the mass strikes. When the plunger of the rebound hammer is pressed against concrete surface the spring-controlled mass of the hammer rebounds.

6. What is rebound index?

Ans: The rebound value read from the graduated scale of rebound hammer is called rebound index.

Subject to Revision

EXPERIMENT NO: 7

AIM OF THE EXPERIMENT:

To perform the M25 concrete mix design in accordance with ***IS 10262:2019.***

APPARATUS REQUIRED:

1) Concrete making materials: Cement, Fine aggregate, Coarse aggregate, Water, Superplasticizer
2) Concrete Mixer
3) Slump cone with tamping rod
4) Cube moulds

THEORY:

1. STIPULATIONS FOR PROPORTIONING

a) Grade designation : M25

b) Type of cement : OPC 43 conforming to IS 8112

c) Maximum nominal size of aggregate : 20 mm

d) Minimum cement content and maximum water-cement ratio to be adopted and/or Exposure conditions as per Table 3 and Table 5 of IS 456 : Moderate (for reinforced concrete)

e) Workability : 75 mm (slump)

f) Method of concrete placing : Chute (Non pumpable)

g) Degree of site control : Good

h) Type of aggregate : Crushed angular aggregate

j) Maximum cement content not including fly ash : 450 kg/m3

k) Chemical admixture type : Superplasticizer - normal

2. TEST DATA FOR MATERIALS

a) Cement used : OPC 43 conforming to IS 8112

b) Specific gravity of cement : 3.15 (let)

c) Chemical admixture : Superplasticizer conforming to IS 9103

d) Specific gravity of

1) Coarse aggregate [at saturated surface dry (SSD) Condition] : 2.68 (let)

2) Fine aggregate [at saturated surface dry (SSD) Condition] : 2.65 (let)

3) Chemical admixture : 1.11 (let)

e) Water absorption

1) Coarse aggregate: 0.5 percent

2) Fine aggregate: 1.0 percent

f) Moisture content of aggregate [As per IS 2386 (Part 3)]

1) Coarse aggregate : Nil

2) Fine aggregate : Nil

g) Sieve analysis:

1) Coarse aggregate : 20 mm down and 10 mm down nominal size each 50%

<table>
<tr><th rowspan="2">IS sieve size</th><th colspan="2">Analysis of Coarse aggregate fraction (Percentage of passing)</th><th colspan="3">Percentage of different fraction (Percentage of passing)</th><th rowspan="2">Recommended percentage of passing of 20 mm nominal size graded aggregates</th><th rowspan="2">Remarks</th></tr>
<tr><th>20 – 10 mm</th><th>10 – 4.75 mm</th><th>20 – 10 mm (50%)</th><th>10 – 4.75 mm (50%)</th><th>Combined 100%</th></tr>
<tr><td>20 mm</td><td>100</td><td>100</td><td>50</td><td>50</td><td>100</td><td>90 – 100</td><td rowspan="3">Conforming to graded aggregates of 20 mm nominal size as per IS 383-2016</td></tr>
<tr><td>10 mm</td><td>0</td><td>76.28</td><td>0</td><td>38.14</td><td>38.14</td><td>25 – 55</td></tr>
<tr><td>4.75 mm</td><td></td><td>2.4</td><td></td><td>1.2</td><td>1.2</td><td>0 – 10</td></tr>
</table>

2) Fine aggregate : Conforming to grading Zone II of Table 9 of IS 383-2016

3. TARGET STRENGTH FOR MIX PROPORTIONING

$f'_{ck} = f_{ck} + 1.65\,S$

or

$f'_{ck} = f_{ck} + X$

whichever is higher (cl. 4.2 IS 10262:2019)

where,

f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

S = standard deviation, and

X = factor based on grade of concrete.

From Table 2 (IS 10262: 2019), standard deviation, S = 4 N/mm^2.

From Table 1(IS 10262: 2019), X = 5.5.

Therefore, target strength using both equations, that is,

a) $f'ck = fck + 1.65\ S$

$= 25 + 1.65 \times 4 = 31.6$ N/mm^2

b) $f'ck = fck + 6.5$

$= 25 + 5.5 = 30.5$ N/mm^2

The higher value is to be adopted. Therefore, target strength will be 31.6 N/mm^2 as 31.6 N/mm^2 > 30.5 N/mm^2.

4. APPROXIMATE AIR CONTENT

From Table 3; cl. 5.2 (IS 10262: 2019), the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.0 percent for 20 mm nominal maximum size of aggregate.

5. SELECTION OF WATER-CEMENT RATIO

From Fig. 1 (IS 10262: 2019), the free water-cement ratio required for the target strength of 31.6 N/mm^2 is 0.47 for OPC 43 grade curve. This is lower than the maximum value of 0.50 prescribed for 'moderate' exposure for reinforced concrete as per Table 5 of IS 456.

0.47 < 0.50, hence O.K.

6. SELECTION OF WATER CONTENT

From Table 4 (IS 10262: 2019), water content = 186 kg (for 50 mm slump) for 20 mm aggregate. Estimated water content for 75 mm slump (cl. 5.3 IS 10262:2019, the required water content may be increased or decreased by 3 percent for each increase or decrease of 25 mm slump value)

= 186 + (3 * 186) / 100 = 191.58 kg

As superplasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 22 percent (cl. 5.3 IS 10262: 2019, by addition of super plasticizing admixture usually decrease the water content by 20 to 30 percent or above at appropriate doses) is considered while using superplasticizer at the rate 1.0 percent by weight of cement. Hence the water content

$= 191.58 \times 0.78 = 149.43$ kg ≈ 150 kg

7. CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.47

Cement content = 150 / 0.47 = 319.14 kg/m3 ≈ 320 kg/m3

From Table 5 of IS 456, minimum cement content for 'moderate' exposure condition = 300 kg/m^3

320 kg/m^3 > 300 kg/m^3, hence, O.K.

8. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGETE CONTENT

From Table 5 (IS 10262: 2019), the proportionate volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 = 0.62. In the present case water-cement ratio is 0.47.

(Approximate values for this aggregate volume are given in Table 5 for a water cement materials ratio of 0.5, which may be suitably adjusted for other ratios, the proportion of volume of coarse aggregates to that of total aggregates is increased at the rate of 0.01 for every decrease in water-cement ratio by 0.05 and decreased at the rate of 0.01 for every increase in water cement ratio by 0.05.) (cl. 5.1.1 IS 10262:2019)

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.47 = 0.62 + 0.01{(0.50 – 0.47)/0.05} = 0.626

Volume of fine aggregate content = 1 – 0.626 = 0.374

9. MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows:

a) Total volume = 1 m^3

b) Volume of entrapped air in wet concrete = 0.01 m^3

c) Volume of cement

= (Mass of cement / Specific gravity of cement) * (1/1000)

= (320/ 3.15) * (1/1000)

= **0.102 m^3**

d) Volume of water = (Mass of water / Specific gravity of water) *(1/ 1000)

= (150 / 1) * (1 / 1000)

= 0.150 m^3

e) Volume of chemical admixture (superplasticizer) (@ 1.0 percent by mass of cementitious material) = (Mass of chemical admixture / Specific gravity of admixture) * (1 / 1000)

= (3.20 / 1.11) * (1 / 1000)

= 0.0029m^3

g) Volume of all in aggregate = [(a-b)-(c+d+e)]

= [(1-0.01) – (0.102 + 0.150 + 0.0029)]

= 0.735 m^3

h) Mass of coarse aggregate

= g × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000

= 0.735 × 0.626 × 2.68 × 1000

= **1233.09 kg/m^3** ≈ **1233 kg/m^3**

j) Mass of fine aggregate

= g × volume of fine aggregate × Specific

gravity of fine aggregate × 1000

= 0.735 × 0.374 × 2.65 × 1000

= **728.45 kg/m^3** ≈ **729 kg/m^3**

MIX PROPORTIONS FOR TRIAL NO.1

Cement = 320 kg/m^3

Water = 150 kg/m^3

Fine aggregate (SSD) = 729 kg/m^3

Coarse aggregate (SSD) = 1233 kg/m^3

Chemical admixture = 3.20 kg/m^3

Free water-cement ratio = 0.47

10. ADJUSTMENT ON WATER, FINE AGGREGATE AND COARSE AGGREGATE (IF THE COARSE AND FINE AGGREGATE IS IN DRY CONDITION)

a) Fine Aggregate (Dry)

= (Mass of fine aggregate in SSD condition) / [1 + (Water absorption / 100)]

= 729 / [1 + (1 / 100)]

= 721.78 kg/m3 ≈ 722 kg/m^3

b) Coarse Aggregate (Dry)

= (Mass of coarse aggregate in SSD condition) / [1 + Water absorption / 100)]

= 1233 / [1 + (0.5 / 100)]

= 1226.86 kg/m^3 ≈ 1227 kg/m^3

The extra water to be added for absorption by coarse and fine aggregate,

1) For coarse aggregate

= Mass of coarse aggregate in SSD condition – mass of coarse aggregate in dry condition

= 1233 – 1227 = 6 kg

2) For fine aggregate

= Mass of fine aggregate in SSD condition – mass of fine aggregate in dry condition

= 729 – 722 = 7 kg

The estimated requirement for added water, therefore, becomes

= 150 + 6 + 7 = 163 kg/m^3

MIX PROPORTIONS AFTER ADUSTMENT FOR DRY AGGREGATES

Cement = 320 kg/m^3

Water (to be added) = 163 kg/m^3

Fine aggregate (Dry) = 722 kg/m^3

Coarse aggregate (Dry) = 1233 kg/m^3

Chemical admixture = 3.20 kg/m^3

Free water-cement ratio = 0.47

PRCEDURE:

1. Calculate materials required so as to cast three cubes as per above proportioning
2. Mix the material together in the concrete mixer
3. Grease the cubes moulds
4. After concrete is prepared, test the workability using slump cone test
5. Pour the concrete in the cube moulds in three layers, each tamped by 25 times
6. Next day demould the cubes and immerse them in curing tank so as to ensure 28 days of curing from day od casting
7. After 28 days, bring cubes from curing tank, make them clean and dry
8. Test them under CTM and average strength is compared with that obtained from RH NDT test

OBSERVATION (After 28 days):

Cube	Load (KN)	Area (mm^2)	Cube Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1		150^2		
2		150^2		
3		150^2		

CONCLUSION:

It is thus found from the compressive strength test that the mean target strength after 28days is achieved. It can be said that concrete is of good quality and has desired strength.

QUIZES FOR EXPERIMENT NO: 7

1) ________ has designated the concrete mixes into a number of grades as M10, M15.

Ans- IS 456-2000

2) Compressive strength of hardened concrete is done by ______

Ans- Cube test

3) The characteristic compressive strength is defined as the strength of the concrete below which not more than_______ of the test results are expected to fall.

Ans- 5%

4) For moderate exposure conditions, the minimum grade of concrete is_______ .

Ans- M25

5) The rate of creep rapidly _______ with time?

Ans- Decrease

6) _________ water-cement ratio content to give adequate durability for the particular site conditions.

Ans- Maximum

7) What is the approximate min proportion for M25?

Ans- 1:1:2

8) Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by________.

Ans- IS 456:2000

9) What should be the minimum water cement ratio?

Ans- <0.45

10) ____ is defined as the design strength determined for the manufacture of reinforced concrete.

Ans- Target mean strength

11) If the trial mix gives a higher 28 days compressive strength value than the design value, then for the next trial

Ans- Water-cement ratio is increased

12) The total number of grades of ordinary concrete stipulated in IS 456:2000 are:

Ans- 3

13) The target mean strength f_m for concrete mix design obtained from the characteristic strength f_{ck} and standard deviation σ, as defined in IS:456-2000 is _____ ?

Ans- f_{ck}+ 1.65σ

14) The grade of concrete M15 means that the compressive strength of a 150 mm cube after 28 days is _______.

Ans- 15 N/mm^2

15) Water cement ratio is defined as

Ans- Ratio between the weight of water to the weight of cement used in concrete mix.

16) The workability of concrete by slump test is expressed as _______.

Ans- mm

17) The maximum particle size of coarse aggregate is _______.

Ans- 75 mm

18) What happens when water to cement ratio decreases?

Ans- Due to lower water, concrete becomes more drier but compressive strength increases.

19) The workability of concrete is defined as the

Ans- Ease with which it can be mixed, transported and placed in position in a homogeneous state.

20) Plain cement concrete is strong in taking ______.

Ans- Compressive stress

##

Subject to Revision

EXPERIMENT NO: 8

AIM OF THE EXPERIMENT:

To study the flexural and shear behaviour of Reinforced Cement Concrete (RCC) beams.

MATERIALS REQUIRED:

- Coarse aggregate
- Fine aggregate
- Cement
- Water
- Reinforcement bars
- Binding wire

APPARATUS REQUIRED:

- Beam formwork
- Cover spacer
- Loading frame
- Supporting pedestals
- LVDT (Linear Variable Differential Transformer)
- Strain gauge
- Data logger

THEORY:

A simply supported beam loaded by two-point loads can either fail in flexure mode or shear mode. In Fig.1, the shear spans and flexure span are shown. If a beam becomes week in flexure (imposed load exceeds the flexural capacity of the materials of the beam), it will fail in flexure span exhibited by vertical clacks there and can be resolved by providing flexural reinforcements either internal or external. If a beam becomes week in shear, it will fail in shear spans exhibited by diagonal shear cracks there and can be resolved either by providing designed vertical shear stirrups or bent up bars in the shear spans either internally or externally.

Flexural cracks on the sides of a beam start at the tension face and will extend, at most, up to the neutral axis. In general, the cracks will be uniformly spaced along the most heavily loaded portion of the beam, i.e., near the mid-span in sagging or over the supports in hogging. A shear failure which is caused by the development of diagonal cracks predominates in higher reinforced concrete beams without transverse reinforcement.

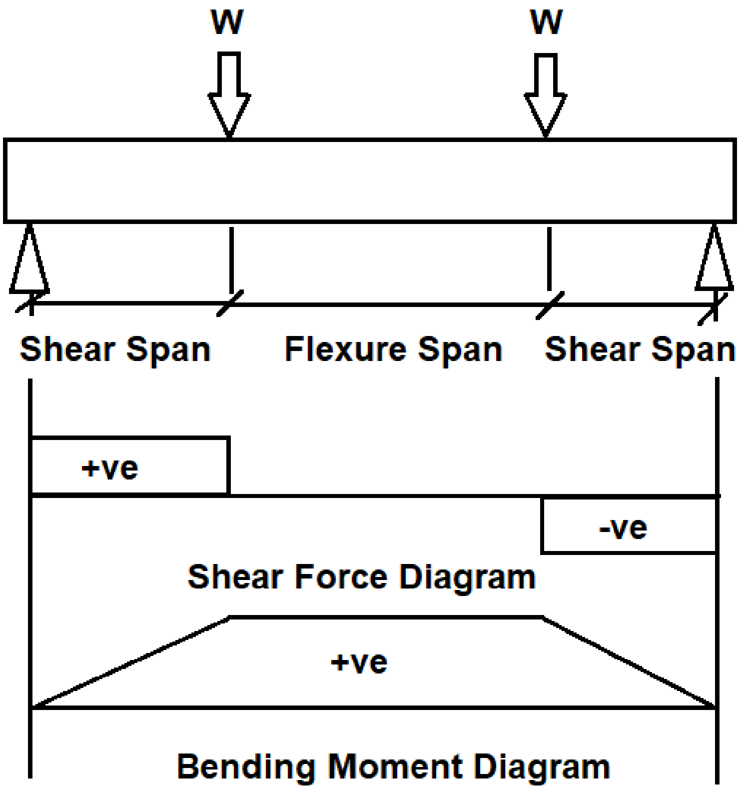


Fig. 1: BMD and SHD in a two-point loaded simply supported beam

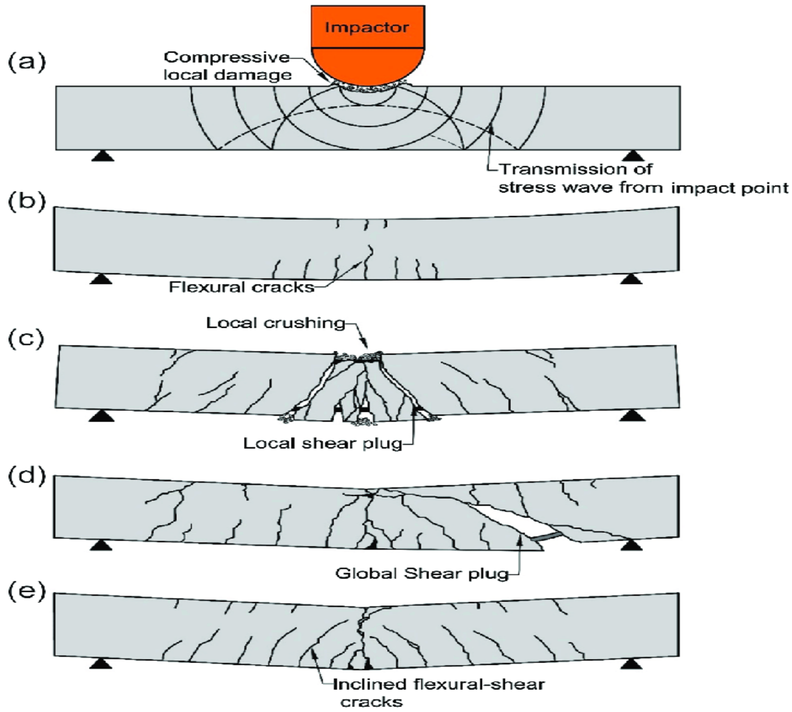


Fig. 2: Crack patterns in simply supported RC beam

The loading pattern on the beam in Fig 1 is called the two-point loading or four-point loading. The main advantage this loading is that, the behaviour of the beam can be studied under pure bending as there is no shear at the central portion of the beam. The phenomenon is depicted by the Fig. 3. The loading pattern in the loading frame is shown as in Fig.4. In order to measure beam deformations under the load, LVDTs are fixed and to measure flexural strain, strain gauges are too fitted as in Fig. 4.

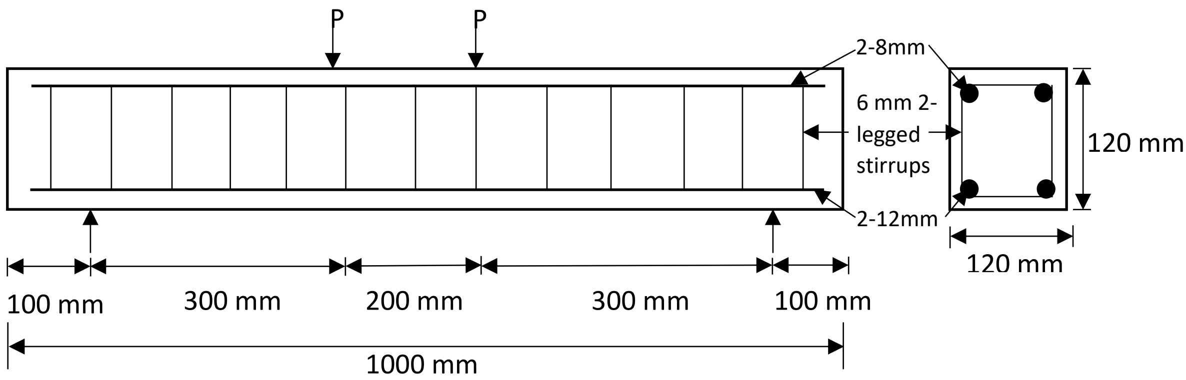


Fig.3. Dimension and reinforcement details of RC beam

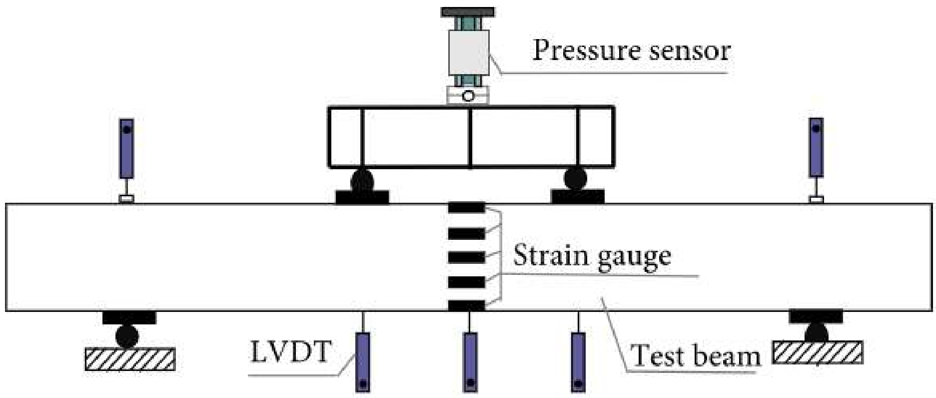


Fig.4. Schematic sketch of test arrangement in loading frame

PROCEDURE:

Sampling of Materials:

Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

Proportioning:

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work and must done according the mix design of concrete.

Weighing:

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

Mixing of Concrete:

The concrete shall be mixed preferably in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimens.

Mould:

The formwork of the beam shall be prepared in desired size and lubricant oils shall be applied on the inner surface of the formwork. The cover spacer and the reinforcement cage, attached with the strain gauge, shall be placed at the desired place, considering the clear cover.

Compacting:

The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The compaction may be done with tamping rod or by using needle vibrator.

Curing:

After 24 hour the RC beam shall be removed from the formwork and kept for curing. The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°C for 28 days.

Placing the Specimen in the Loading Frame:

The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen shall then be placed in the machine in such a manner that the load shall be applied to the uppermost surface as cast in the mould and the axis of the specimen shall be carefully aligned with the axis of the loading device. No packing shall be used between the bearing surfaces of the specimen and the rollers. The LVDTs shall be placed properly in desired place to measure the deflection and the data logger shall be attached to the strain gauges to take the strain data from the strain gauges attached to reinforcements and concrete surface. The load shall be applied without shock and increasing continuously and the load shall be increased until the specimen fails, and the maximum load applied and the corresponding deflection of the specimen and strains in the reinforcements and concrete surface shall be recorded. The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

OBSERVATION:

- Length of the specimen (l): _______ mm
- Width of the specimen (b): _______ mm
- Depth of the specimen (d): _______ mm

Sl. No.	Specimen Name	Ultimate Load (kN)	Corresponding Deflection (mm)	Type of Failure
1				
2				

RESULTS:

Plot the graph for load vs. deflection response and stress vs. strain response

CONCLUSIONS:

The load deformation and stress strain curves are plotted for the two-point loaded beam. The crack patterns are carefully monitored too.

##

Subject to Revision

EXPERIMENT NO: 9

AIM OF THE EXPERIMENT:

To compare the experiment and theoretical values of the horizontal thrust in a three hinged parabolic arch and to plot the Influence Line Diagram (ILD) for the horizontal thrust in the three hinged arch

APPARATUS REQUIRED:

1) 3-hinged parabolic arch

2) Scale

3) Weights and hanger

4) Thread

THEORY:

An arch is a curved beam in which horizontal movement at the support is prevented. Hence there is a horizontal thrust induced at the support. An arch hinged at the support and having a third hinge anywhere is called a 3-hinged arch

There are four unknowns and to solve this, it can be done by using four equations

Available, $\sum m=0$--(1)

$\sum v=0$--(2)

And moment at the **third hinge** is zero-------------------------------(3)

Taking $\sum M_a = 0$ (Fig. 1)

$P * X= V_b * L$

$V_b = PX / L$ ---(4)

So, **$V_a = P - V_b = P (L – X) / L$** --------------------------------------(5)

For horizontal thrust (H),

$\sum Mc = 0$

$(V_b * L/2 = H*h$

So, **$H = (V_b *L)/(2h)$** ---(6)

So, **$H= P X / 2h$** (by putting Eq. (4) in Eq. (6))--------------------(7)

where, X is the distance from left support of arch to the hanger location where load is to be hung (Fig. 1)

P is the applied load on arch at any X

H is the horizontal thrust at supports

V_a and V_b are vertical reactions at support A and B

L is span length of arch

h is the central rise of arch

Horizontal thrust: The horizontal component of the reaction at either lower support end is called the horizontal thrust. This can be computed by equating the bending moment at the crown hinge C to zero

So, **H = P X / 2h** (Eq. 7**)**

If load is at centre, X = L/2, so, **H=P L / 4h**

ILD: An influence line diagram is defined as a function whose value at a point represents some structural quality as a unit load is placed at a point.

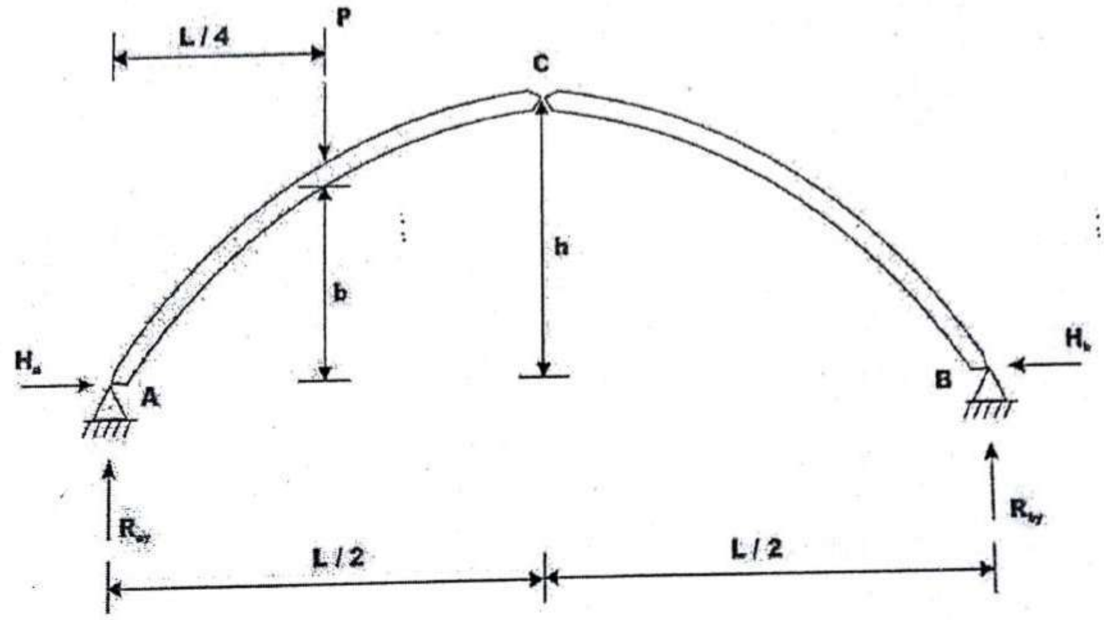


Fig. 1: Three hinged arch

<u>PROCEDURE</u>:

• Measure the span length (L) and height of the hanger position (b) above springing line by means of thread and scale.

• Apply some **initial load** to the string which passes over a pulley at right hand support to neutralize the horizontal thrust due to self-weight which is called **seating load** or **balancing load.**

• Find out the balancing weight or load over the pulley with gentle tapping.

• Then apply the load through the needle hanger and find balancing load at the string with gentle tapping.

- Then increase the load step and corresponding balancing load was found out.

- Apply a unit load at different hanger position and find the corresponding balancing load and plot the ILD.

- Plot following curves as mentioned below:

(1) Check the parabolic arch profile that satisfies the equation of parabola:

$y = \frac{4h}{L2} X(L - X)$ ---(8)

Draw both experimental curve and curve satisfying above equation

(2) Draw the ILD for horizontal thrust.

<u>OBSERVATION:</u>

Table 1: Check for the parabolic profile of Arch (Experimentally and analytically)

Sl No.	**Horizontal Distance (cm) from left support**	**Experimental Height from Springing line of arch (cm)**	**Theoretical Height from Springing line of arch (cm)**
1			
2			
3			
4			
5			
6			
7			
8			
9			

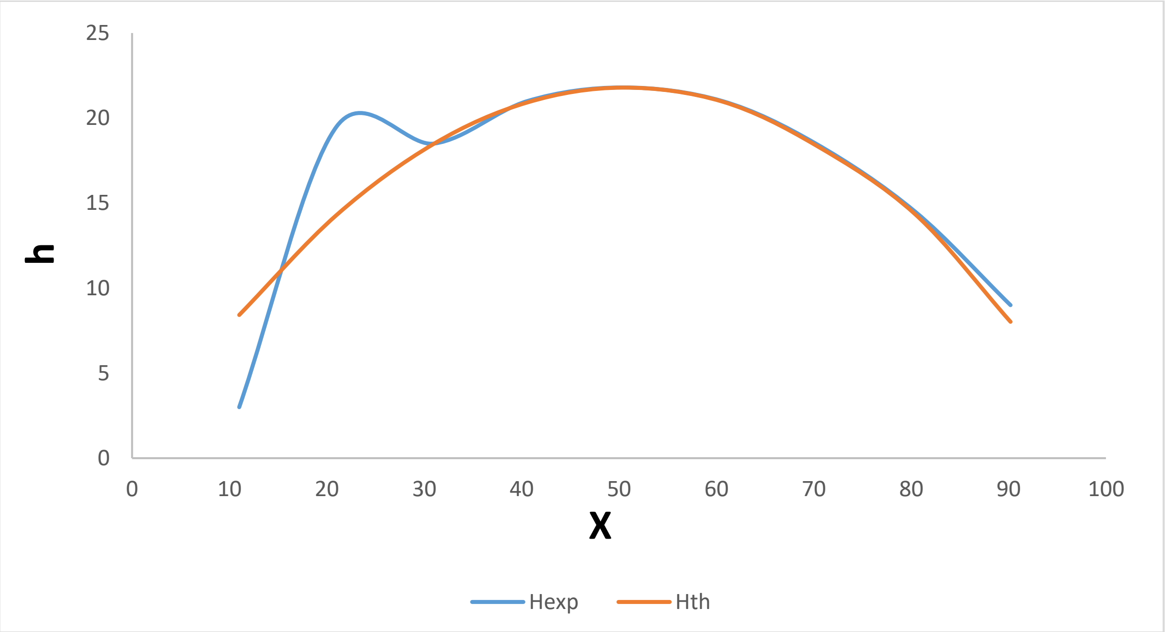


Fig. 2: Curve for the parabolic arch profile (Experimental and Analytical)

Table 2: H for Varyng load at hanger 2 (Experimentally and analytically)

Sl No.	Hanger No.	Load Applied (kg)	Balancing Load (kg)	H_{th}	H_{exp}	Difference	% Error
1	2	1					
2	2	1.5					
3	2	2					

Table 3: H for Varyng load at hanger 3 (Experimentally and analytically)

Sl No.	Hanger No.	Load Applied (kg)	Balancing Load (kg)	H_{th}	H_{exp}	Difference	%Error
1	3	1					
2	3	1.5					
3	3	2					

Table 4: H for Varyng load at hanger 4 (Experimentally and analytically)

Sl NO.	Hanger No.	Load Applied (kg)	Balancing Load (kg)	H_{th}	H_{exp}	Difference	% Error
1	4	1					
2	4	1.5					
3	4	2					

Table 5: H for Constant load at varying hanger (Experimentally and analytically)

(Determination of ILD)

Sl No.	Hanger NO.	Load Applied (in kg)	Balancing Load (in kg)	H_{exp}	H_{th}	Difference	%Error
1	1	2					
2	2	2					
3	3	2					
4	4	2					
5	5	2					
6	6	2					
7	7	2					
8	8	2					
9	9	2					

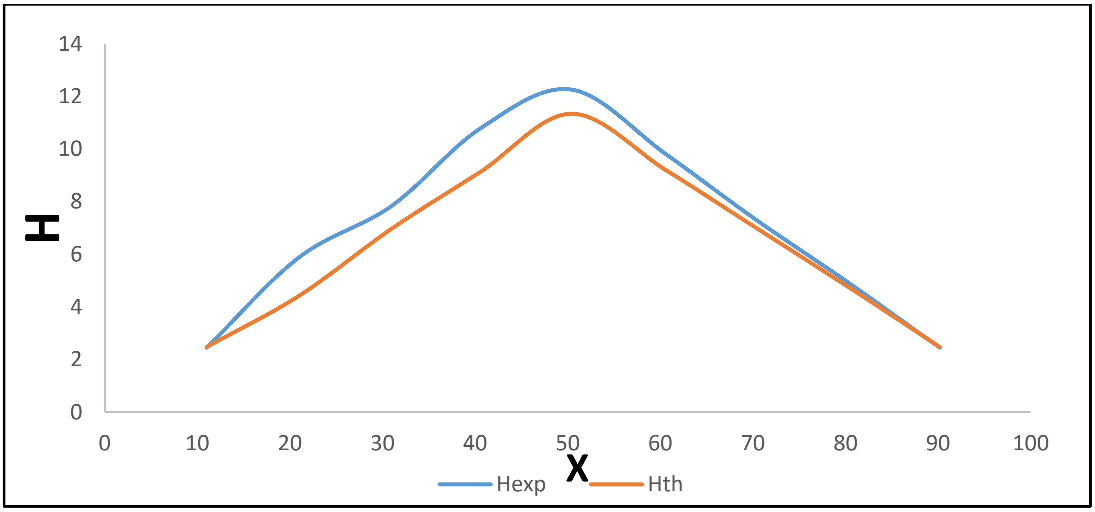


Fig. 3: H for Constant load at varying hanger (Experimentally and analytically)

(Determination of ILD for H)

CONCLUSION:

The horizontal thrust for the 3-hinged arch was calculated for both theoretical and experimental thrust and percentage error was computed. This error is due to instrumental, experimental and personal errors. Then the ILD for the horizontal thrust was drawn.

QUIZES FOR EXPERIMENT NO: 9

1)Top most part of an arch is called ________

Ans-Crown

2) Shape of three hinged arch is always:

Ans-Parabolic

3) Internal bending moment generated in a three hinged arch is always:

Ans-0

4)Internal shear force generated in a three hinged arch is always:

Ans-0

5)What is the degree of indeterminacy of a fixed arch?

Ans-3

6)What is the degree of indeterminacy of a two hinged arch?

Ans-1

8) Floor loads are transmitted from slabs to which part in a floor girder system?

Ans-Floor beams

9) For drawing ILD, what value of test load is assumed?

Ans- 1 unit

10) Maximum point of ILD always lies at the point at which load is applied. (True or False)

Ans-False ***Subject to Revision***

EXPERIMENT NO: 10

AIM OF THE EXPERIMENT:

To compare the experimental and theoretical displacements of the roller ends of a two hinged arch and to draw the profile.

APPARATUS REQUIRED:

1. Dial Gange
2. Scale
3. Weight and hanger
4. 2 hinged arch

THEORY:

Arch is a structure which develops horizontal thrust for applied vertical loads. Let us consider a two hinged parabolic arch of span ‘l’ and rise ‘h’.

From equation of parabola, **y = (4h)/ (l^2) * x(l - x)**

Where, y= Vertical height at a point from pinned end

H= Central rise

h= central rise of arch

l= length of span

w= applied load

a= Distance where load applied

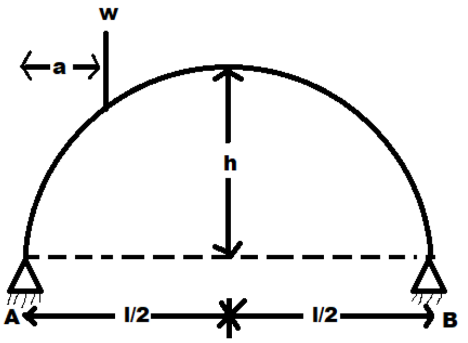
$$\oint m'y\,dx = \int_0^a wy dx$$

$$= \int_0^a wx\,\frac{4hx(l-x)}{l^2}\,dx$$

$$= \int \frac{4hw}{l^2} \int_0^a (lx^2 - x^3)dx$$

$$= \frac{4wh}{l^2}\left[\frac{lx^3}{3} - \frac{x^4}{4}\right]_0^a$$

$$= \frac{4wh}{l^2}\left[\frac{la^3}{3} - \frac{a^4}{4}\right]$$



(2 hinged Arch With point load at A distancew of 'a' from pinned end)

PROCEDURE:

1. First the **roller end** was locked and load applied on a hanger, such that no displacement observed.

2. The lock was released and the load is applied at a distance from a fixed end.

3. Then it is observed that there is some displacement and it was noted down the tabular form.

4. The same process was repeated for three set up.

5. The actual shape of arch was plotted by measuring the shape with thread and tape

6. Then the actual shape vs theoretical shape was plotted.

OBSERVATION:

Profile of two hinged Arch:

Actual span (cm) from one end											
Theoretical span from one end											

Rise of arch:

Actual rise of arch											
Theoretical rise from one end											

Displacement:

S.l no.	Load (kg)	Initial Reading	Final Reading	Displacement In (cm)	Actual displacement (c.m)	% Error
1						
2						
3						

Graphs to be drawn:

- The rise of two hinged arch vs. distance along the span to be drawn
- Displacement vs. load (kg) to be drawn

CALCULATION:

$$\Delta s = \frac{4wh}{l^2}\left[\frac{la^3}{3} - \frac{a^4}{4}\right]$$

For varying load ‘w’ of 1 kg, 2 kg and 3 kg and a= 0.405 m, l = 1.02 m

Displacements can be calculated to be:

$\Delta s1$ = 0.0145 m

$\Delta s1$ = 0.0291 m

$\Delta s1$ = 0.0437 m

CONCLUSION:

It is found from the experiment that the experimental and theoretical displacements of roller end of a two hinged arch is calculated and the percentage error is computed. This error is due to instrumental, experimental and personal errors. Then the actual and theoretical profile of arch was drawn.

##

Subject to Revision